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| **Lesson Activity** | **Implementation Notes** | **Pedagogical Strategies** |
| **Part I. Defining and delimiting the problem (75 minutes)** | | |
| Elicit and build background  knowledge on the problem of  HAIs (10 min) | 1. Facilitate a whole class discussion to elicit students’ background knowledge:  * *Why do doctors and nurses wear gloves, masks, and gowns during medical procedures?* * *What might happen to patients if doctors and nurses didn’t wear this equipment?*   When necessary, prompt students to think about the spread of pathogens, including bacteria. Point out prior learning on cell theory (related to DCI LS1.A), if applicable.   1. Have students read two CDC infographics: <https://bit.ly/2JS5fPG> and then add additional information to their responses to the prompts. | **Document student ideas:**  Place a T-chart with the two prompts at front of class on chalk or white board, Smartboard or on chart paper.  To make this information public, jot students’ responses on the T-chart during the initial discussion and after reading the infographics. |
| Provide context for  the design problem  (20 min) | 1. Have students consider the following questions while watching the video(s):  * *What is the nurse attempting to do in the video?* * *Why is she doing it this way?* * *What are potential issues with the process she is using?*   Video 1: <https://youtu.be/vCjoo6LOwz8>  Video 2: <https://bit.ly/3ce0IDf> | **Check for understanding:**  Place a T-chart with the prompts at front of class on chalk or white board, Smartboard or on chart paper and jot students’ responses on the chart after they have watched the video(s). **OR**  Give pairs or small groups (3-4) of students a copy of a blank T- chart and have them fill it out while or after watching the video(s). Then hold a whole class discussion to formatively assess students’ understanding of the problem. |
| Present the design problem, identify criteria and constraints (45 min) | 1. Present this design problem statement:   *Your goal is to re-engineer packaging for sterile gloves to make it easier for health professionals to self-don.*   1. Provide each team with one pair of sterile gloves still in their packaging. 2. Ask design teams to make a list of potential criteria for a successful prototype.  * Display or provide each team with a copy of Figure 2 to help them think about the needs of end-users and stakeholders.  1. Collectively determine **design criteria** by sorting sticky notes into groups with each group of stickies representing one criterion. 2. Collectively determine **design constraints** for each criterion and **testing procedures** that will be used to determine whether or not a prototype has met each criterion (see Table 5).  * Provide each design team with a blank copy of the criteria and constraints matrix to fill out for their records (see Supplemental Materials). | **Group students into design teams:** Before presenting the problem statement, divide students into pairs or small groups (no more than four students). Students in design teams will collaborate on potential designs, prototyping, presenting and writing their design briefs.  **Clarify the criteria for a successful design:** Give design teams sticky notes and ask them to write one criterion per sticky note. Then as a whole class, begin to sort the stickies into groups of related criteria.  **Determine constraints on the design:** Say to students, “*Now that we have our criteria, we need to determine the limits or metrics we’ll use*.”  Then, “*For criterion 1* (e.g., easy/efficient to self-don), *what do you think is a reasonable metric to decide if a prototype has met this criterion?*” (e.g., can self-don in less than 1 minute)  Then, “*How might we measure this* (i.e., our testing procedure)*?*” (e.g., use a stop watch to time each team member as they self-don)  Repeat this for each criterion. |
| **Part II. Generating design concepts** (85 minutes) | | |
| Generating design concepts  (40 minutes) | 1. **Brainstorming design concepts**: provide each design team with engineering or graph paper to draw and label design concepts, then ask each member of the team to draw at least one design concept (preferably working individually). Tell students to label each structure, or feature, of their design and briefly describe its function. 2. **Communicate about design concepts**: Ask each member of the design team to share their design concept with their team members by describing the features of the design and the functions of those features, and how the design will meet the design criteria, especially the criterion of reducing or eliminating the chances that end-users will spread bacteria or other pathogens.  * *Optional*: Have each design team present to the whole class he similarities and differences among the design concepts on their team. | **Be sure to show students the materials** available for prototyping prior to generating (drawing) design concepts. This helps ensure students don’t generate overly complicated designs that aren’t feasible for prototyping.  **Brainstorming design concepts:** Remind students their engineering drawings are for communication, not for aesthetic appeal, as they might be in an art class. Rough sketches are OK as long as they communicate the essential features/structures of the design.  **Check for understanding**: While students are generating design concepts, rotate among student groups and ask probing questions such as, “*Tell me about your design. How will the features of the design meet the criteria?*”, “*What purpose will this feature of your design serve? How does this design feature work with others in your design?*”, “*How does your design ensure that medical professionals will be able to maintain sterile field (reduce or eliminate the spread of bacteria?*” These questions will help you gauges students’ understanding of the challenge and the ability of their design to meet the criteria, which is ultimately to design a product that keeps patients safe from HAIs.  **Compare/contrast designs:** During team share-out, remind students not to evaluate one another’s design, but instead listen carefully to how their team members’ designs are similar to and different from theirs. |
| Evaluating design concepts (45 minutes) | 1. **Evaluate design concepts**: Provide design team with a copy of the student tradeoff matrix (see Supplemental Materials). Show them how to set up the baseline design concept (any one of the three or four concepts) and how to use the -1, 0, +1 rating system (see Table 6). Then, allow them to complete their tradeoff matrix as a team. 2. **Justify their design concept selection**: Using evidence from the tradeoff matrix, students should explain in writing why they chose the design concept they did to advance to prototyping with particular attention to reducing the spread of pathogens that cause HAIs. | **Eliminating the popular vote**: Rating (evaluating) the design concepts require judgement and justification. While intended to be a tool to make concept selection more “objective”, the overall purpose is to think critically about the feasibility of each concept in meeting the criteria rather than choosing the most “popular” design concept.  **Check for understanding**: The written justification of each team’s design concept selection for prototyping provides information on the ability of their design to meet the criteria. |
| **Part III. Building and testing prototypes** (90 minutes) | | |
| Constructing prototypes  (60 min) | 1. **Manage materials**: Provide design teams with access to materials and instructions on how to use them (see Safety Notes in the article) 2. **Build the first-gen prototype**: Using the design concept they selected using the tradeoff matrix, allow them time to work as a team to build a first-generation prototype of their design concept.  * *Optional*: Give each member of design teams specific roles such as materials procurement, adhesives manager(s), subtractive manufacturer (i.e., the person who cuts things into pieces), etc. | **Setting limits on materials**: Communicate with design teams about the importance of taking only enough materials needed to build their prototype. It’s common for students to take handfuls of materials at first, rather than just what they need. You could also set limits in advance on how much of each material the teams have available for prototyping.  **Periodic time checks**: Set a classroom timer, visible to students, that counts down the amount of time they have for prototype construction. Some teams will take a long time to construct their prototype if a time limit is not set. |
| Testing prototypes  (30 min) | 1. **Prototype testing**: Provide each team with a copy of the design validation table (see Supplemental Materials) and have them set up the table by writing in the criteria and testing method (or have it filled out for them). Explain to the students how to use the testing instruments, if necessary. Remind students to write down their data immediately after measurement so they don’t forget the values. | **Make testing efficient**: Set up stations in different parts of the classroom with testing instruments. Provide students with instructions on how to rotate among the testing stations so there isn’t a log jam of students at one particular testing instrument.   * *Optional*: If using the Glo Germ powder, set this up at a station that you can directly manage. Otherwise students might make a mess or use an unnecessary amount of the powder. The point of this powder is to model the spread of pathogens when sterile field is broken. |
| **Part IV. Refining the design** (120 minutes) | | |
| Presenting first-gen designs  (60 min) | 1. **Communicate about their first-gen prototype**: Ask each design team to present to the whole class the following about their first-gen prototype:  * Essential features of the design and their intended functions * The outcomes of their tests and whether or not their design met the criteria * Report on whether or not their prototype allowed end-users to maintain sterile field  1. **Give and receive feedback**: Allow students not presenting to give verbal or written feedback to each presenting team about how they might refine or improve their prototype. Give individual students (or teams) prototype presentation feedback forms (see Supplemental Materials) to fill out for presenters. | **Provide presentation guidelines**: Tell students they have 3-5 minutes to present their prototype, its strengths and weaknesses. Provide norms about giving feedback to other teams; namely that any comments made about another team’s design should be constructive and actionable.   * *Note*: Presentations can be formal or informal. Informal: post the guidelines on the board and allow students to speak extemporaneously about their prototypes. Formal: Have design teams prepare 2-4 PowerPoint slides to present to the class with each member contributing to the presentation. |
| Constructing second-gen prototypes  (60 min) | 1. **Refine the design**: Once each design team has presented, have each team reflect on the outcomes of their testing and the feedback they received. Ask they to explain how they will refine or improve their design, and document their plans by responding to the prompt at the bottom of the design validation table.  * *Optional*: Have each team submit a new or revised design concept drawing with their written justification to show how they will improve their first-gen prototype and maintain sterile field.  1. **Build and test the second-gen prototype**: Using the same procedures as Part III, allow students to improve their first-gen prototype or build a wholly new second-gen prototype and test it using the same procedures as before. | **Use design failure as improvement**: It’s important to communicate to students that design failure is a normal part of engineering. Engineers use tests to determine the strengths and weaknesses of a prototype so they can make it better.  **Check for understanding**: The written justification for improving their prototype serves as a check of the students’ understanding of how to use data to refine their designs. |
| **Summative Assessment** | | |
| Final Design Brief | 1. **Communicate about the second-gen prototype**: Ask students individually or with their design team to write a design brief about their second-gen prototype. | See design brief guidelines and rubric in Supplemental Materials. |