**Lesson Plan: USB Pen**

**Project Overview**

An electronic device is often designed for a specific audience or group of consumers in terms of aesthetics and functionality. In this project, a USB pen is designed for a specific target audience. The design thinking process that underlies this project involves developing an understanding of the end users and the market for this type of device. Subsequent stages include the development of concepts which are subsequently transformed into virtual models for potential production as physical prototypes produced with 3D printing and/or laser cutting. These prototypes can subsequently be tested, refined, and integrated into a final presentation.

**Software**: Autodesk® Inventor®  
**Time:** 6 to 10 hours  
**Difficulty:** 1 Brain  
**Subject(s):** Engineering, Art, Math, Science

**Concepts Addressed**

* User-centered research helps engineers and designers establish a solid foundation for the development of effective design solutions.
* Developing a profile of the intended user(s) of a product or service is essential to establishing the needed criteria to guide successful development.
* The proliferation of consumer products, particularly in the tech and fashion sectors, creates opportunities for new product entries in the area of accessories that offer consumer personalization, increased product longevity, and enhanced performance.
* New automated design and manufacturing technologies allow for the low-volume production of products that meet specific criteria for individual users. This emerging trend is referred to as *mass customization*.
* Engineers and designers use a variety of tools and techniques ranging from freehand pencil sketches to sophisticated digital modeling to explore ideas and communicate concepts and technical directions to others.
* Parametric modeling software, such as Autodesk® Inventor®, has dramatically streamlined the process of product development from the identification of user needs to the production and distribution of finished goods.
* The design thinking process is a work-flow path that promotes the development of a design.
* Low cost rapid prototyping technologies such as laser cutting and 3D printing have streamlined the product development process.

**Learning Objectives**

After completing this lesson, students will be able to demonstrate growth in the following areas.

**Process Skills and Knowledge**

Students will be able to:

* Use the design thinking process to successfully create a physical prototype.
* Explain how 2D sketches and digital models can be used as visualization tools for design ideation.
* Profile the end user of a product to create a *persona* of the end user to aid in design of a new product alternative.

**Academic Content**

Students will be able to:

* Explain the basic principles of user-centered research.
* Explain the significance of 2D and 3D visualization for the development of designs form concepts to fished production prototypes.
* Explain how writing, data acquisition and data analysis competencies are employed in the development of a product.
* Explain the role that material science plays in achieving the functional and aesthetic goals for a consumer product development project such as a USB Pen.
* Explain the role of environmental sustainability practices in a product development project.
* Explain the essential aspects of mass customization practices.

**Prerequisites**Have the students watch these technical videos included the *USB\_Pen\_Video\_Datasets* folder to prepare for the project:

**Key Terms**

***3D printing*** is a type of additive manufacturing, there are many different types of 3D printers, but most of the home and consumer 3D printers are specifically FDM printers (fused deposition modeling printers).

***Additive manufacturing*** is a process where material is added together to create an object, opposed to traditional subtractive manufacturing, where material is removed and cut away.

***CNC*** stands for Computer Numerical Control, as such a CNC machine is a machine that is controlled by a computer; a 3D printer is a CNC tool.

***Design for disassembly*** is the use of assembly methods and configurations that allow for cost-effective separation and recovery of reusable components and materials.

***End users*** are the people who will be using the product.

***Ethnography*** is a [detailed](http://www.businessdictionary.com/definition/detailed.html) [study](http://www.businessdictionary.com/definition/study.html) of a group to describe its behavior, characteristics, cultural mores, and so on.

***Laser cutting*** is a subtractive machining process that uses a CNC controlled machine to cut material using a laser. Laser cutters normally only cut flat materials such as plywood, plastic, and metal sheets.

***Mass customization*** in [marketing](http://en.wikipedia.org/wiki/Marketing), [manufacturing](http://en.wikipedia.org/wiki/Manufacturing), and [management](http://en.wikipedia.org/wiki/Management) is the use of flexible computer-aided manufacturing systems to produce custom output. Those systems combine the low unit costs of [mass production](http://en.wikipedia.org/wiki/Mass_production) processes with the flexibility of individual [customization](http://en.wikipedia.org/wiki/Customization).

***Mass production*** involves the manufacturing of large quantities of standardized products, frequently using assembly line [technology](http://www.answers.com/topic/mass-production). Mass production refers to the process of creating large numbers of similar products efficiently.

***PCB*** stands for Printed Circuit Board, this is the board onto which all other circuit components are affixed and wired to.

***Profiling*** is the process that is used to study individuals to assess their interests, preferences physical and cognitive abilities in relation to a proposed design development project.

***Prototype*** is a physical or virtual model used to evaluate the technical or manufacturing feasibility of a particular 3D design product concept, technology, process, end item, or system.

***Semiconductors*** are materials that are only partially conductive. By adding materials to semiconductors it’s possible to change their conductive properties. Semiconductors are integral to all modern electronics.

***Sketch model***refers to a model fabricated quickly with low cost, using easy-to-manipulate materials for the purposes of exploring multiple ideas.

***USB*** stands for Universal Serial Bus, and is a specific industry standard port and programed protocols that can now be found on many devices ranging from computers to battery chargers.

***USB pens*** are flash memory storage devices with a USB connector. This device is often referred to as a flash stick, USB pen, or data stick.

***User-centered research*** or using observational methods to study and understand in both social and physical settings is a powerful and increasingly widespread technique for uncovering unmet user needs and desires.

**Project Discussion Guide**

**Essential Project Conceptual Questions**

* Why is it critical to engage in market research at the outset of a product development project?
* What types of research strategies can be employed to develop insights regarding the users that may purchase the proposed product?
* What are the advantages and disadvantages of customized manufacturing in contrast to high volume mass production processes?
* How might the proliferation of affordable consumer grade rapid prototyping technologies such as 3D printing, and laser cutting impact the development and marketing of consumer products?
* In the past decade what changes have occurred in the area of portable data storage that might influence the design of the proposed product?

**Essential Project Design Questions**

* What person or group of people will represent your targeted market?
* What specific functional criteria and emotional needs or desires must be addressed in your proposed design?
* What are the practical reasons for having a case around the printed circuit board of a USB pen?
* Will this USB pen ever need to be disassembled? What are some advantages and disadvantages to being able to disassemble it?
* How can specification for the design of your USB Pen accommodate tolerance errors that may occur during 3 D printing or laser cutting?
* What are the budget constraints for your proposed product accessory?

**Day-to-Day Plans**

Review the individual lesson plans provided for this project, lesson 1-6, and the project scheme of work (SOW). Apply the design thinking process below as a reasoning practice to promote unique student outcomes and a deeper understanding of the project content.

**Understand: *Watch and Listen***   
To establish a solid foundation for the USB Pen project, students need to have a clear understanding of what they are being challenged to do. The best starting point is to carefully review the project design brief. Distribute the student pre-test and have students spend ten to twenty minutes developing their responses to the questions. Your next job is to facilitate a student discussion built around the pre-test questions. These can be conducted as a full class or small group discussions. As outlined in the project brief, the primary goal of this phase is for your students to establish an understanding of the purpose for the USB Pen including the functional, emotional, and psychological needs of the identified end user(s). The

You may want to remind the students that Albert Einstein once said, “The mere formulation of a problem is far more essential than its solution.”

**Explore: *Develop a Knowledge Base***Through the Explore process you want students to develop a full understanding of the persona of the intended customer for the product accessory. This understanding helps students to fill in specific data on the design criteria matrix in the Define phase. A good place to start is to form teams in which students can discuss the essential project conceptual and design questions listed above.

The next step is for students to develop a game plan for filling in knowledge gaps. Depending on the time available, this inquiry can range from some brief online research to more formal research practices that may include interviewing potential consumers for the USB Pen. An important first step in the Explore phase involves conducting a thorough analysis of the current range of USB pens on the market to determine what unique characteristics might be incorporated into a new design.

**Note**: It is critical that during this process students keep track of their findings in a notebook or journal. In some instances, digital photography and videotaping can serve as an excellent medium for capturing important insights.

**Define: *Clarify Requirements***

This critical stage in the design process involves establishing the criteria for the project. These factors include important variables such as the persona of the targeted customer. This requires identifying important aspects of who they are and how they want to be viewed in society; the functional, emotional and psychological needs they would want to be addressed by a product such as the USB Pen. In this phase, it is also critical for students to identify criteria relative to the physical nature of a product accessory such as strength, durability, ease of use, comfort, and safety.

**Note**: *Open up the Design Criteria Worksheet, which will help you in completing the Define and Explore phases.*

**Ideate: *Creativity***this is the time for students to come up with as many ideas as possible for their product . While you want students to explore many concepts, remind them that it is good practice to keep some of the design criteria in the back of their minds as they explore ideas. Throughout the Ideate phase, a variety of techniques can be used to visualize a wide range of possibilities:

* 2D sketches on paper
* 2D orthographic and perspective sketches using Autodesk Inventor software.
* Quick-form studies or sketch models
* Virtual models using Autodesk software

The goal is to get students to visually communicate to themselves and others the essential direction you will take and refine in the next phase of prototyping.

**Prototype: *Test***In this phase, students use key concepts derived from the Ideate phase to create virtual and physical prototypes with the software. Students can watch the technical learning videos, explore the datasets from the example project, and refer back to the Digital Study Packets as they learn the skills that transform their concepts into reality. Encourage students to assist each other in learning the software.

**Refine: *Almost There***In this phase, you want your students to leverage the power of the software to refine aspects of the design. As students proceed through this phase, remind them to keep referring back the basic criteria that they previously established. Encourage students to engage in a mental practice of asking themselves if the details that they are incorporating help define a design that fulfills the functional and emotional needs and desires of the “clients.”

**Solution: Final Presentation**This phase is vital for preparing students for future success in school, careers, and life in general. The Solution phase is where you ask students to demonstrate how this project has helped them expand and enhance the *four Cs* of their learning and innovation skills: critical thinking, communication, collaboration, and creativity.

Instruct the students to prepare and conduct small group presentations that capture the important aspects of each of the previous phases. Ideally, students should be aware from the outset that the results of their efforts in design phases 1 – 7 will culminate in a final presentation.

**Note**: Emphasize that a successful presentation must clearly define the problem that guided the design and articulate the key criteria that are addressed in the solution.

Stress the importance ofusing software tools to visualize, animate, and present the same way real professionals do every day.Remind students that many colleges, universities, and employers place high value on digital portfolios that convey how a student thinks, how they work with others, how they can generate creative solutions, and how they communicate their ideas and knowledge through a variety of written, visual, and oral formats. By investing effort into this project your students will be one step closer to their goal for careers and/or college.

**Note**: If time is limited, you may opt to have students share their final presentation electronically. This provides an opportunity to generate feedback from peers and teacher.

**Differentiated Instruction**

* Encourage students to review the lesson and skills videos in small groups.
* Have small teams of students collaborate to complete one design criteria matrix by dividing up the work.
* Identify specific websites that students can use for the Define and Explore stages.
* Provide some students with a set of predefined design criteria and background content to modify the Define and Explore stages.
* Have small groups collaborate on the Ideate, Refine, Prototype, and Presentation stages. Have some students focus on the development of physical sketches and sketch models while collaborating with team members who focus on digital prototyping.
* Provide students with self and peer evaluation forms to be filled out at the completion of each phase.
* Provide students with models of successful student presentations with clear examples of each Design phase.

**Non-Native Speakers**

* Encourage students to tap into their own culture and life experience to discover prior knowledge of the project topic.
* Provide English/first language translation dictionaries and/or electronic translation devices.
* Allow the student to prepare materials in their primary language and have it translated later.
* Pair ELL students with native English speakers.
* Provide a translator for viewing of videos.

**Special Needs Students**

* Provide prefabricated modeling components.
* Engage the help of aides to assist in physical sketch modeling and prototypes.
* Accommodate students by allowing additional time and/or reducing the scope of project requirements.
* Provide any necessary accommodations for access to technology such as alternative input devices, larger font sizes, speech recognition, and so on.

**STEAM Connections**

**Background**

The design of a consumer electronic, such as this USB pen, creates opportunities to dive into a deep inquiry regarding the electronics, materials, and mechanics behind consumer electronics and the manufacturing processes required to design and produce them.

**Science**

* Material selection is often determined by the material properties. With a FDM (fused deposition manufacturing) printer, the extruded material is melted in order to be extruded through the printing nozzle. Investigate other possible materials (other than ABS and PLA plastics) that could be used for 3D printing based on their melting temperatures and viscosity. Investigate why other plastics like thermoset plastics might be used for 3D printing applications?
* While most people understand that laser cutting uses a laser, few actually understand what a laser is, how it’s made, and why it is suited for rapid prototyping and manufacturing. Explore Light Amplification by Stimulated Emission of Radiation (LASERS) how they are created and the two main properties that make lasers useful.

**Technology**

* The concept of mass customization is based upon the integration of a number of key technologies that enable designers to create virtual prototypes using software such as Autodesk Inventor. The data embedded in the virtual prototypes can subsequently be used to manufacture small quantities of a particular design to fulfill the individual requirements of clients. Depending on the USB pen that you created, investigate various types of automated manufacturing technologies that can be used to take the virtual prototype to a finished product. These manufacturing process include 3D printing, laser cutting, but also other forms of manufacturing such as stereo lithography, high speed cnc machining, water jet cutting, custom small batch casting .
* The type of memory utilized in a drive such as the one in this project is referred as “flash” memory incorporated into the circuitry of a computer chip. Like most electronic circuitry, this flash memory chip is made using semiconductors that have been “doped” with other materials to create a circuit. Explore this process and gain an understanding of what a simple transistor is and how it works in order to gain a better understanding of how data could be stored inside the flash memory of your USB pen.

**Engineering**

* The look and feel of a consumer electronics product can be altered by adding materials or graphics to the exterior housing. In many cases, the new materials are attached to the surface using a variety of adhesives. Investigate the various types of adhesives that can be used based for your USB pen on various properties such as bond strength, resistance to corrosion, cost, and application methods.
* In engineering many products are designed to have a certain expected lifetime driven bb obsolescence of electronic components as well as profit incentives related to introducing new models. The use of flash memory in a device introduces an additional factor associated with product life expectancy. The flash memory used in the USB pens can only be rewritten so many times before that particular circuit for a bit of memory decays. This means that eventually a flash memory device will fail from use. Investigate current and anticipated performance standards for flash memory consider how this type of memory impacts current and future consumer electronics markets.

**Art**

* In the world of accessories for consumer electronics, an interesting market has developed for custom-designed decals that transform a monochrome housing for products such as a laptop into a canvas for personalized artistic expression. Develop a series of graphic inspired decals that could be applied to a mass produced USB pen Present a minimum of ten concepts developed as sketch models for review by the client, a panel of students, and design professionals.
* An area in which the concept of mass customization has taken hold can be found in the apparel and jewelry markets. Conduct online exploration of websites where customers can interactively select their own design features for products, such as pendants and rings that the manufacturer will subsequently produce and ship as a personalized design. Develop concepts for designer USB pens that could be custom designed by consumers via a web site that can then be produced and shipped directly to the consumer.

**Math**

* Boolean algebra is a form of algebra where logic operators are used instead of mathematical operators. This form of math is extremely important to programing. The USB pen in this project uses NAND flash memory to store it’s data, NAND being a boolean operator. Investigate Boolean algebra and it’s uses and design a simple circuit diagram using Boolean operators.
* Before a product is ever manufactured by a company, a wide range of cost factors must first be considered prior to production. These considerations include factors such as costs associated with procurement of materials and components, labor, operational overhead, shipping and marketing. Use a spreadsheet to calculate your costs based on these parameters to help you determine how much you could sell your product for. How do these numbers change with increased volume of units produced? At what point should the use of 3D printing be replaced by another higher volume process such as injection molding?

**Science and Math Matrices**

Projects in the Digital STEAM workshop create opportunities for teachers and students to connect concepts in Math and Science to real world projects. for example with the USB Pen students could develop algebra projects around variables such as units sold, production costs and profit margins. The design of the product entails calculations related to the geometric form of the pen.

**Math Matrix**

|  |  |  |
| --- | --- | --- |
| **Grade 7** | **Grade 8** | **Algebra I** |
| Area | Ratios and proportions | Systems of linear equations |
| Volume | Area | Ratios and proportions |
| Ratios and proportions | Volume | Area |
| Modeling | Transformations | Volume |
| Graphing | Tessellations | Transformations |
|  | Systems of linear equations | Tessellations |
|  |  | Quadratic equations |

|  |  |  |
| --- | --- | --- |
| **Geometry** | **Algebra II** | **Trigonometry** |
| Area | Systems of linear equations | Use of vectors |
| Volume | Modeling | Determine forces acting on materials and objects |
| Transformations | Linear inequalities | Determine distances, speed, acceleration |
| Calculating measurements indirectly | Right triangle trigonometry | Triangle trigonometry for indirect measurement |
| Cartesian coordinates | Cartesian coordinates | Coordinates: Cartesian, polar |
| Right triangle trigonometry | Production costs of modular parts |  |

|  |  |
| --- | --- |
| **Pre-Calculus** | **Calculus** |
| Linear equations | Area of complex shapes |
| Inequalities | Volume of complex shapes |
| Multivariable equations | Forces |
| Trigonometry | Vectors |
| Calculating indirect measurements | Optimization |

**Science Matrix**

|  |  |
| --- | --- |
| **Chemistry** | **Physics** |
| Materials and material finishes | Forces on objects |
| Resistance to corrosion | Simple machines |
| Adhesives | Energy conservation |
| Interchangeable materials | Ergonomics |
| Makeup of molecules | Electronics systems |
| Chemical composition of recycled content | Micro-electronics |
| Strength and weight of materials | Electrical conductivity |
| Chemistry of phone accessory production | Radio waves |

**Build It**  
When you ask an adult what they remember most about school, the answer often refers to something they produced―something they built, wrote, performed, or generated through some form of visual media. Such activities can take extra time, but the benefits are worth it. And don’t stop with just one USB pen, try designing an entire line, with each new design using a different persona of the end user.

**Extension Ideas**

* Use Autodesk® Inventor® software to develop a line of “skins” to personalize a small computing device such as a smartphone or a laptop.
* Use Autodesk® Maya® to create a short commercial or advertisement featuring your USB pen design that also markets towards the persona the drive was designed for.

**Assessment Processes**  
The assessment process for all of the projects in this curriculum will provide students with formative feedback for each of the seven essential phases. The rubrics that are included as a separate document will guide students in knowing what is expected for each phase and the criteria used to evaluate the quality of the work. For each project, students complete a self and peer evaluation. These include a reflective narration for each phase, accompanied by a point score derived from the rubric. These evaluations are accompanied by a teacher evaluation that also includes a narrative and numerical score for each phase along with a cumulative score. The STEAM questions, Extension Ideas, and the optional Build It activity offer students an opportunity to take what they learn in the assessment process and apply that knowledge to enhance the quality of their work and increase their scores.