Key: Yellow highlight = required component

An Assistive *Artistic* Device

Subject Area(s) Problem Solving

Associated Unit None

Associated Lesson None

Activity Title An Assistive Artistic Device

Image 1

Image file: IMG_3144

ADA Description: Image shows a person painting on a piece of paper using an assistive device that holds a small paintbrush and is attached to the wrist.

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Caption: Some people have disabilities with their hands and have trouble holding things. Assistive devices can help people do things they need or want to do such as grasping or holding a paintbrush.

Grade Level 8 (7-9)

Activity Dependency

Time Required 500 minutes

Group Size 2

Expendable Cost per Group US $5.00

Summary

In this activity, students learn how to design and develop an assistive device for a child that has a problem with fine motor skill development and cannot grasp and control objects. In the process of designing the device, they learn the Engineering Design Process (EDP) and how to use it to solve a problem. After learning about the effects of disabilities and fine motor skills, they apply the EDP to create an assistive device for a student to hold a small paintbrush or crayon.

This project includes a 3D modeling and 3D printing component (Fig. 1), but can be done without that if resources are limited or do not include access to a 3D printer. The project can be completed in a different manner using traditional fabrication processes (e.g., layout, cutting, shaping, forming, machining, assembling and finishing of materials).

Engineering Connection

Engineers use creativity and imagination to solve problems to make the world a better place for everyone. People are living better and longer today because of Biomedical Engineers who develop new technologies in the health and medical field such as cures for illnesses, assistive technologies, new medicines and repairs for the heart. Biomedical Engineers use the EDP to work at finding solutions to problems that directly relate to the human body. The design and development of assistive devices, such as eyeglasses, hearing aids, and wheelchairs, improve the quality of life for people with disabilities.

Figure 1

Image file: IMG_2480

ADA Description: Image shows a 3D printer in action and progress of a 3D print.

Source/Rights: 2016 Thomas Oliva, RET Program, Worcester Polytechnic Institute.

Caption: 3D printers allow design ideas to be quickly produced as models in a process called rapid prototyping.

Engineering Category = 3

Choose the category that best describes this activity's amount/depth of engineering content:

1. Relating science and/or math concept(s) to engineering
2. Engineering analysis or partial design
3. Engineering design process

Keywords

3D modeling, assistive device, biomedical engineering, disability, engineering design process (EDP), fine motor skills, prototype

Educational Standards

Massachusetts

- MS-ETS1-7(MA). Construct a prototype of a solution to a given design problem.
- MS-ETS2-6(MA): Describe how a product can be created by using basic processes in manufacturing systems, including forming, separating, conditioning, assembling, finishing quality control and safety.
- MS-ETS2-7(MA): Recognize that processes that transform materials into products can be controlled by humans or computers.

ITEEA Standards
Grades 6 – 8
Design

- 8.E: Design is a creative planning process that leads to useful products and systems.
- 8.G: Requirements for design are made up of criteria and constraints.

NGSS Standards, May 2013
Middle School 6-8, Engineering Design
MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. Use a model of each solution to evaluate how variations in one or more design features, including size, shape, weight, or cost, may affect the function or effectiveness of the solution.

MS-ETS1-4. Generate and analyze data from iterative testing and modification of a proposed object, tool, or process to optimize the object, tool, or process for its intended purpose.

CCSS Standard
WHST.6-8.9: Draw evidence from informational texts to support analysis, reflection and research.

Pre-Requisite Knowledge

For students: while no pre-requisite knowledge is mandatory for this activity, it would be helpful if students had some experience with 3D modeling. This would save time in not needing time to teach 3D modeling. This project can also be done without the 3D modeling component.

For teachers: experience with some type of 3D modeling is important if it will be taught to students. However, this project can also be produced in a traditional shop or other classroom setting without using the 3D modeling and 3D printing.

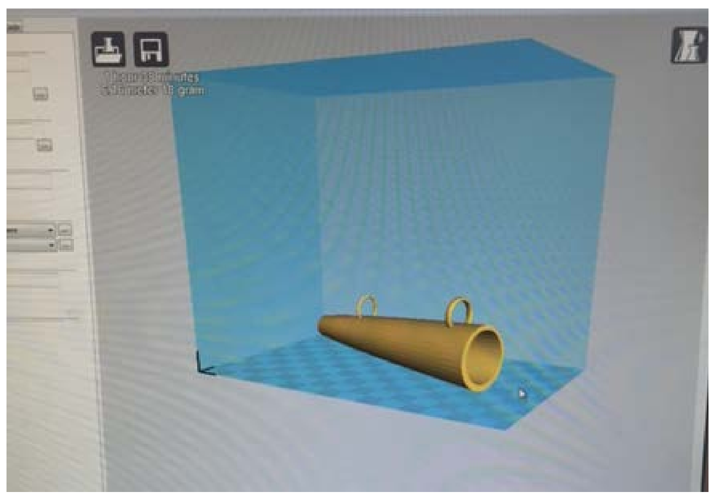
No specific 3D modeling program or 3D printer are required for this project. Teachers and students can use what is available and/or familiar.

Learning Objectives

After this activity, students should be able to:

- Solve an open-ended design problem
- Use the Engineering Design Process to solve a problem
- Develop multiple solutions to a design problem
- Describe/explain the impact of assistive devices

Image 2
Image file: IMG_2479
ADA Description: Image shows a computer generated digital 3D model of a prototype.
Source/Rights: 2016 Thomas Oliva, RET Program, Worcester Polytechnic Institute.
Caption: Designs can be generated into prototypes by humans or computers.



Materials List

The teacher should have access to a laptop and projector to show necessary presentations. If one is not available, information can be written on a board or photocopied and passed out.

Students will select their materials for this project. The chosen materials must adhere to the project constraints and criteria regarding cost, weight and safety, etc.

To share with the entire class:

- Computers with Internet access
- Paper, pencils, rulers

- Various hand and machine tools for cutting, shaping, forming, joining, assembling and finishing their designs. These may include rulers or tape measures, power or hand saws and power or hand drills.
- Materials for developing devices which may include various woods, plastics, metals, cardboard, rope or fabric.
- 3D printer and filament (PLA or ABS)
- Scale to weigh final prototype

Note: This project is designed to be created in a design and/or prototyping shop or lab. If one is not available, it may be done in a typical classroom but may require some modifications.

Introduction / Motivation

Have you ever thought about how important your hands are in everyday life? Probably not! When we don't have problems with things, we tend to not realize how important they are. We need our hands and fingers constantly from the very moment we get out of bed right up to when we go back to bed. If you kept track of all the things you did for even half of a day, you would probably be surprised the amount that we depend on that part of our body. Now, think about what you might have to do WITHOUT the use of your hands! You could even challenge yourself to see what this is like in your own life by taping up one hand, maybe your dominant hand, for part of the day so you couldn't use it. What would you do? How would that affect the things you need and want to do each day?

Some people have problems with their fingers and hands due to accidents, birth defects and different physical problems like arthritis. When you are using your hands for something it is called a fine motor skill or task. Assistive devices can help people that have a problem or disability with their hands and need help doing things that require fine motor abilities. Use your creativity to design and develop an assistive device that will help a disabled person with fine motor skills hold a paintbrush or other drawing utensil. Improving the quality of human life is an important aspect of engineering!

Vocabulary / Definitions

Word	Definition
3D modeling	A type of computer software that makes use of three axes to create a digital file of a three dimensional (3D) object.
3D printing	A prototyping method which creates a physical model from a digital 3D file by adding material in multiple, fine layers.
assistive device	A device designed to improve the life of a disabled person by helping them complete a task that they would not be able to do.
biomedical engineering	A creative field that relies on math and science to develop solutions to problems in human life and the environment.
constraint	A restriction or limitation placed on a design.
criterion	A standard, measure or way by which something can be evaluated or judged.
disability	A condition that affects the physical, social or emotional state of a person.
engineering design process	An organized, iterative process that guides engineers through the creation of a solution which meets an objective to solve a problem.
fine motor	The movement of small muscles in the human body.
prototype	A preliminary version of a design which converts an idea into a functional, physical model for evaluation or proof of concept.
rapid prototyping	A process used to quickly create a physical model from a computer developed design typically with a 3D printer.

Procedure

Background

This design project is partly focused on the development of an assistive device and partly on the application of the Engineering Design Process (EDP).

Assistive devices come in many different types and forms for many different needs. Students should clearly understand that an assistive device is something a person would use based on a disability, not just because they may want to use one. Assistive devices improve the quality of a disabled person's life. Students must understand this as a core idea of what their design will, or should, accomplish. This project specifically targets a lack of ability to grasp items based on a disability of the hand resulting in a fine motor skill problem or need.

Teachers should have a good working knowledge of the EDP to prepare students adequately and guide them throughout the project. The EDP framework provided in the EDP handout is from the Massachusetts Curriculum Frameworks, but other versions of the EDP can also be used. The project is structured to follow the steps of the EDP:

- Identify the problem, research the problem, develop possible solutions, select the best solution, build a prototype, test the prototype, communicate the results, redesign.

This project also makes use of a general shop outfitted with various hand and power tools. While lack of these resources may make this challenging to undertake, it will not exclude a modified way to work through the project. For example, if resources are limited, very simple prototypes can be constructed of cardboard and fabric for a simpler proof of concept. Tools and resources needed with this version may be as basic as scissors, glue and rulers. Those items can also be identified at the beginning if necessary.

Knowledge of material properties is important to enable the teacher to guide students if questions or problems arise during the process of selecting materials for the project. The teacher should be comfortable discussing how materials can be flexible, rigid, brittle, hard, soft, elastic, durable, heavy, light, etc. Furthermore, the teacher could help student connect the idea of material properties and the unique project constraints. For example, materials that are brittle may not be a good choice due to the safety constraint. Likewise, paper may not be a good material due to the durability constraint.

3D modeling, sometimes referred to as solid modeling, is way to generate a design using digital means. It can be done typically using a variety of free or paid versions of software (including online versions) that function in an X,Y,Z, or length, width and height, environment. For example, instead of a student creating an image of a square or cube in a drawing program, they would be creating a solid (3D) model that would be sent to a printer for output.

3D printers have become reasonably priced for classrooms and user friendly for students. The process relies on a connection between a computer on which a student will generate their design and a printer to produce the digital design into a prototype.

Note: The author used a free online resource titled Tinkercad (www.tinkercad.com) with students for the 3D modeling and a New Matter MOD-t printer (www.newmatter.com) for the output of the prototypes.

Before the Activity

- Establish work groups ahead of time if desired. Students can work together in their groups from the start (not mandatory) or beginning with the research component.

- It may be a good idea to gather any materials, adhesives or fasteners ahead of time that students may need during this project. Students may also bring in their own materials. These could include fabric, various plastics and woods, metal, cardboard or other materials. If you do not have access to a wide variety of fasteners or materials, consider giving students a small list of them and they can choose from the list.

With the Students

Day 1

- Have students take the pre-test
- Use the Engineering Design Process (pdf) to introduce (or review) the steps of the Engineering Design Process (EDP). Students should copy this into their notebooks:
  - Identify the problem, research the problem, develop possible solutions, select the best solution, build a prototype, test the prototype, communicate the results, redesign.
- Show presentation– Assistive Artistic Device Project Criteria introducing the following:
  - Introduce problem statement:
    Design an assistive device to hold a paintbrush, crayon or marker for a disabled student.

  - Introduce all criteria for the project. Students will copy this down in their notebooks:
    The device must:
    1. Be safe
    2. Be durable
    3. Easy to put on and use
    4. Weigh less than 4 ounces
    5. Cost less than $5.00 to make
    6. Attach to a child's hand or wrist
    7. Hold a small painting or drawing utensil

  For criteria #3, students should take periodic weight measurements of their materials.
  For criteria #4, students keep track of the accruing costs by using the Bill of Materials.
  For criteria #5, students should take and document various hand and wrist measurements.

- Connect the problem statement to the EDP- (Step 1- Identify the Problem). Explain that it is important to clearly identify the statement of need before the process of design begins.
- Include time for questions and discussion about the EDP or the project criteria.

Day 2

- Using the Internet, have students conduct the project specific research questions using the Assistive Device Research sheet.
- Students begin brainstorming ideas for the project. They can keep notes in a notebook, make rough sketches or document ideas that were generated from the research task. Two different plans for the device are required.

  Note: *If needed, students can have additional research time on the computer after this.*

Day 3

- Continue to brainstorm and develop possible solutions for their device..
- As student generate ideas, they should use the Decision Making Matrix to help them select their final design to develop into their prototype.
- As students begin to identify potential materials, they should prepare a list of what materials, and how much of each, are required by their approved design. As the design evolves, students should research material costs and use the Bill of Materials to keep a running tally of overall cost.

- Work with student groups to review/approve designs as they develop and it is agreed that all design criteria are met.

Note*: To meet the cost constraint, a value should also be determined for each of the designs. It can be challenging to determine the cost of the 3D printed part. However, certain programs (such as Cura) can be used to assess the gram weight of the design. Using the cost and size of the spool of filament, the cost for the 3D printed part can be easily calculated. For example, if a 1 kg spool of filament costs $30, the cost per gram is .03¢. If a design uses 32 grams of material, the 3D printed part would cost .96¢.*

Days 4-8

- Build and evaluate prototypes. The development of prototypes is exclusively the responsibility of students. It can be expected that all students will not finish at the same time based on complexity of design, availability of 3D printers, time needed for each print, etc. Flexibility with time may be necessary. If necessary, students can build a mock up out of cardboard or other inexpensive materials before creating the actual prototype. This may help students better decide and understand how their design will fit onto a student's hand or wrist. Additionally, students should be shown and know how to develop a 3D model. Based on the complexity of the 3D printer and the printing process, students can be shown how to send their own print job to the printer or follow a printed set of instructions to do it. Each printer has different print protocols so there is no one uniform way to explain this.

Note*: A this point the teacher should monitor the design lab space to help with supplies and materials, assist with any problems that arise, and monitor student use of tools and machines. Safety guidelines and proper use instruction should be given for all tools and equipment to be used by students. This can be done as necessary as some students may not use certain tools and machines that may be available.*

Figure 1

Image file: IMG_2480

ADA Description: Image shows a 3D printer in action and progress of a 3D print.

Source/Rights: 2016 Thomas Oliva, RET Program, Worcester Polytechnic Institute.

Caption: 3D printers allow design ideas to be quickly produced as models in a process called rapid prototyping.

Days 9-10

- The design should be evaluated against original constraints (e.g., cost, safety, weight of device, etc.). This can be done by the designers and it should include the actual weighing of the device.
- A performance assessment should be done by three other students to evaluate the device while using it to perform the intended task (painting with a small paintbrush). Students who evaluate another group's device must fill out the attached Evaluation Sheet while or right after they evaluate a device. During the evaluation, students who evaluate MUST do so with the understanding that it has been

designed so ***it is not expected to be held by the user in any way.*** This must be done as such to simulate a fine motor skill disability.

  - **Optional idea**: While many devices may work with equal success, students can be recognized in some way for the most cost efficient design.

- Students should revise or redesign their devices based on user feedback after testing. **As an option, the teacher can insist that users give one form constructive criticism regarding the design. Recreating the design after evaluation can be done at the discretion of the teacher if time and budget permit.**
- Students will create a **one** slide presentation to communicate the design results. It must include:
  - A slide title with a name for the device
  - A list of group members
  - A brief description of the design task
  - A picture of the device being used
  - Labels for materials and parts **with** arrows
  - The total cost of the device
  - ***This slide will be presented to the class to communicate the results of the design.***

At any time, the device can be graded using the included Grading Rubric.

At the conclusion of the activity, student will take the Engineering Design Process Post-test.

Attachments

Assistive Artistic Device Decision Making Matrix (docx)
Assistive Artistic Device Decision Making Matrix (pdf)
Assistive Artistic Device Evaluation Sheet (docx)
Assistive Artistic Device Evaluation Sheet (pdf)
Assistive Artistic Device Grading Rubric (docx)
Assistive Artistic Device Grading Rubric (pdf)
Assistive Artistic Device Project Introduction (pptx)
Assistive Artistic Device Project Introduction (pdf)
Assistive Artistic Device Presentation criteria (pptx)
Assistive Artistic Device Presentation criteria (pdf)
Assistive Artistic Device Presentation rubric (docx)
Assistive Artistic Device Presentation rubric (pdf)
Assistive Device Research (docx)
Assistive Device Research (pdf)
Assistive Device Research ANSWER KEY (docx)
Assistive Device Research ANSWER KEY (pdf)
Bill of Materials (docx)
Bill of Materials (pdf)
Engineering Design Process graphic (pdf)
EDP Pre-test/Post-test (pptx)
EDP Pre-test/Post-test (pdf)
EDP Pre-test/Post-test ANSWER KEY (pptx)
EDP Pre-test/Post-test ANSWER KEY (pdf)

Safety Issues

The following guidelines were developed to ensure student safety in this environment.

- Students must be trained to use any or all hand or power tools

- Safety glasses must be worn when using hand or power tools
- Proper behavior is expected at all times in the shop area

Assessment

Pre-Activity Assessment

1. Engineering Design Process Pre-test: Have students complete the Engineering Design Process Pre-test to gauge knowledge before project begins.

Activity Embedded Assessment

Reflection Questions: During design and development, have students spend time reflecting on and answering the items listed below; these questions are intended to be formative. Either ask students to write down their answers for teacher review, or check their understanding through student/teacher discussion. Either way, the answers are designed to help students keep continual focus on the design process. Student answers also indicate whether they understand how the design process works. End each class period by having students do an exit activity or self-evaluation to monitor daily understanding and project progress. Expect teams to progress at different rates, with every group eventually addressing and achieving all the items below.

1. State how your design addresses the project criteria (displayed below):
   The device must:
   - Be safe
   - Be durable
   - Weigh less than 4 ounces
   - Cost less than $5.00 to make
   - Attach to a child's hand or wrist
   - Hold a drawing or painting utensil
2. Which of your two proposed designs did you choose? Why?
3. How do you determine if something works or doesn't work?
4. Does the assistive device achieve the intended objective?

Post-Activity Assessment

1. Engineering Design Process Post-test: Students will take the post-test to measure knowledge growth.
2. Design teams will create a project presentation that will be scored using the included rubric.

Activity Scaling

- For lower grades, this project can be done without the 3D modeling component. Designs can be fabricated out of simpler materials such as fabric and cardboard. In this case, material properties may have to be changed or not considered at all.
- For higher grades, other 3D modeling programs can be used (e.g., Solidworks, Autodesk Inventor) and the designs can be more detail or complexity.

Additional Multimedia Support

Image- Engineering Design Process graphic
http://www.doe.mass.edu/frameworks/scitech/1006.pdf#search=%22engieering%22

References

http://www.doe.mass.edu/frameworks/scitech/1006.pdf#search=%22engieering%22

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Classroom Testing Information

This project was tested at Forest Grove Middle School in Worcester, MA. Students were in a general level 8th grade enrichment class titled Technology & Engineering. The class meets for ten weeks and has 25-30 students per class. In total, (throughout a school year) nearly 425 students participated in this project.