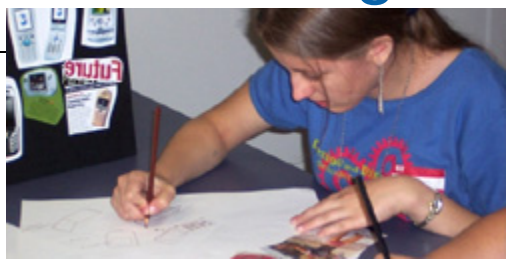
Session 11

Design Requirements and Drawings

Making, Modeling, and Materializing



In This Session:

A) Checking in on the Design Process (45 minutes)
- Student Handout

B) The Perfect Fit: Meeting Needs Through Design (45 Minutes)
- Student Handout
- Student Reading

C) Conceptual Drawing: Thinking on Paper (60 Minutes)
- Student Handout
- Student Reading

In this session, students refine their design efforts with product requirements and drawings. In *11A: Checking in on the Design Process*, they look at a checklist of steps that follow the design process to determine how far they've come, and look ahead to the next steps. Next, in activity *11B: The Perfect Fit: Meeting Needs Through Design*, students learn how a designer considers the needs of the user to define minimum requirements for a design, and students then develop design requirements for their own projects. In a third activity, *11C: Conceptual Drawing: Thinking on Paper*, students learn how drawing helps the thinking process, then put pen to paper to make a series of conceptual drawings. By the end of the session, students have a more fully developed project and are ready for the next steps, modeling and testing their ideas.

Supplies

- Pencils and pens, rulers, graph paper (if not in design notebooks)

Design Requirements and Drawings

Key Concepts: Session 11

Session 11 aids students in furthering their design plans by helping them to come up with **design requirements** for their project and by providing instruction for translating their ideas into **drawings**. The session helps students develop a better understanding of the visual aspects of the project as they make detailed drawings of their projects to communicate needs and to help refine the project.

Key Concepts
A key component of the design process is the making of sketches and diagrams to go along with the project. In fact, many products have come about because of "napkin drafting," a more crude and simplistic way to communicate ideas. Encourage students to doodle, sketch, and make diagrams before the actual construction occurs. This session concentrates on using elements of mechanical drawing to show the students how the visualization of a project can help to refine the needs of the design.

Although mechanical drawing is commonly carried out by computers now, especially in the revision stage of design, drawings are still the most widely used communication tool in the engineering community. The primary reason for this is because drawings often serve as documentation of requirements. Drawings are used to produce quotes, determine manufacturing methods or processes, and inspect parts to ensure they meet the requirements defined within the drawings. Making a readable drawing is key to assuring that design team members can look at it and understand what's required.

Drawing the design of the project is an important step in refining the project and identifying some issues with the design. It is a good idea to stress to the students that if they change something in the design to get around an issue, they should write out what the issue was and why they changed it. Remind the students that in three months, they might not remember why they made that change and might try to change it back.

Drawing Methods
This session serves as an introduction to basic drawing techniques. It begins with students learning to draw lines and circles using graph paper. Students should come to understand that showing their project from all angles and with component parts will help them to identify potential problems and to refine the project without having to build it first. It is useful to have a basic understanding of the different types of sketches.

Orthographic sketches show a three-dimensional object in two dimensions by displaying the front, top, and side view. When drawn, each view is evenly in line with each other. The front view is located at the bottom left. The top view is directly above the front view. The side view is directly to the right of the front view.

Other types of sketches include (not addressed in the session) include: isometric, oblique, and perspective. An **isometric sketch** is a three-dimensional drawing in which the horizontal axes form a 30-degree angle with the true horizontal line. An **oblique sketch** is a pictorial drawing in which the front view of an object is shown as true size and shape. The top and side view is at a

Key Concepts: Session 11 (continued)

30-degree angle. A **perspective sketch** is a pictorial drawing in which lines move "away" from the view and converge.

More About Conceptual Drawing

Lo, Jack. *The Patent Drawing Book*. Berkeley, CA: Nolo Press, 1997.

Walker, J. R. *Exploring Drafting*. Tinley Park, IL: Goodheart-Wilcox, 1996.

Session 11, Activity A

Checking in on the Design Process

Goal
Understand the design project timeline.

Outcome
Students know where they are and what comes next on their design project.

Description
Students review a checklist for their design project and look ahead to what they will be doing. It is not a direct and linear progression through the series of steps. The steps may be repeated, and there may be small cycles between some of the steps. While they see that checklist steps follow the design process, students also discuss the non-linear nature of design.

Supplies
None

Preparation
None

Procedures

1. Introduce the session by asking students to think about where they are with their project—closer to the beginning, or to the end? Somewhere near the middle? How can they tell? Introduce the checklist handout as an organizer for the work they have done and will be doing in order to complete the design project—a refined working prototype.

2. Discuss the steps in the checklist and point out that while the checklist follows the design process, the design process is not linear with one step always following another. Some steps are revisited time and again; others cause the designer to change direction. The process changes as the designer's ideas change.

3. Review the schedule. Discuss goals and work time available in and out of class time.

4. Allow time for students to review their progress, complete the checklist, and discuss any questions that come up.

Wrap Up
Discuss any questions about the design process and review expectations for the project work ahead.

Follow With
In *11B: The Perfect Fit: Meeting Needs Through Design*, students define design requirements for their project that focus on the needs of the user.

Checking in on the Design Process

Handout: Session 11, Activity A

The Design Process: Getting From "Think" To "Thing"
The checklist below is adapted from the design process steps. This is a tool to keep you organized and thinking about where you have been and where you want to go.

1. Identify a design opportunity. (Session 7)

- ☐ Identified many design opportunities (needs, problems, or cool things to design).
- ☐ Narrowed the list of opportunities to three for further research.

2. Research the design opportunity. (Session 7)

- ☐ Refined my design opportunities with interviews and other data-gathering research.
- ☐ Selected one design opportunity to address.
- ☐ Wrote a problem statement to clarify and explain to anyone what I will solve with a design solution.

3. Brainstorm possible solutions to the problem. (Session 7)

- ☐ Expanded my possible solutions using SCAMPER and other research.
- ☐ Evaluated my solutions using criteria that we determined.
- ☐ Narrowed my solutions to three possibilities.
- ☐ Began thinking about the types of materials I could use for my solutions.

4. Draft a Design brief. (Session 8)

- ☐ Wrote a design brief with a problem statement, a description of user needs, a proposed solution, and a sketch of the solution.

5. Research and refine your solution. (Session 9)

- ☐ Researched and refined my proposed solution using the U.S. Patent Office Web site and other resources.
- ☐ Took notes and wrote down information from my research.
- ☐ Interviewed experts and possible users to analyze my project for feasibility, safety, and other implications of my solution.
- ☐ Researched materials and methods that would be appropriate for constructing my project.
- ☐ Conducted a project analysis to consider any changes to my solution.

11A Handout: Checking in on the Design Process (continued)

6. Prepare design requirements and conceptual drawings. (Session 11)

- ☐ Developed design requirements that focused on the needs of the user.
- ☐ Completed conceptual drawings.

7. Build models and component parts. (Sessions 12, 13, and 14)

- ☐ Analyzed my project design for its systems, components, and parts.
- ☐ Planned models to build and what each model would test or be able to demonstrate.
- ☐ Built a model or models of components of my design.
- ☐ Developed a project plan for completing my design.

8. Build the solution prototype. (Session 15)

- ☐ Conducted further research, model building, and testing, as needed to complete a working prototype.
- ☐ Developed specifications.
- ☐ Completed first working prototype.
- ☐ Analyzed prototype for functional improvements.

9. Test, evaluate, and revise your solution. (Session 16)

- ☐ Prioritized improvements needed and built new or revised prototype to meet priorities.
- ☐ Evaluated prototype for function, feasibility, safety, aesthetics, and other criteria.

10. Communicate the solution (Session 18)

- ☐ Presented my solution to an audience.
- ☐ Gathered feedback and made appropriate changes to prototype.

Session 11, Activity B

The Perfect Fit: Meeting Needs Through Design

Goal
Fine-tune a project design by taking a closer look at the needs of the user.

Outcome
Students fine-tune their project design by producing parallel lists of user needs and the project design requirements that address those needs.

Description
The activity starts with an example of a product—the Terry* bicycle—that was improved when the needs of the user were given a closer look. Students look at the design innovations that improved this product and the user needs that prompted the improvements. Next, students consider the needs of their intended users and write design requirements for their own projects.

Supplies

- Print pictures of the Terry bicycle from www.terrybicycles.com/index.html*.

Preparation
None

Procedures
A Look at Design Requirements: The Terry Bicycle, www.terrybicycles.com/index.html*.

1. On *11B Reading: The Perfect Fit: Meeting Needs Through Design*, read together the story of Georgina Terry, a bike racer who saw that there was no production of women-specific bikes and started her own company to produce bikes for women. Ask: Given the woman bicyclist's physical needs, what design features should be considered in making a better bike for her? List these user features on the board one at a time.

User Needs	Design Requirements
Shorter arms and torso	Shorten the distance from the handlebars to the seat (the cockpit length) by making the top tube length shorter.
Smaller hands	Shorten reach to brake levers.
Narrower shoulders	Make narrower handlebars.
Shorter legs	Shorten crank arms for more efficient spin.

11B: The Perfect Fit: Meeting Needs Through Design (continued)

2. Explain: Many everyday bikes have a good deal of adjustability. The seat can be moved forward, the brake lever reach adjusted, and the seat stem raised. Higher performance road bikes are another problem. The big difference is when a bike is sized more compactly for women, a new problem arises. The tight geometry of the racing bike doesn't work with regular racing wheels; you run into toe-wheel overlap, where the tips of your shoes hit the front wheel when turning and pedaling at the same time. This was the biggest problem Terry took on in her new design.

3. Discuss how she might have solved this problem. Then explain that she solved the problem by designing a new, smaller front wheel, allowing the bike to have the same

   geometry with the smaller frame. Suggest that this new problem get added to the list.

4. Ask: What was her new problem? What was the design solution? Show students pictures of the Terry bike.
   Terry's biggest innovation:

User Needs	Design Requirements
Smaller bicycle frame causes toe-wheel overlap	Smaller front wheel

Your Design Requirements

1. Have student designers look at their users' needs, and turn them into minimum requirements. Suggest that they refer back to the user characteristics and scenario that they came up with in *8A Handout: User Profile*.

2. Suggest that students use the same process that Georgina Terry used. She looked at the users' needs to determine the requirements. Discuss specific factors that designers consider when they look at their users' needs, and suggest that students consider these as well:

   - Appropriate weight and size
   - Durability
   - Ease of use (functionality)
   - Safety

3. Have students fill out the chart on their handout.

4. Provide work time, and encourage students to discuss their ideas with one another as they work. When they finish, have students get in groups of four or five and explain their users' needs and design requirements to each other. Feedback from members of the group will help designers refine their efforts.

11B: The Perfect Fit: Meeting Needs Through Design (continued)

Wrap Up
Have students refer to the design process checklist and ask them which step they are on (Step 6). Ask if there are any steps they want to revisit after looking at design requirements—a common next step is a return to a previous step!

Follow With
The next activity, *11C: Conceptual Drawing: Thinking on Paper*, gives students a chance to analyze their projects in a visual way.

The Perfect Fit: Meeting Needs Through Design

Handout: Session 11, Activity B

Your Design Requirements

Now consider the user of your product and what requirements might be necessary in order to meet the needs of the user. Refer back to the character identities and scenarios that you did in *8A Handout: User Profile*. Make a chart like the one below in your notebook and fill out the requirements.

User Needs	Design Requirements

The Perfect Fit: Meeting Needs Through Design

Reading: Session 11, Activity B

Many products have been improved when the needs of the user were given a closer look, including the Terry* bicycle. After looking at this design innovation based on the users' needs, you'll consider the needs of your intended users.

A Closer Look at Design Requirements: The Terry Bike Success Story
Georgina Terry, a bike racer, felt disadvantaged when she raced using a man's bike. She thought she could perform better if the bike fit her better. Even though she had a bicycle that was designed for a rider her height, and even though she had adjusted the seat and handlebars just so, it still didn't seem right. She realized that her bike might be designed perfectly for a man her height, but a woman is put together differently, and needs a different bike design.

She looked into the physical differences between men and women, and here's what she found out: When a woman and man of the same height are compared, the woman typically has longer legs, shorter arms, and a shorter torso than the man. She has smaller hands and feet, a wider pelvis, and less muscle mass as well. Design requirements for a women's bicycle emerged from her research:

User Needs	Design Requirements
Shorter arms and torso	Shorten the distance from the handlebars to the seat (the cockpit length) by making the top tube length shorter.
Smaller hands	Shorten reach to brake levers.
Narrower shoulders	Make narrower handlebars.
Shorter legs	Shorten crank arms for more efficient spin.
Smaller bicycle frame causes toe-wheel overlap	

The Problem
When a bike is sized more compactly for women, a new problem arises. The tight geometry of the racing bike doesn't work with regular racing wheels; you run into toe-wheel overlap, where the tips of your shoes hit the front wheel when turning and pedaling at the same time.

The Solution
How do you think she solved this problem? After studying pictures of a Terry bike, what was her solution? Add her solution to the design requirements chart above.

The Terry bicycle is popular with women, because, as she puts it, "a woman isn't just a smaller version of a man." In her first year, 1985, she sold 20 women's bikes; the following year, 1,300;then 5,000, and today it's a multimillion-dollar enterprise.

Session 11, Activity C

Conceptual Drawing: Thinking on Paper

Goal
Learn how conceptual drawings help fine-tune a design.

Outcome
Learners make conceptual drawings of their projects that show all the parts of the design.

Description
Student designers take their project another step farther along the design process as they make conceptual drawings of their project ideas. They learn that the drawing process is a helpful part of refining a design concept, bringing to light practical concerns that need to be resolved, such as how component parts fit together. Drawing from a variety of perspectives helps illustrate all the features of a design and helps the designer communicate ideas to others.

Supplies
Pencils, pens, rulers, graph paper (if not in design notebooks)

Preparation
None

Procedures
Drawing Basics

1. Pass out rulers and pencils for initial drawing. Students are usually more comfortable drawing, initially, in something that can be erased and corrected. Rulers help with straight lines.

2. Learning how to use graph paper is a good first step in developing mechanical drawing skills. The grid provides a ready scale that aids in sketching proportionally by counting the squares within the object to be drawn.

3. Explain and have students practice drawing a straight line using the following method:

    - Place a dot where you want the line to begin and one where you want the line to end. In sketching long lines, place one or more dots between the end dots.
    - Tell students to swing their hand in the direction that they want the line to go, and then back again a couple of times before touching pencil to paper. In this way, they get the feel of the line. They should then use the dots to guide their eye and hand to draw the line.
    - Draw lines with a series of short strokes instead of one stroke. This provides better control of the direction of the line and the pressure of the pencil to paper.
    - Suggest holding the pencil about an inch from the point to help with seeing the drawing. Vertical lines are usually sketched downward on the paper. Slanted

lines may be drawn from either end toward the other. For better control, students can rotate the paper.

4. Tell students to sketch lightly at first. Essential lines can then be darkened.

5. To sketch circles and arcs, instruct students to do the following:

   - To draw a circle on grid paper, decide the diameter of the circle and the placement and then make tick marks at the 12 o'clock, 6 o'clock, 9 o'clock, and 3 o'clock positions.
   - Draw the arcs between the tick marks. Alternatively, use a straight line to draw a circle. Do this by drawing two straight lines that cross each other at right angles. The point at which they cross is the center of the circle. The four lines radiating from the center will serve as the radii of the circle.
   - Measure an equal distance on the on each radius from the center. Sketch a square.
   - Now sketch a circle, using the angles of the square as a guide for each arc.

6. Use this as practice to get the students out of the "I can't draw" mindset. Have students draw three different views of an object with a lot of straight lines—like an overhead projector or the blackboard or an easel and stress to them that you do not want a 3-D view of the object, but you want to see what it looks like from the side, the top, and the front. Using the graph paper, they can apply the basic drawing techniques.

7. Have students trade drawings with someone else that they normally don't work with, and see if each student can identify parts.

Drawing Different Views

1. Discuss how that, in addition to drawings made along the way, final drawings are made, too, before a product can go into production. Why? Drawings are needed if the designer applies for a patent; also, before the product is manufactured, drawings aid communication between the designers, engineers, and the manufacturer.

2. Discuss how seeing the object as a set of shapes is important to sketching ideas. If you know how to draw each of the shapes, then drawing the object is easier. Explain that designers show an object from several views. Have students look at the first drawing on the handout and discuss what the different views show about the object. Tell students that drawing their project might involve two or three drawings, one of each unique side, and maybe the inner workings as well. They may want to label parts and use arrows to show how parts move.

3. For the second set of drawings, have students to try to match the objects shown in 3-D on the top row in their front, side, and top views.
   (answers: A=3, B=2, C=1, D=4, E=9, F=8, G=5, H=6, and I=7)

11C: Conceptual Drawing: Thinking on Paper (continued)

4. Ask students if they recognize the next set of drawings *(different views of the crankshaft toy)*. Can they tell what views they are seeing? Have them label each figure with its viewpoint: top, interior, and side. Each drawing helps show different aspects of the device. Then, direct them to look at the last drawings done by former *Design and Discovery* students.

Imagine...

1. Before having students draw their projects, do a visual imagery activity. Have students close their eyes or rest their heads on their arms and try to picture their project. Speak slowly with thinking time between the questions and statements.

    - Try to get a picture of your project in your mind. Can you see it?
    - Try to picture the user using the product. Can you picture the device doing its job?
    - Imagine its size. How big is it?
    - Can you picture the materials it's made of?
    - How about the parts? Try to imagine each of them. Imagine one part connecting to another. Can you see how they work together?

2. Ask students to look up and talk about their ability to visualize their design. Ask how knowing what it looks like helps a person design a product *(knowing the end result makes it easier to design; it's a way of refining and improving a design; lets the person look at parts in relation to the whole; conceptual and practical problems that need work will become evident)*.

Begin Drawing

1. Decide if you prefer students to use pencil or pen at this point. However, it is recommended that students get used to drawing with pen so that they keep a record of their drawings and changes made to their drawings.

2. Start students on drawing a series of sketches of their design in their design notebooks. The first sketches will help them think through their design; others will be attempts at showing it as they see it in their mind's eye. Suggest that they may want to start with the most obvious features of the design and then move toward the ones that have not been resolved. Labels, notes, and arrows showing the motion of moving parts are helpful.

3. If the student doesn't know what the internal workings of their project will be, have them concentrate on the outside views and what is needed for the project to interact with the user. Have them go through the user needs and requirements *(11B Handout: The Perfect Fit: Meeting Needs Through Design)* and make sure all of them are addressed.

4. Discuss that drawings are used to describe and document designs. It is important that the sketch is easy to understand and tells the story behind your design intent.

11C: Conceptual Drawing: Thinking on Paper (continued)

5. Encourage students to draw repeatedly and not worry about making a perfect rendering—this is a thinking step, and the successive drawings are a helpful record of their thinking process. Remind them to draw the device from top, side, and front views, and even an interior cutaway view if it is helpful.

6. After 10 or 15 minutes of drawing, have students pause for a moment, and encourage them to talk about their efforts. Ask them to recommend tricks and tips they are finding that might be helpful to their fellow drafters—their suggestions can be really encouraging at this stage. Remind students to draw their design from all sides, and draw each view large enough to label parts and motion, and then have them continue.

7. Emphasize that the drawing doesn't have to be perfect, but that the resulting figure should be clear and detailed enough to tell someone who doesn't know anything about their project what it is and does.

Wrap Up
Have students talk about their drawings and show them to one another. What do they like about them? What new design considerations came up as a result of drawing? Is there a drawing technique they can recommend? The next step will be to model their design, and having a strong image of it will be helpful. Suggest that students continue drawing and refining their ideas before the next session.

Also suggest that students may want to make other visual representations of their ideas such as collages.

Read *11C Reading: Meet a Communication Designer*.

Follow With
Session 12, *Planning for Models and Tests*, has students planning models to test their ideas.

Conceptual Drawing: Thinking on Paper

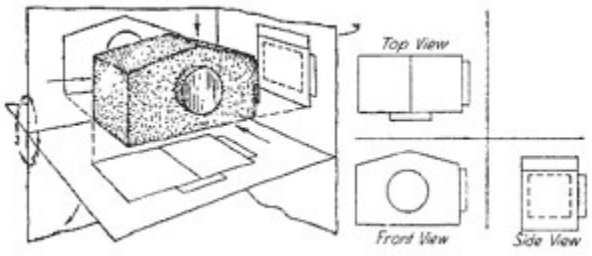
Handout: Session 11, Activity C

Drawing From All Sides

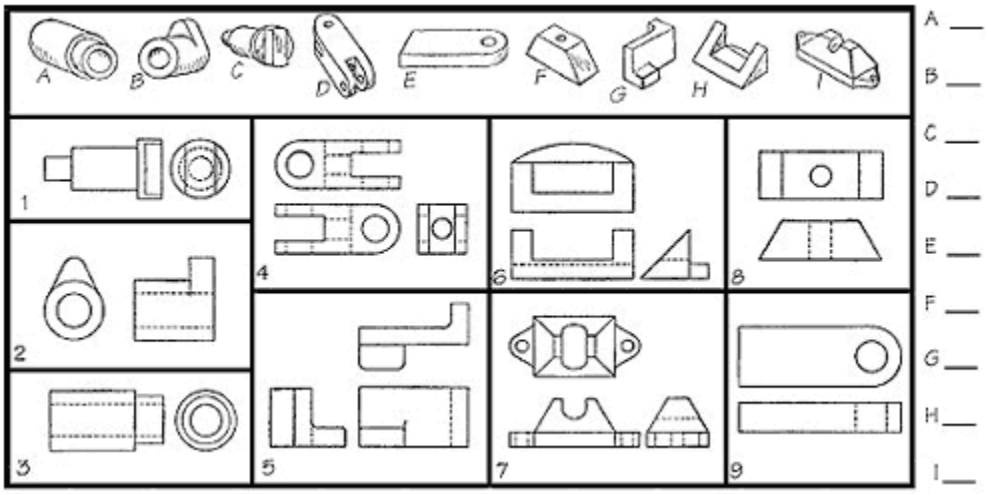
Drawing your ideas can help you visualize your plan and will be very useful when you make your model. You may find it helpful to draw the different components and parts of your project—from different perspectives. You will probably have several drawings of your project as your ideas evolve.

This activity begins by learning some basic mechanical drawing techniques. You'll learn how to draw a line and a circle on graph paper. You will then use these techniques to draw an object in the room. This should be done in your design notebook.

1. Compare the 3-D drawing of the object below to the three views of the object on the right. What do the three views show you about the object that you didn't know from the 3-D version?

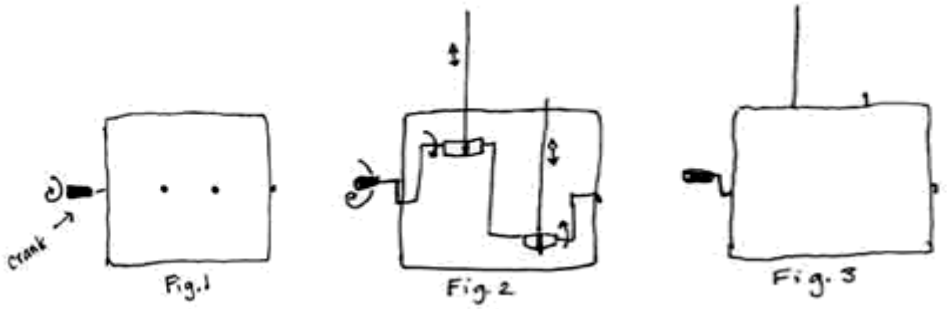


2. Match the object in the top row with its orthographic sketch.

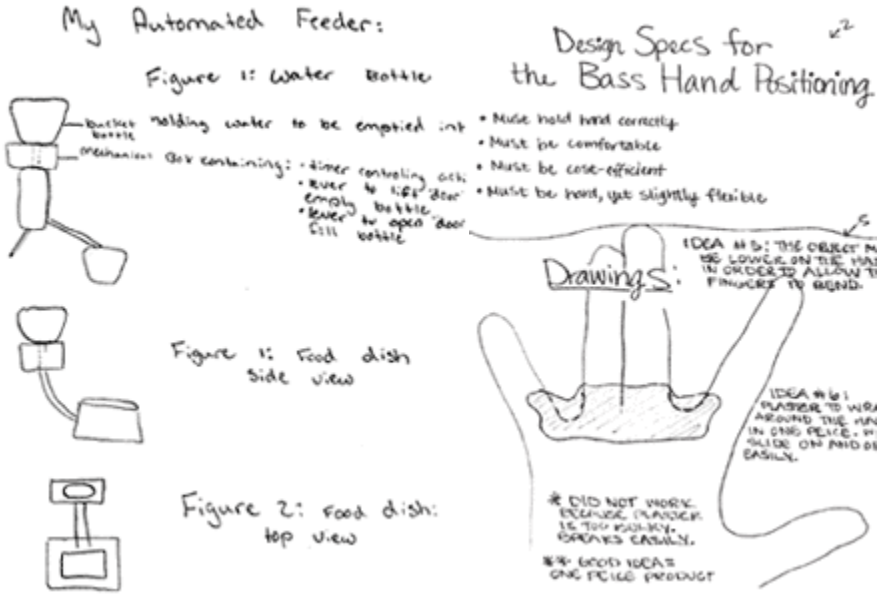


11C Handout: Conceptual Drawing: Thinking on Paper (continued)

3. What object is shown here? Label the different figures: interior, top and side.



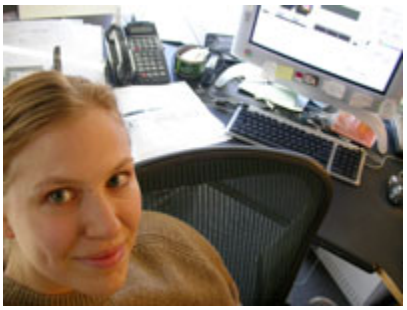
4. Here are some samples of past *Design and Discovery* students' drawings. Can you tell what they are?



5. Now, in your design notebook, try your hand at conceptual drawings for your project. Be sure to draw different views as well as individual drawings of the components and parts. Make many drawings. You can't have too many. Make your drawings large enough to label components and show the direction of any movement that may be appropriate to your design.

Meet a Communication Designer

Reading: Session 11, Activity C



Chelsea Vandiver
Senior Communication Designer
ZIBA Design

Introduction
Hello, my name is Chelsea Vandiver. I am a senior graphic designer at ZIBA Design. I studied graphic design at the University of Washington. After graduation, I worked as a conventional graphic designer, designing packaging, letterheads, and brochures that were destined for the recycling bin days after coming off the printing press. I didn't find the work satisfying. I knew that I wanted to add value, not clutter to people's lives. Fortunately, I found a job at a product development firm. Now, at ZIBA Design, I work on projects like signage systems, user interfaces, and products that improve people's day-to-day lives.

A Typical Day
I spend a large part of my day participating in collaborative brainstorms and work sessions with an inspiring group of product designers, environmental designers, brand specialists, and engineers. The beauty of working together on a multidisciplinary team is that the result is larger and greater than what any of us could have developed on our own.

Challenges
I've worked at ZIBA Design since 1997, and every day I learn something new. Each project has its own set of unique challenges that force me to continually grow and expand in new ways.

Advice
My advice to younger people entering the design or engineering field is to not be afraid to collaborate and share your work with your friends and teachers.

About ZIBA Design
ZIBA Design is an international design firm that has designed products for many global companies, including FedEx, Microsoft, Intel, Fujitsu, Black & Decker, Sony, Pioneer North America, Dial, and Clorox. www.ziba.com*