Literacy Design Collaborative

Catching Sun with a Donut

★ TASK ★ LADDER

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Adapted from "Battelle Design Module Template" by Kelly M. Gaier Evans and Peter DeWitt

Special note: The lab in this module is adapted from the Solar Cell Lab written by Matthew Stoltzfus at Ohio State University. The lab itself was originally inspired by the following video: https://www.youtube.com/watch?v=bVwzJEhMmD8.

This module has been developed from the Battelle Design Module Template. In this module, students build a solar cell using titanium dioxide (TiO2) extracted from donuts. Students initially conduct background research on dye-sensitized solar cells and the dyes used, and proceed to experimentally determine the best dye and TiO2 casting method to produce a solar cell. Students build their solar cells according to their research and experimental results, and test the function of the solar cell. Students write up a formal report to detail their findings.

As an LDC module, literacy skills are emphasized here. In addition, this module focuses on building strong lab skills. Students research and practice a variety of lab procedures in each phase of the module, and thereby become much more confident in the lab setting.

Production is the essence of STEM education. Purposeful production is the definition of design. The Battelle Design Module Template is based on the process Battelle Memorial Institute engineers go through in designing and prototyping solutions to the world's problems and opportunities. This process has led to the Xerox machine, the CD, and countless other innovations! This Template is meant to be applied in a "real-world" manner—optimally driven by authentic partnerships with your community. Your community partner can help identify a need and parameters for the students' design, as well as then serving as an authentic audience for your students' work. There is a world of opportunities out there that is waiting for our students' design ability. Use this LDC module to help the students scaffold and capture their design process with excellence.

Note: The Design Process requires that students already have the ability to test solutions in a controlled manner (i.e., carry out a controlled experiment). It is advisable, therefore, that your students be relatively fluent in experimentation prior to completing this module. If your students do not yet have a sound foundation in experimentation, please see the Battelle Education Controlled Experiment Module Template. These modules are part of a three-part Battelle LDC Science Collection: Data Analysis, Controlled Experimentation, and Design. The series represents a continuum of skills that build upon each other.

We thank David Chase (Principal Research Scientist at Battelle) for his assistance in sharing his work processes and providing real world examples to include in this module.

GRADES	DISCIPLINE	COURSE	PACING
9 - 12	Science	Chemistry	N/A

Section 1: What Task?

Teaching Task

Task Template BETA A - Argumentation

Which dyes allow us to most efficiently harvest energy from the sun using dye-sensitized solar cells (DSSCs)? After reading the request for proposals (RFP), conducting background research on DSSCs, and designing and testing dyes for DSSCs, write a critical design report in which you describe your design and argue its effectiveness in meeting the requirements of the RFP. Support your response with evidence from your research. Include data tables to help convey your message to your readers.

Standards

Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects

WHST.9-10.7 — Focus

Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

SL.9-10.4 — Focus

Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

RST.9-10.3

Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

RST.9-10.6

Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, defining the question the author seeks to address.

RST.9-10.9 — Focus

Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

WHST.9-10.8

Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

WHST.9-10.9

Draw evidence from informational texts to support analysis, reflection, and research.

WHST.9-10.1 — Focus

Write arguments focused on discipline-specific content.

Next Generation Science Standards

Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. **Focus**

HS-PS2-6 **Focus**

Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

HS-PS3-3 **Focus**

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Texts

- **Request For Proposals_DSSC_2015.docx**
- **Text List for Catching Sun.docx**

Student Work Rubric - Argumentation Task - Grades 9-12

	Emerging	Approaches Expectations	Meets Expectations	Advanced
	1	2	3	4
Controlling Idea	Makes a general claim with an unclear focus.	Establishes a **clear** claim **that addresses the prompt**, with an **uneven focus**.	Establishes **and maintains** a **clear, specific, and credible claim** that addresses **all aspects** of the prompt.	Establishes and maintains a **precise, substantive** claim that addresses all aspects of the prompt. **Acknowledges limitations and/or the complexity of the issue or topic**.
Selection & Citation of Evidence	Includes minimal details from sources. Sources are used without citation.	Includes **details, examples, and/or quotations** from sources that are **relevant to the claim**. **Inconsistently** cites sources.	Includes details, examples, and/or quotations from sources that **support** the claim and **supporting ideas**. **Consistently** cites sources **with minor formatting errors**.	Includes **well-chosen** details, examples, and/or quotations from sources that **fully support** the claim and supporting ideas. Consistently cites sources **using appropriate format**.
Development / Explanation of Sources	Explanation of ideas and source material is irrelevant, incomplete, or inaccurate.	Explains ideas and source material **to support the argument**, with **some incomplete reasoning or explanations**.	**Accurately** explains ideas and source material and **how they support** the argument.	**Thoroughly** and accurately explains ideas and source material, **using logical reasoning to support and develop** the argument.
Organization	Lacks an evident structure. Makes unclear connections among claims, reasons, and/or evidence.	**Groups ideas and uses transitions** to develop the argument, with **some lapses in coherence or organization**.	**Groups and sequences** ideas to **develop a cohesive argument** . Uses transitions **to clarify the relationships among claim(s), reasons, and evidence**.	Groups and sequences ideas **in a logical progression in which ideas build to create a unified whole**. Uses **varied** transitions to clarify the **precise** relationships among claim(s), reasons, and evidence.
Conventions	Major errors in standard English conventions interfere with the clarity of the writing. Language or tone is inappropriate.	Errors in standard English conventions **sometimes interfere** with the clarity of the writing. Uses language and tone that are **sometimes inappropriate** for the audience and purpose.	**Consistently applies** standard English conventions; **minor errors**, while noticeable, **do not interfere** with the clarity of the writing. Uses language and tone **appropriate to the audience and purpose**.	Consistently applies standard English conventions, **with few errors**. Demonstrates **varied syntax** and **precise word choice**. **Consistently** uses language and tone appropriate to the audience and purpose.
Content Understanding (Generic)	Attempts to include disciplinary content in explanation or argument but understanding of content is weak; content is irrelevant, inappropriate, or inaccurate.	Briefly notes disciplinary content relevant to the prompt; shows basic or uneven understanding of content; minor errors in explanation.	Accurately presents disciplinary content relevant to the prompt with sufficient explanations that demonstrate understanding.	Integrates relevant and accurate disciplinary content with thorough explanations that demonstrate in-depth understanding.

Background for Students

iPhones, DVDs, Amazon.com, televisions, cameras, automobiles—all of these items were designed solutions to the needs/opportunities of society. Often, we believe that these products were a "stroke of genius"—or the fruit of some momentary creative miracle. While creative breakthroughs do occur at times in a moment, "luck is what happens when preparation meets opportunity." (Seneca) The needs/opportunities of society are waiting for purposeful, designed solutions. The design process is fun! It is both creative and calculated. This LDC module seeks to guide you through that creative and calculated process for the purpose of a great design product.

In this project, you will be designing a dye-sensitized solar cell (DSSC), using titanium dioxide extracted from donuts and a dye of your choice. The attached texts will guide you in the background studies, but you are expected to explore DSSCs in greater depth.

Extension

Not provided

Section 2: What Skills?

Preparing for the Task

TASK ENGAGEMENT: Ability to connect the task and new content to existing knowledge, skills, experiences, interests, and concerns.

IDENTIFYING FEATURES OF ENGINEERED PRODUCTS: Ability to identify engineered products and identify their features.

Interpreting a Request for Proposals (RFP)

UNDERSTANDING THE LIST OF REQUIREMENTS: Ability to read, understand, analyze, and interpret a list of design requirements to create a list of features for an appropriate design solution.

UNDERSTANDING THE STATEMENT OF WORK IN LIGHT OF THE TIMELINE: Ability to scale the scope of a project to fit the time available.

SEEKING CLARIFICATION ON RFP: Ability to identify gaps in understanding about design requirements or statement of work and communicate those gaps in understanding as questions that can be answered by the organization or individual that issued an RFP.

Creating Possible Solutions (Concept Design)

BACKGROUND RESEARCH: Ability to understand the existing bodies of knowledge related to the problem and find designs that have been previously developed by others to glean useful information from the approaches they took.

BRAINSTORMING POSSIBLE SOLUTIONS: Ability to engage in a collaborative, creative process to brainstorm many possible solutions to an RFP.

ANALYZING POSSIBLE SOLUTIONS: Ability to engage in theoretical, technical analysis of brainstormed, possible solutions in order to identify pros/cons of each solution - in reference to an RFP's list of requirements and scope.

Preparing and Presenting a Proposal

COMMUNICATING POSSIBLE SOLUTIONS: Ability to condense possible solutions into a simple paper or presentation that presents one or more options and potential pros and cons of that (those) solutions.

BIDDING THE PROJECT: Ability to identify all needed resources for proposed product/solution and to communicate those needs to the institution that issued the RFP.

Detailed Design

TESTING CRITICAL DESIGN COMPONENTS: Ability to test critical subsystems for feasibility.

FINALIZING DESIGN: Ability to incorporate critical component test results in order to adjust the design of subsystems (and overall design) as necessary in order to ensure final design solution adequately addresses the list of requirements contained in an RFP.

Design Report

TITLE PAGE: Ability to make a title page with appropriate identifying information.

BACKGROUND: Ability to communicate the background on "why we are doing what we are doing."

DETAILED DESIGN INFORMATION: Ability to communicate (with words and graphics) the details of a design solution and how it is built/executed.

DEFENSE OF DESIGN: Ability to clearly articulate (using evidence) how the design solution meets the original design requirements as laid out in an RFP.

EXECUTIVE SUMMARY/ABSTRACT: Ability to write a brief, comprehensive, and accurate summary of an issue/need and designed solution to that need.

Section 3: What Instruction?

PACING	SKILL AND DEFINITION	PRODUCT AND PROMPT	SCORING GUIDE	INSTRUCTIONAL STRATEGIES
Preparing for the Task				
10 mins	**TASK ENGAGEMENT**: Ability to connect the task and new content to existing knowledge, skills, experiences, interests, and concerns.	**WHITE-BOARD ACTIVITY TO ENCOURAGE TASK ENGAGEMENT** With the person sitting next to you, document your answers to the following questions on your whiteboards: 1. What (or how many) items that you carry with you on a daily basis require some amount of energy to function? 2. What are the main sources of energy that you are familiar with? 3. What sources of energy do you use on a daily basis? Give one example of what the energy is used for. 4. Do you own any items that are solar-powered? What items?	None.	1. Distribute white boards and markers. 2. Set timer for 10 minutes and instruct students to answer the above questions on their whiteboards. 3. At the end of the 10 minutes, have individual students/groups report their answers to the questions. 4. Use the questions/answers as a conversation starter in leading to the introduction to the project on dye-sensitized solar cells. (Some things to possibly discuss: non-renewable vs. renewable energy sources, batteries, making batteries from natural products, how chemistry plays a role in batteries.) 5. Teacher should move around the room listening to make sure students are accurately and succinctly answering the questions above with their classmates.
10 mins	**IDENTIFYING FEATURES OF ENGINEERED PRODUCTS**: Ability to identify engineered products and identify their features.	**CLASS DISCUSSION TO SUPPORT UNDERSTANDING OF IMPORTANCE OF ENGINEERING** Respond to the following question: Identify items you are aware of that are products of a team of engineers.	List meets expectations if it includes: • Many items students use daily that are a product of a team of engineers • A conclusion that every item on the market is a product of a team of engineers.	1. Ask students to share out an example of an item that is a product of a team of engineers. Through a class discussion, students will evaluate whether the item is a product of engineering. 2. Ask students to come up with criteria for what makes an item "engineered."

				Some examples of items to discuss include cell phone, shoes, apples. Students will be able to deliver a lengthy list of items they use daily that are products of a team of engineers. Students will be able to come to the conclusion that every item on the market is a product of a team of engineers.
Interpreting a Request for Proposals (RFP)				
30 mins	**UNDERSTANDING THE LIST OF REQUIREMENTS**: Ability to read, understand, analyze, and interpret a list of design requirements to create a list of features for an appropriate design solution.	**UNDERSTANDING THE SCOPE OF WORK EXIT TICKET** After reading the request for proposal project document, identify the main purpose of the project, what materials will be provided, what materials will be required for you to provide, and what variables are present in the project.	A mastery-level student product will include an accurate description/list of: • The scope of the work • The materials required • The materials provided by the student • The variables at play in the project.	1. Students will be given the project document to explore on their own for about 10 minutes. 2. After 10 minutes, provide students the exit ticket and allow for immediate clarifying questions. Discuss the main features of the project together. 3. Instruct students to start filling in the exit ticket, answering each of the questions based on the information provided in the document. 4. As a class, students should ask clarifying questions to allow all students to fully grasp the scope of work described in the project. 5. Collect the exit ticket.
	Additional Attachments: **RFP DSSC 2015.docx** **DSSC Understanding Scope of Work Exit Ticket.docx**			
10 mins	**UNDERSTANDING THE STATEMENT OF WORK IN LIGHT OF THE TIMELINE**: Ability to scale the scope of a project to fit the time available.	**IDENTIFYING A TIMELINE GRAPHIC ORGANIZER** In groups, complete the Identifying the Timeline document in order to identify the main components of the project and the time frame allotted to each piece of the project.	Mastery-level work will: • Accurately identify the components of each phase of the project • Set due dates for specific components within the project.	1. Give students the Timeline document and instruct them to identify the main components of each phase of the project. The following list describes the different phases of this project: • Research Phase (background research, dye

				research) • Donut Day (extracting titanium dioxide from donuts) • Casting Slides Day (practice making titanium dioxide paste and casting slides, make real slide) • Dye Day (practice dye extractions, determine best dye to use, dye slides) • Assembly and Test Day (assemble solar cell, test for performance) • Final Report Write-Up 2. Discuss the time frames for completing each phase.
	Additional Attachments: **Identifying a Timeline.docx**			
10 mins	**SEEKING CLARIFICATION ON RFP**: Ability to identify gaps in understanding about design requirements or statement of work and communicate those gaps in understanding as questions that can be answered by the organization or individual that issued an RFP.	**POST-IT NOTE CLARIFYING ENTRANCE TICKET** On a Post-it note, write one question you have about the project that you would like clarified. If you have multiple questions, use one Post-it note for each question. All questions are welcome!	None.	1. Place a pile of Post-it notes at each table and instruct students to write the questions they want answered on the Post-it note. Students will write questions soliciting clarification on any step of the lab. The note should then be placed on the board or other teacher-selected location to be answered. 2. Use the Post-it notes to guide a discussion to clarify questions students still have about the project.
Creating Possible Solutions (Concept Design)				
1 hr	**BACKGROUND RESEARCH**: Ability to understand the existing bodies of knowledge related to the problem and find designs that have been previously developed by others to glean useful information from the approaches they took.	**UNDERSTANDING DYE-SENSITIZED SOLAR CELLS GRAPHIC ORGANIZER** Visit the following links to learn more about dye-sensitized solar cells (DSSCs). **Document your findings from your research on the Explore DSSCs graphic organizer.** From your research, you should be able to answer the following questions: • What is a dye-sensitized solar cell (DSSC)? • How does a DSSC work?	A mastery-level response will include: • A completed graphic organizer with accurate answers to each question.	1. Distribute and read selected relevant portions of the paper Dye-Sensitized Solar Cells by Michael Gratzel. 2. Give students the Exploring DSSCs handout and the related Graphic Organizer. Read through the handout with the

	• What are the main components of a DSSC? • What dyes are useful in making DSSCs? • How efficient are DSSCs? Use the following resources to begin answering the questions above, but DON'T feel that you can ONLY use these resources! Make sure to document and bookmark every resource that you use. **Wikipedia's explanation:** http://en.wikipedia.org/wiki/Dye-sensitized_solar_cell **Learn more about dye-sensitized solar cells:** http://gcell.com/dye-sensitized-solar-cells **Watch a video on how to make a DSSC:** https://www.youtube.com/watch?v=3KRHJSOgzcw **Game to make your own solar cells:** http://community.nsee.us/concepts_apps/dssc/DSSC.html		students and instruct them to use the Internet to explore what is known about dye-sensitized solar cells. 3. Instruct students to start with the provided links to research the questions about dye-sensitized solar cells and document their findings on a graphic organizer. Emphasize the necessity for bookmarking helpful sites that they can use later in their references. 4. While students are working, circulate the room to help answer questions and direct students to helpful resources. While the teacher is circulating, they should listen to students as they communicate their findings to their classmates. 5. After the class has completed the graphic organizer activity, ask students to report out their findings and discuss the technical details of a dye-sensitized solar cell and relate it back to the project for building the solar cell. 6. At the end of class, provide the 3-2-1 exit ticket and ask students to fill it out with what they have learned, what they still don't know, and what they are excited about regarding the upcoming project.

Standards:

RST.9-10.9 : Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

RST.9-10.8 : Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.

RST.9-10.2 : Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.

RST.9-10.1 : Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

	Additional Attachments: **The Gratzel Cell: Where Next? by Laurence m. Peter** **A low-cost, high-efficiency solar cell based on dye-sensitized colloidal TiO2 films by O'Regan and Gratzel** **Photoelectrochemical cells by Michael Gratzel** **DSSCs by Gratzel.pdf** **Dye-Sensitized Solar Cells by Michael Gratzel** **Explore DSSC Chart.docx** **Explore DSSCs.docx** **Game to make your own solar cells:** **Watch a video on how to make a DSSC:** **Learn more about Dye-Sensitized Solar Cells:** **Wikipedia's explanation:** **VIDEO: LDC Design: Background Research**			
10 mins	**BRAINSTORMING POSSIBLE SOLUTIONS**: Ability to engage in a collaborative, creative process to brainstorm many possible solutions to an RFP.	**LISTING POSSIBLE DYES** Make a list of 10 or more possible dyes that can possibly be used for the dye-sensitized solar cell.	Student product meets expectations if: • A list of 10 or more dyes is created • The list reflects discoveries from student background research.	1. Begin by discussing the importance of the dye in the dye-sensitized solar cell. Discuss the technical details related to the structure of the molecule and how the dye functions in turning solar energy to electrical energy. 2. Give students time to do quick research to make a list of 10 dyes (or more) from which to start. Students should not yet have their minds set on a single dye but should have a set of dyes that can be narrowed down later. Remind students to look at their graphic organizers from the background research section completed in a previous class. One of the questions students researched was "What dyes are useful in making DSSC's?" This will be a good place to begin today.
30 mins	**ANALYZING POSSIBLE SOLUTIONS**: Ability to engage in theoretical, technical analysis of brainstormed, possible solutions in order to identify pros/cons of each solution - in reference to an RFP's list of requirements and scope.	**VETTING THE POSSIBLE DYES GRAPHIC ORGANIZER** From the list of 10 possible dyes, select three on which to do further research. Complete the Vetting the Dyes Graphic Organizer to evaluate the three factors (technical, time, and money) affecting the choice of dye. List the pros and cons associated with each dye and reference any resources you use.	A mastery-level work will demonstrate an accurate list of pros and cons of each of the three important factors (technical, time, and money) related to the choice of dye.	1. Instruct students to select three dyes from their list of 10. 2. Discuss reasons for choosing the dyes. Ask students the important features of the dye that might guide their decision.

- Suggestions for responses: time for extraction (time), difficulty of extraction (technical/time), price of the dye (money), time it takes to acquire the dye (time), shipping costs (money) if applicable, etc.

- Provide students the the Vetting the Dye Graphic Organizer. For each dye, students should do further research to explore the pros and cons associated with the technical, time, and money factors related to the choice of dye. Lead students in a discussion about what information they will need to research as they evaluate their dyes:
  - Regarding the **technical**—the quality of the dye and ability to absorb light is of high importance. A dye that only absorbs a narrow range of wavelengths may not be the most efficient in producing electrical energy.
  - Regarding the **time**—some dyes will be easy to extract, while others will require multiple, time-consuming steps to extract. Lengthy extractions require extra time, which means you have to pay for that time spent on that step. You have a fixed amount of time to complete this project, and there is little room for deadline negotiation. Suppose you want to order the dye from a particular vendor, and it won't be available for

				three weeks? You likely won't be able to settle on that dye, even if it is going to be the best dye in terms of light absorption and energy production. • Regarding the **money**—you must consider how expensive your dye is! Some dyes are a couple dollars, while others are hundreds of dollars. • Direct students to provide references to support their evaluation of each dye.
	Additional Attachments: **Vetting the Dye Graphic Oranizer.docx**			
Preparing and Presenting a Proposal				
45 mins	**COMMUNICATING POSSIBLE SOLUTIONS**: Ability to condense possible solutions into a simple paper or presentation that presents one or more options and potential pros and cons of that (those) solutions.	**COMMUNICATING THE DYE CHOICES IN A PARAGRAPH** Using the information collected in the Vetting the Dye Graphic Organizer from the previous mini-task, write a paragraph that carefully outlines the dye selection process. Make sure to discuss each of the three dye possibilities by describing the pros and cons in terms of time, money, and technical. Provide evidence from your research to support your decisions for using the dyes. Include references! **This paragraph will be used in your critical design report.**	Student work that meets expectations will: • Be written in passive voice • Be concise • Discuss three dyes, time, money, and technical issues • Include references.	This mini-task builds on the previous task in which students used a graphic organizer to research possible dyes. 1. Students will be instructed to use the graphic organizer to write a paragraph that will be used in the lab report. 2. After completing the paragraph, students will self-assess the quality of their paragraph by reading the paragraph out loud and use a checklist (to be written on the board) to determine whether all features of the prompt have been addressed. Checklist: • Passive voice • Concise writing • Dye 1: Time • Dye 1: Technical • Dye 1: Money • Dye 2: Time • Dye 2: Technical • Dye 2: Money • Dye 3: Time • Dye 3: Technical • Dye 3: Money • References

				• No opinions formed yet!
40 mins	**BIDDING THE PROJECT**: Ability to identify all needed resources for proposed product/solution and to communicate those needs to the institution that issued the RFP.	**COMPLETING THE DYE PROPOSAL FORM** Use the Dye Proposal Form to clearly document the extraction procedure for each of the three dyes. Some dyes require little preparation, while some dyes will require extensive preparation. Be sure to include all required techniques, glassware, and chemicals required for the extractions. ****Don't forget—all dyes are student-supplied! All extraction materials (glassware, chemicals) will be teacher-supplied.****	Student work meets expectations if the dye proposal form: • Is complete, concise, and accurate • Has necessary glassware, chemicals, and lab equipment listed • Ranks dye choices for preference.	Remind students: In the previous mini-tasks, you took a list of 10 possible dyes and narrowed them down to three possible dyes. You looked at time required for extraction, difficulty of extraction, and the price of the dye and extraction. 1. Allow students time to research the extraction/preparation techniques required for each of their three dyes. Instruct students to use the Dye Proposal Form to document each extraction procedure. Emphasize the necessity for including all relevant details—type of glassware, chemicals required, and lab equipment required. 2. Individually conference with students to determine what types of extractions they will need to perform to ensure they understand the process. 3. Instruct students to bookmark and document all references utilized for use in their critical design report. 4. Students should turn in their Dye Proposal Form at the end of class in order for the instructor to review the proposals and ensure all chemicals and materials are available for the dye extraction phase.
	Additional Attachments: **Catching Sun with a Donut DYE PROPOSAL FORM.docx**			
Detailed Design				
1 hr and	**TESTING CRITICAL**	**SUBSYSTEM TEST 1: CASTING THE SLIDES**	A mastery-level	1. Instruct students to

30 mins	**DESIGN COMPONENTS**: Ability to test critical subsystems for feasibility.	Using the procedures outlined in the DSSC request for proposal, you will practice casting titanium dioxide onto microscope slides. Document how much titanium dioxide and acetic acid is used, the time for grinding the mixture, and take a picture of your resulting paste. Document the casting process by taking note of any special techniques you might have tried and found successful (or unsuccessful). Take pictures of your practice slides.	response should include documentation of how the paste was made, pictures of the pastes, explanation of special techniques used in casting, and pictures of the cast slides.	make a data table in which they collect data on the quantity of chemicals used, time for grinding, and qualitative description of the resulting paste. A picture should also be taken. 2. Model the slide-casting techniques for students. 3. Instruct students to practice casting slides using their paste and document any notes on the qualities of the paste after being cast (too thick, too thin, cracked, lumpy, etc.). 4. Discuss casting methods with students to determine the methods that worked well. Have students highlight the test data that corresponded with the best slide. 5. Cast slides should be approved.
1 hr	**TESTING CRITICAL DESIGN COMPONENTS**: Ability to test critical subsystems for feasibility.	**SUBSYSTEM TEST 2: PREPARING THE DYE** Prepare/extract each of the three dyes according to the procedures outlined on the Dye Proposal Form. Once extracted, use a Vernier Spectrometer to measure the wavelengths of light being absorbed by the dye.	Masterly-level experimental notes will be clear and concise and should be included on the Dye Proposal Form. A final dye selection should be documented that is based on experimental evidence. The final dye selection should also refer back to the time/technical/money as part of the final decisions on dye choice.	1. Allow students to begin their dye extraction. Emphasize the use of the Dye Extraction Notes form for documenting any experimental notes regarding the methods for extraction, relative concentration, light absorption of the dye. Also emphasize the need to concentrate the dye as much as possible—**avoid overdiluting the dyes!** 2. Meet with each student group individually (once they have all three dyes prepared) and use the Vernier Spectrometer so that each group can make observations and collect data on the wavelengths of light absorbed by each dye. 3. Send data from the Vernier Spectrometer to

				each group for them to have for further analysis. 4. Instruct students to evaluate their results and determine which of the three dyes will be their final choice when building the solar cell.
	Standards: **RST.9-10.3** : Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.			
	Additional Attachments: **Catching Sun with a Donut DYE EXTRACTION NOTES.docx** **VIDEO: LDC Design: Testing Critical Design Components**			
30 mins	**FINALIZING DESIGN**: Ability to incorporate critical component test results in order to adjust the design of subsystems (and overall design) as necessary in order to ensure final design solution adequately addresses the list of requirements contained in an RFP.	**FINAL DYE CHOICE PARAGRAPH** Using information gleaned from the subsystem test runs, write a paragraph that describes the final dye choice. Explain your reason for choosing the dye in detail—what worked well, what did not work well. Discuss your reasons for eliminating your other dye choices.	A final dye choice paragraph which meets expectations: • Uses data collected from subsystem testing • Clearly states the choice of dye • Explains why the other two dyes did not get chosen.	1. Instruct students to compile their information gathered during testing to write a clear, concise paragraph to explain why the dye was chosen and why the other two dyes were not chosen. 2. After writing their paragraph, instruct students to self-assess their work by reading their paragraphs aloud and using the checklist of required content for this paragraph. Checklist • Passive voice • Concise writing • Final dye choice is stated clearly • Experimental evidence for dye choice is provided • Other dye choices that were eliminated are stated clearly • Experimental evidence supports reasons for elimination
	Standards: **WHST.9-10.7** : Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.			

Design Report				
10 mins	**TITLE PAGE**: Ability to make a title page with appropriate identifying information.	**CREATE A TITLE PAGE** Create a title page using the information below: **Critical Design Report Title (should be a scientific title—not intended to be creative or funny, but descriptive of what this project was focused on)** **Group Name: Group Members (in alphabetical order)** *Metro Early College High School, Columbus, OH 43210* *Submitted under the supervision of Tamara Beilke: Date Submitted*	The title page meets expectations if it is neat and includes all of the above information.	1. Show examples of title pages and evaluate them for qualities of professionalism. 2. Instruct students to create a title page including the required information. 3. Check over work to ensure all important information is included.
	Additional Attachments: **A Not-Good Title Page.docx** **A Good Title Page.docx**			
30 mins	**BACKGROUND**: Ability to communicate the background on "why we are doing what we are doing."	**WRITING THE BACKGROUND INFORMATION** Using information gleaned from the Explore DSSCs activity, write one to two paragraphs introducing the project. Questions to answer: • Why is solar energy important? • What types of solar cells are available? • What is the advantage of using a dye-sensitized solar cell? • What kinds of dyes are used in a DSSC?	Student response meets expectations if: • One to two paragraphs provide a thorough background of the project and answer the required questions • Paragraphs are concise and written in passive voice.	1. Distribute examples of scientific papers to students to look over. Using the examples, discuss the purpose of a background/introduction section of a paper. Identify key features of the introduction section (reason for the work, previous examples of research conducted, proposal for the research to be demonstrated in the paper). 2. Provide time for students to begin writing their introduction section. Use the prompt questions as a guide for what content students should include in the introduction. 3. Instruct students to use their Dye-Proposal paragraph previously written to conclude the introduction section. 4. Instruct students to check for passive voice, concise writing, and answers to all questions above.
	Additional Attachments: **Graztel paper.pdf** **Photoelectrochemical cells.pdf**			

30 mins	**DETAILED DESIGN INFORMATION**: Ability to communicate (with words and graphics) the details of a design solution and how it is built/executed.	**WRITING THE DETAILS OF THE DESIGN: PROCEDURES** Use the quantitative and qualitative data collected throughout the lab to write two to four paragraphs that completely explain the procedures used in the lab. Include: • Techniques used to extract titanium dioxide • Quantities, times, techniques used to make the titanium dioxide paste and cast the slides • Extraction techniques for the dye (if necessary) • Preparation of the dye • Procedure for constructing the solar cell This section should be detailed enough for someone to repeat the work you did and obtain equivalent results. It should NOT be bullet points or written as commands. Use pictures taken from the lab! Use passive voice.	The student product meets expectations if the written procedure is complete, can be followed and repeated by a peer to obtain equivalent results, and is written in passive voice (not as commands).	1. Distribute examples of scientific articles to students. 2. Have students take a few moments to identify features of the article and highlight examples of passive voice constructions. 3. Discuss the organization of information within the procedure section. Note the inclusion of materials and the format for delivering each step of the procedure. Discuss the use of passive voice for writing the procedure as opposed to using bullet points or commands. 4. Provide time for students to begin writing their procedures. Emphasize the need for including all required sections as described in the prompt.
	Standards: Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. **WHST.11-12.2** : Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.			
	Additional Attachments: **Procedure Paper 1.pdf**			

30 mins	**DEFENSE OF DESIGN**: Ability to clearly articulate (using evidence) how the design solution meets the original design requirements as laid out in an RFP.	**WRITING ABOUT RESULTS/FUTURE CONSIDERATIONS**
		In one paragraph, detail the results of the experiment. Use the following questions to guide your discussion. Include actual data evidence to support your claims.
		
		• What was the overall voltage of your solar cell?
		• How did it compare with other solar cells?
		• Did it perform similar to others using the same dye? Better? Worse?
		• Draw conclusions about the results. What features of the solar cell construction may have contributed the most to the overall results?
		  ◦ Did the titanium dioxide coating remain in-tact?
		  ◦ Did the dye actually dye the coating?
		
		Provide two suggestions for improving the solar cell, dye, or any aspect of your project. Do not say “we think” or “something to try is” in your suggestion.
			Defense of design meets expectations if it provides:
			
			• The results of the experiment (including the actual voltage reading)
			• A discussion of how the solar cell functioned compared to others
			• A full evaluation of the solar cell construction based on the guiding questions from the prompt
			• Two suggestions for how to improve the solar cell in the future.
				1. Instruct students to write a paragraph to answer the prompt above. Students should use entire class data and compare their solar cell function to others. Students should consider similar dye selections and discuss their results in relation to others with the same dye choice (if applicable).
				
				2. Allow students time to self-assess using the checklist below.

				Checklist • Passive voice • Concise writing • Results clearly stated • Solar cell function is discussed in detail • Two future considerations included
45 mins	**EXECUTIVE SUMMARY/ABSTRACT**: Ability to write a brief, comprehensive, and accurate summary of an issue/need and designed solution to that need.	**UNDERSTANDING AND WRITING AN EXECUTIVE SUMMARY/ABSTRACT** AFTER you write the rest of the critical design report sections, write a one-paragraph summary of the entire work—WHAT was done, HOW it was done, and the RESULTS.	A mastery-level abstract is one paragraph (about 250 words) in length. It includes concise information about what was done, how it was done, and what the results were.	1. Use the attached link to go to the Purdue OWL page on Abstracts/Executive Summaries. Discuss with students the purpose of the abstract and read through the example abstracts on the page. Discuss the differences between the example abstracts and the applications to this project. 2. Allow time for students to begin writing their abstracts using their previously written sections as a guide. 3. Instruct students to self-assess using the following checklist. Checklist • Passive voice • Concise writing • One paragraph or approximately 250 words • What was done • How it was done • Results • Suggestions for future work
	Additional Attachments: **The Report Abstract and Executive Summary**			

Instructional Resources

Student Handout

Catching Sun with a Donut STUDENT Handout.docx

RFP DSSC 2015.docx

Teacher Resource

- **VIDEO: LDC Design: Background Research**
- **VIDEO: LDC Design: Testing Critical Design Components**

Section 4: What Results?

Student Work Samples

Meets Expectations

Solar Cells Sample 1.pdf

Approaches Expectations

Solar Cells Sample 2.pdf

Not Yet

Solar Cells Sample 3.pdf

Teacher Reflection

Did students perform better or worse than you expected?

Both. On the whole, I expected each group to turn in a complete document with each of the required components complete. I didn't get that. However, for this being the first report of this caliber that they have ever been expected to produce, the quality of the work was definitely a step in the right direction.

Were there parts of the rubric that all students seemed to do well on?

Students seemed to get a very good understanding of what dye-sensitized solar cells are and were able to articulate that in their work.

Were there parts of the rubric that all students struggled with?

Students had a hard time using in-text citations and using research to support their claims. They put citations at the end of their documents, but there were few listed, and never discussed within the text. Students also scored low on the Plan the Design and the Design Solutions sections. They did not include sufficient details to support their design, and should have included more schematics and data to support their claims.

If you were to re-teach this module, which parts of your instructional ladder would you definitely keep and what parts would you consider replacing or modifying?

The lab components are essential to the project, despite the time required to complete. I would modify the way the writing components are instructed because there were clear deficits in student understanding of what was expected to be included and how it was to be formatted. Having sample reports to show the students will really help next time.

If students do not have experience writing in passive voice, consider adding a skill and mini-task which would have them “translate” a wordy, active-voice paragraph into more scientific writing style. That would be pretty quick—and get them ready for practicing the desired writing style you want.

Anything else that comes to mind that you would change for next time?

The titanium dioxide extraction did not go quite as planned. The source video shows the filtration being done by gravity, but this didn't work the first time we tried it. We adapted the procedure to use buchner funnels to filter the mixture, but that still didn't work well. We ended up having to use stock TiO2 which isn't quite as exciting as using

donuts. If the goal is to teach lab efficacy, it's a good idea to try the donuts because it is a real example of how lab practice doesn't always go as planned.

When casting the slides, students should not cast the square in the corner. It was helpful to cast the slide offset to the edge so that there was enough room to connect the multimeter.

All Attachments

- Request For Proposals_DSSC_2015.docx : https://s.ldc.org/u/7ke4qz0kq56a9mqj7jurfzv5u
- Text List for Catching Sun.docx : https://s.ldc.org/u/29dj0in68yj9eanfgpmn3mnsy
- Solar Cells Sample 1.pdf : https://s.ldc.org/u/2ryii28uvd0g1bejxhq0g343s
- Solar Cells Sample 2.pdf : https://s.ldc.org/u/bgmqgxundpra2cya1nz0rnemk
- Solar Cells Sample 3.pdf : https://s.ldc.org/u/654zciacqcvnh10yyth7ywb2p
- Catching Sun with a Donut STUDENT Handout.docx : https://s.ldc.org/u/5s4omtmbyk4usf40sxjitjo3r
- RFP DSSC 2015.docx : https://s.ldc.org/u/cnc4fdv151ijcvcfjzp7chg3k
- VIDEO: LDC Design: Background Research : https://s.ldc.org/u/d0h7p7f34c7ldxgy62furxghh
- VIDEO: LDC Design: Testing Critical Design Components : https://s.ldc.org/u/59dgyhuppxlnjuef5ajiw1xz4