Erik Shettig, 2015-16 Kenan Fellow

Title	Evaluating Sensors and the Impacts of Physiological Stress: Designing a wearable device for Rescue Workers (human and animal).
Introduction	Topics in this lesson covers what sensors are, how they work, and how to apply them in different scenarios. For example, Rescue Workers are increasingly using devices that communicate when they are in danger due to such events as an increase in temperature, loss of light, presence of toxic gas, unstable mobility, etc… They are not only using these devices to keep themselves safe, but also their K-9 assistants (Rescue Dogs). The introduction provides background information about this lesson plan as well instructional techniques, what students are to learn, and activities or assessments that you think are noteworthy. As humans, we can sense, or detect, different things. We can sense touch by feeling objects and textures (tactioception). We can sense taste through our taste buds (gustaoception). We can sense light and color through our eyes (ophthalmoception). We can sense noise through our ears (audioception). We can sense scent through our nose (olfacoception). Every day, we use these senses to maintain our lives by staying safe (watching out/listening for dangerous situations…such as looking both ways before crossing the street or smelling the presence of a flammable gas) and making decisions (like what food tastes the best or which clothes look better than other clothing). Just as humans can sense different things, so can certain pieces of technology. Technology that can sense things is a sensor. Engineers have designed sensors that can sense sound (microphone), temperature, movement, light, pressure, gasses, chemicals, textures, electricity, and numerous more. We use sensors every day, even without realizing it. When a person goes into a building with automatic doors, a sensor detects the presence of a person and sends an electrical signal to a controller that will open the door. Weather is measured and predicted by using temperature sensors to detect the temperature, humidity sensors to detect the humidity, pressure sensors to detect the barometric pressure, anemometers to detect wind speed, etc… Sensors enable us to stay safe, stay informed, and even stay healthy. Currently, the economy is investing in wearable sensors that can monitor one's health and provide that data to the individual and to doctors. Rescue workers are also taking notice so they can protect themselves and personnel when conducting search and rescue operations. In this project, students will explore the world of sensors by designing a wearable device for Search and Rescue personnel that utilizes the use of one or a combination of sensors to monitor a safety factor related to the health of the rescue worker. Students will learn and practice wiring circuits and programming microcontrollers. Examples: A student can use a temperature sensor to communicate the temperature of the environment the rescue worker is experiencing A student can use an Ambient Light Sensor to detect how much light a rescue worker is working in

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	A student can use an accelerometer to detect the motion of the rescuer to detect their position (standing or fallen).The introduction provides background information about this resource as well as instructional techniques, what participants are to learn, and activities or assessments that you think are noteworthy.
Real Science Application	The Advanced Self-Powered Systems of Integrated Sensors Technologies (ASSIST) Center in conjunction with NCSU, NSF, and a variety of partnerships is working on developing not only wearable devices that utilize nanotechnology to monitor the health of an individual but also in developing wearable devices that are self-powered through energy harvesting devices. These wearable devices can possibly help detect and monitor heart rate, glucose levels, respiratory levels, body temperature, and even mobility. These sensors use programming to collect the data, transmit it wirelessly, store it locally, and even communicate alarms pertaining to dangerous settings. Researchers are also looking to utilize these technologies in monitoring the health of rescue workers and rescue animals. By focusing on the health of humans and animals, we are bringing in the One Health Initiative. The One Health initiative (http://www.onehealthinitiative.com/) discusses how maintaining a clean environment in addition to healthy living and proper medical care can benefit society. These sensors can be sewed into clothing or attached to the body in some form. As they wear these devices, their health information is collected and monitored. If the rescuer experiences too high of temperature, they can be warned their temperature is climbing and they need to get out or cooled. If a rescuer falls or becomes trapped, an accelerometer can communicate that to people outside so they can send help. If heart rate increases, the rescuer can be warned to leave the area or somehow rest to lower their heartrate. By keeping rescue workers safe, we can prevent further incidences and even fatalities. This section contains science specific background information for the facilitator/facilitator related to this resource, including the research program goals that this project incorporates and underlying scientific principles.

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Curriculum Alignment	This section contains the curriculum alignment of the lesson to the North Carolina NC Essential Standards of Science or Math, ITEEA Standards for Technological Literacy, and the Next Generation Science Standards (NGSS) or Common Core Math. **ITEEA Standards for Technological** ***Middle and High School*** **Standard 1.** Students will develop an understanding of the characteristics and scope of technology.(F,G,J,L) **Standard 2.** Students will develop an understanding of the core concepts of technology. (N,P,Q,R,S,W,X,Y,Z,AA,BB,FF) **Standard 4.** Students will develop an understanding of the cultural, social, economic, and political effects of technology. (D) **Standard 5.** Students will develop an understanding of the effects of technology on the environment. (I) **Standard 8.** Students will develop an understanding of the attributes of design. (E,G,H,J,K) **Standard 9.** Students will develop an understanding of engineering design. (G,H,I,J,K,L) **Standard 10**. Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving. (F,J) **Standard 11.** Students will develop the abilities to apply the design process (H,I,K,L,N,O,P,Q,R,) **Standard 12.** Students will develop the abilities to use and maintain technological products and systems. (H,I,K,L,N,O,J) **Standard 17.** Students will develop an understanding of and be able to select and use information and communication technologies. (K,M,N,Q) **Next Generation Science Standards** ***Middle School*** **MS-ETS1-1**. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. **MS-ETS1-3**. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. **MS-ETS1-4**. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

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	High School **HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants. **HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. **HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
Learning Outcomes	• Students will use sensors to demonstrate a wearable device that detects elements and provides feedback related to the safety of a rescue worker. • Students will administer the engineering design process to design a wearable device that uses sensors • Students will program and test an Arduino LilyPad. • Students will explain how sensors work. • Students will identify sensors and indicate how that apply in society. • Students will explain what the One Health Initiative is and how it plays a role in our lives.
Time Required and Location	The following schedule is set to 90 Minute Blocks over the course of 4 weeks inside a classroom with readily accessible computers and tools. Parts of project can be edited to accommodate shorter periods. **Day 1** – Introduction: What Are Sensors (30 min) Introduce Arduino LilyPad (60 min) Identify parts and resources Show programming example Student exploration of product **Day 2** – Arduino LilyPad exploration (60 min) Practice Programming with Blink Program and others Introduce Project (30 min) Criteria and constraints Engineering design process Resources **Day 3-4** – Programing Practice **Day 5** – Review/continue to introduce project requirements (as much time as needed) Have students begin project (remainder of class time).

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	Days 5-25 - Students complete design of product. It may also be beneficial to take the first 15 - 20 minutes of class to share tips and hints on Arduino programming, connecting circuits, use of sensors, etc… ***Estimated schedule*** **4-8**: Define a Problem, Brainstorm Possible Solutions, Generate Ideas, Research Ideas, Specify Criteria and Constraints, Consider Alternate Solutions, Select an Approach, Develop Written Proposal **5-20**: Programing and Building of Product **20-23**: Testing and Improvements **Day 24-25**: Presentations

Materials Needed	**Teacher List:** • 1 Teacher LilyPad Arduino Kit example for demonstration and practice - https://www.sparkfun.com/products/11262 • 1 Teacher accessible computer with Arduino program • USB Cable - A-to-mini B - https://www.sparkfun.com/products/11301 • Spare building materials for students • Marker or other coloring utensils • Paper (construction, graph, blank, etc...) • Rulers • Scissors **Student List (the following quantities are per group of 3 students):** • 1 Design challenge sheet and design portfolio worksheets • 1 ProtoSnap - LilyPad Development Board – Available at Sparkfun and other retailers: https://www.sparkfun.com/products/11262 • 1 USB Cable - A-to-mini B - https://www.sparkfun.com/products/11301 • 1 Computer with Arduino Programming Software and Arduino LilyPad compatible USB Drive. • Fabric, foam, and other building materials. Students should be encouraged to obtain own materials
Safety	This activity is relatively a safe activity. Please note the following precaution. • Small amounts of electricity are being worked with. This poses a risk of non-life threatening and very small amount of shock if bare wires or leads are touched by a person. • Sewing is a very likely method of how students will assemble their wearable device. This poses a risk of sticking fingers or other parts of the body with needle. If a student is stuck, tend to the student's needs first, then properly dispose of the needle or properly clean it with alcohol. • Parts of Arduino LilyPad are very small with jagged edges. These should not be placed into one's mouth or swallowed.

	• Some students may choose to use tools such as scissors, knifes, saws, or other similar hand tools. Precaution and proper training should occur before utilizing these tools. • When using any of the hand tools, students should wear safety glasses. Hot glue may be used. Be aware this poses a risk for non-life-threatening burns.
Participant Prior Knowledge	This unit is design for the Technological Design course of the ITEEA and NC CTE Technology, Engineering, and Design Curriculum. Students should know the following: • The Engineering Design Process • Parts of a System • Parts of the Designed World (The technological Systems) It is a plus if students have an idea of the following (but it is not at all required): • Electricity and Circuits • Programing How Sensors Work
Facilitator Preparations	• Become familiar with the Arduino LilyPad. • Develop basic understanding of Arduino Programming Language. • Develop an understanding of what sensors are and how they are used in society. • Computers should have the Arduino Programming software downloaded and installed before the project. • Confirm Arduino LilyPads work on student computers before the project. • Arrange students in groups of no more than three. • Prepare or download a sample program that is confirmed to be working, for demonstrating to students. • Prepare a link to or a handout of the Design Challenge and Design Portfolio worksheets for each group (1 per group). • Arrange the classroom so students have constant access to a computer. • Internet access is highly recommended but not 100% needed for programming and building.
Activities	**Day 1 (15 Minutes):** The teacher will start of the class by asking the students what sensors are and how they play a role in their lives. Have students, as a class, form a definition of sensors. Take their definition of what a sensor is and expand on it by informing them that a sensor is a device that senses (or detects) the characteristics of its surrounding. Sensors do this by taking in different forms of energy and converting them to another form. A temperature sensor takes thermal energy and converts it to electrical energy. This electrical energy is measured and calculated by a controller and then communicated through numbers or other outputs such as lights or sounds. Inform

	students that our own body uses natural sensors called the 5 senses. We can sense touch by feeling objects and textures (tactioception). We can sense taste through our taste buds (gustaoception). We can sense light and color through our eyes (ophthalmoception). We can sense noise through our ears (audioception). We can sense scent through our nose (olfacoception). Every day, we use these senses to maintain our lives by staying safe (watching out/listening for dangerous situations…such as looking both ways before crossing the street or smelling the presence of a flammable gas) and making decisions (like what food tastes the best or which clothes look better than other clothing). During this time and for the rest of the discussions, try and show examples of sensors. These can be light sensors, touch sensors, temperature sensors, accelerometers, etc… (Smartphone leveler app uses accelerometer to detect position, doctors use electronic thermometers to sense body temperature, motion sensors are used to open doors, gas sensors in cities are used to detect poisonous gasses in the air.) **Day 1 (45 Minutes):** Present and discuss with the class how sensors are a system. They all have an input, process, and output. In our temperature sensor example, the thermal energy is the input, the process is converting it to electrical signal and transmitting it to the controller, and the controller communicating the temperature is the output. This output can lead to feedback such as a numerical reading of the surrounding temperature or the illuminating of LEDs signally temperature. Have students take about 2 minutes of <u>silently</u> thinking of examples of sensors they experience in their lives and what types of sensors different professions must utilize. After those 2 minutes, have students discuss for 5 minutes examples of sensors and the careers that use them. Once that time is up, discuss as a class what each group came up with for about 5 minutes. Conclude the discussion of sensors by confirming the definition of sensors, jobs that use sensors, and how they impact society. (Doctors using electro-cardio grams to sense heart-rate and save people's lives). **Day 1 (20 minutes):** Display the Arduino LilyPad **(See resource "Arduino LilyPad Parts" at end of plan)**. This is a wearable device that use sensors such as a temperature sensor, a light sensor, switch, buttons, and accelerometer. Students will be using this technology to expand their understanding of sensors and apply the engineering design process to develop a wearable device that uses sensors to monitor health conditions as well as accommodating One Health Challenge requirements (explained on day 2). It is important to go over with students the parts of the Arduino LilyPad Development Board. Explain each piece of the board, what they do, how they work, and an example of how they function in real-world applications. Cover, with the class, each part of the LilyPad. • Arduino LilyPad Simple Board – Holds the program for the device, has a battery connection which leads to the different digital and analog connections. • FTDI Basic Breakout – Connects the Arduino LilyPad Simple Board to the computer so that programs can be uploaded onto the board. • LilyPad Button – Is an input device that completes a circuit and results in an action when pressed. Much like when you go to an elevator and select a floor to go to, you push a button that inputs information to the elevator that it needs to go to a certain floor. Another example is when you press a doorbell button.

	• LilyPad Slide Switch – This input device is a simple switch that completes a circuit and results in an action. Similar to an on and off switch on a device. When you switch it on, the device turns on, and when you switch it off, the device turns off. • LilyPad Bright White LED – The White Light Emitting Diode (LED) shines white when on and acts as an output device. LEDS use a low amount of energy and can shine very brightly (do not stare at them). Because they are a diode, they only work with electricity flowing one way through. Make sure to connect them correctly (positive to positive, negative to negative) in order for them to work. LEDs are used heavily is outdoor lighting. When the sun sets, the white LEDs will come on and illuminate the outside while using a low amount of energy. • LilyPad RGB Tri-Color LED – This LED is an output device that can shine red, blue, or green. It can show one, two, or all three colors at once. When more than one of the colors is on, the colors mix to form different colors (when red and blue shine you see violet). These are in electronic billboards to show an array of colors and images. • LilyPad Light Sensor – A light sensor is an input device that detects how much light is hitting the sensor. Much like how a solar panel produces electricity when hit with light, the light sensor produces a certain voltage depending on how much light is hitting it. This voltage can vary and show differences in light levels. Many streetlights have light sensors on them so when it light gets to a certain low amount, the streetlights will switch on. • LilyPad Temp Sensor – This sensor is an input device that takes thermal energy, converts it to electrical energy, and uses that electrical energy to calculate a temperature. Many hospitals use electric temperature sensors to detect body temperature and get exact numerical temperature readings for better healthcare. • LilyPad Buzzer – This is an output device that emits an audible tone. Smoke alarms use buzzers to emit a very loud alarming noise to communicate the presence of smoke and possibly fire. • LilyPad Vibe Board – This output device vibrates. Many current game station controllers have Vibe Boards installed on them to provide motion feedback for when a character falls or when a vehicle hits an object. These Vibe Boards are typically in the handles of the controller, which fit in the user's hands and are easily felt when activated. **Day 1 (10 minutes and as needed into next class period):** Once you have explained the board to the students, demonstrate for them how the programming works. **For this demonstration, you can use the simple "Blink" program provided by Arduino or in the programming guide at the end of the lesson.** Refer to the programming example at end of lesson plan for detailed information on the programming example to show students. Show students the importance of properly programming. Do this by inserting common errors (excluding ;'s, misspelling commands, not identifying outputs/inputs, not declaring states, etc…) and showing how to resolve them.

	DAY 2: (You can start Day 2 with an hour of exploration): Students can then practice with the Arduino LilyPad board and programming them. **DO NOT ALLOW THEM TO BREAK-UP THE BOARD BEFORE PRACTICE FOR THE SAKE OF CONVENIENCE. The board comes pre-connected for practice before taking apart for product build.** Provide them with at least an hour or more to explore the Arduino tools. They can do this in groups of 2 -3 and help each other practice. Each student can work on practicing their own programming and put it on their group boards to test their work. They will have to share the board among the 2 – 3 of them. Encourage them to share codes and resources as a practice of collaboration **Day 2 (30 Minutes):** After the students are comfortable with the Arduino board and programming, you should introduce the Design Challenge to them. Make sure they are in groups of no more than 3 if they are not grouped already. Read aloud from the Design Challenge sheet (DESIGN CHALLENGE AND DESIGN PORTFOLIO OUTLINE are at after the comments). At this time, also introduce general information about the One Health Initiative (http://www.onehealthinitiative.com/about.php) in addition to the One Health Challenge (http://assistonehealth.com/). Discuss how the initiative is affecting current research and industry standards. Identify and clarify the challenge, the associated criteria and constraints, as well as up any misunderstandings for students. Show how the Design Portfolio (outlined in the Design Challenge Sheet) has each group documenting each step of the Engineering Design Process during their product development. **Day3: (As much time as needed during one class period)** Review with students the project requirements. Allow students to continue practicing with their Arduino Lilypad Boards. **Days 4 – 20**: Once students are comfortable with the programming and the tools at hand, they may proceed with the design process at their own pace. Provide each group with a hard or digital copy of the Design Challenge and Portfolio **(Available at end of lesson).** A recommended pace is in the timeline from section **"Time and Required Location**" above. Because of the number of requirements, this project lasts for about 4 weeks of class time (on block scheduling with 90-minute blocks). Be advised you may alter the requirements for sake of time. While students are working, walk around the classroom staying informed on their progress and answering any questions you feel need answering. It may be beneficial to take the first 15 - 20 minutes of class during these days to share tips and hints on Arduino programming, connecting circuits, use of sensors, sections of the Design Portfolio, etc… to make-clear any misunderstandings. **Days 4-8**: Define a Problem, Brainstorm Possible Solutions, Generate Ideas, Research Ideas, Specify Criteria and Constraints, Consider Alternate Solutions, Select an Approach, Develop Written Proposal **Days 5-20**: Programing and Building of Product **Days 20-23**: Testing and Improvements **Days 24 – 25**: Conclude the project by having each group present their solution to the design problem and submit their Design Portfolio. **(A presentation rubric in addition to a final grade rubric is available at the end of the lesson)** Each presentation should be 6-10 minutes long. You may choose to have a gallery walk so

	everyone can walk around and see each other's designs. You may also use anonymous voting to vote for the top three designs.
Assessment	Rubrics will aide in assessing (1) Design Portfolio (2) the oral presentations, and (3) the functional ability of the final product. See the following rubrics at end of the unit plan: 1. Rubric for Design Portfolio 2. Rubric for Final Product 3. Rubric for Presentation
Critical Vocabulary	Ambient Light Sensor: A device that detects the amount of light in the vicinity. Feedback: Information about reactions to a product, a person's performance of a task, etc., used as a basis for improvement. Input: What is put in, taken in, or operated on by any process or system. LED (Light Emitting Diode): A semiconductor diode that emits light when a voltage is applied to it and that is used especially in electronic devices (as for an indicator light). Loudspeaker: An apparatus that converts electrical impulses into sound, typically as part of a public address system or stereo equipment. Motor: A machine, especially one powered by electricity or internal combustion, which supplies motive power for a vehicle or for some other device with moving parts. One Health: The collaborative effort of multiple disciplines — working locally, nationally, and globally — to attain optimal health for people, animals and the environment". Output: A place where power or information leaves a system. Process: A series of actions or steps taken in order to achieve a particular end. Rescue Worker: Someone who works to bring people out of danger, attack, and harm especially after a disaster, accident. Sensor: A technological device that detects or measures a physical property and records, indicates, or otherwise responds to it. System: a set of connected things or parts forming a complex whole, in particular. Temperature: a device, typically, a thermocouple or Resistance Temperature Detector, which provides for temperature measurement through an electrical signal. A thermocouple (T/C) is made from two dissimilar metals that generate electrical voltage in direct proportion to changes in temperature.
Community Engagement	Examples of possible community engagement: • Inviting guest speakers to help introduce project • Presenting projects to industry, research, and educational professionals • Relating work to projects completed or being completed locally • Participating in local competitions based around project (One Health Competition at NCSU).

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	• Participating in school science fair, STEM fair, parent night, etc…
Extension Activities	Extension Activities: • Have students develop an advertisement for their product. They must develop the advertisement to persuade consumers to purchase their device. • Allow students to research professions related to their device. They should then identify professionals within those fields then contact said professional and interview them about their thoughts on their product. Provide students the opportunity to redesign and improve their device beyond what they already create.
Modifications	1. Create a small group of students who struggle with comprehension and, particularly, have a limited vocabulary. Guide a read-aloud session, discussing small sections of reading at a time to aid comprehension of the design challenge and talking through decoding of difficult words. 2. If students who are inexperienced with programming really struggle at the programming and it becomes detrimental to their self-confidence and completion of the project, then provide them with program they can edit for their product's needs. 3. If students prefer to type their work than to write-out / use CAD software to draw rather than hand-draw their drawing then allow them to use the computers. 4. If a student is unable to work with another student then do not group him or her together. Due to the length of this project, it is best to form groups where students can work for long periods together. If students have trouble with English, group them with students who can help understand steps in the project.
Alternative Assessments	This section contains alternative assessments designed for special audiences, such as students with learning disabilities or English language learners. • The above may use same rubric with teacher-made modification to meet each accommodation.
References	Sparkfun LilyPad Development Board Tutorial: https://www.sparkfun.com/tutorials/308 Arduino Programming Notebook: http://playground.arduino.cc/uploads/Main/arduino_notebook_v1-1.pdf 547ITEEA Technological Design, Second Edition: http://www.iteaconnect.org/EbD/Samples/HighSchool/TechDesign.htm NCSU Center for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST): http://assist.ncsu.edu/ One Health Initiative: http://www.onehealthinitiative.com/about.php One Health Challenge: http://assistonehealth.com/

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Supplemental Information	Attached Documents Include: • Design Portfolio • Arduino LilyPad Board Guide • Arduino LilyPad Programming Guide
Comments	• This lesson follows along with the ITEEA Technology, Engineering, and Design course in mind. • It functions within other CTE Technology, Engineering, and Design courses.
Author Info	Erik Schettig (eschettig@wcpss.net) is a Technology, Engineering, and Design Education teacher as well as acting CTE Department Chair at Middle Creek High School within the Wake County Public School System. He has been teaching for 4 years and is a graduate of NC State University with a Bachelor's and Master's degree in Technology, Engineering, and Design Education. Dr. Jesse Jur researches in the field of nanotechnology focuses on the development and modification of unique nanostructures of conductive and insulating materials by atomic layer deposition. These nanostructures function in various applications including textiles and photovoltaics. He currently works at the ASSIST Center at NC State University.

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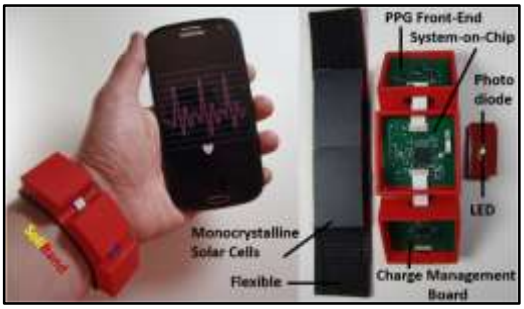
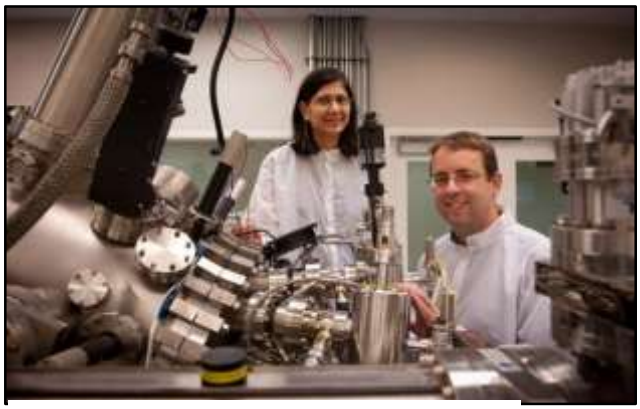
Design Challenge:

Every year, communities around the world experience both natural and man-made disasters that require the skills of rescue workers and animals. These rescuers must experience extreme temperatures, dangerous terrain, in addition to numerous other life-threatening conditions to save the lives of others. These disasters can include fires, earthquakes, aircraft crashes, sinking ships, train derailments, severe storms, tsunamis, and even terrorism. As they are working in these extreme conditions, they must be aware of their surroundings. In order to provide such awareness, rescue workers use sensors to detect and provide information about the dangerous conditions surrounding them. These sensors can be used to monitor the temperature around them, the amount of oxygen they have to breathe, in addition to their position within their environment.



Research Project from ASSIST NCSU


Researchers at NCSU working on developing self-powered wearable sensors.

You and your engineering firm are tasked with developing a wearable device with sensors that can be used by rescue workers to stay better informed about their surrounding environment. A design portfolio, documenting your design process, is required. In addition, you must develop an advertisement and informational poster on your product. The device you design should integrate into an article of clothing or wearable accessory. In addition, it must clearly accommodate the safety of rescue personnel (human or animal). The following are Criteria and Constraints your group must follow:

Criteria:

- Device must be wearable
- Device must be powered by battery or energy harvesting device
- Device must function
- Device must utilize the Arduino LilyPad Development Board
- Device must incorporate at least 2 sensors, a button or switch, and output devices
- Student must program the Arduino LilyPad device
- Device must meet One Health Initiative standards
- A complete design portfolio must be turned in
- An ad **and** informational poster must be developed

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Constraints:

- Only 5 weeks of time will be provided for research and development
- You may only use Arduino programming software
- You will only be provided with one Arduino LilyPad Kit
- Your device should only focus on rescue worker safety (you may choose what type of rescue worker field)

Design Portfolio / Engineering Design Process Outline:

Use the pages following this outline as the worksheets for you design portfolio. You may choose or be instructed to hand write/draw some of the pages (such as brainstormed ideas).

1. Title Page (Teacher will provide example towards time of due date)
2. Table of Contents (Teacher will provide example towards time of due date)
3. Defining a Problem
    a. Defining a Problem Worksheet
4. Brainstorm Possible Solution
    a. 3 Brainstormed Ideas
        i. Drawing
        ii. Paragraph Definition
5. Generate Ideas
    a. Group Interview
    b. Ranked 5 highlights of device
6. Research Ideas and Explore Possibilities
    a. Patent Search / Existing Product Search
    b. Reverse Engineering an existing product
7. Specify Criteria and Constraints
    a. List 7 Criteria of the design of your product
    b. List 7 Constraints of the design of your product
8. Consider Alternative Solution
    a. Provide a paragraph of your back-up plan
9. Select an Approach
    a. Provide a paragraph of why you chose your approach (include highlights) and how you plan on completing the project.
    b. Time-line of your project
    c. Materials List

- **d.** List of responsibilities of each group member
- **e.** Provide a detailed drawing (hand-drawn or CAD) including dimensions

10. Make Prototype

- **a.** Provide 3 images of group research and planning
- **b.** Provide 2 images of programming
- **c.** Provide 5 images of building the device

11. Testing and Evaluating

- **a.** Provide a paragraph of how you tested you device, how your product performed, changes you had to make and why you had to make those changes.

12. Refine Design

- **a.** Provide a paragraph of improvements you would make and why you would make them if you had more time.

13. Communicate Results

- **a.** Present your Product and Design Portfolio to the class
- **b.** Present Ad and Informational Poster to class

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Defining the Problem

1. What are the problems and/or needs that justify the project?

2. Describe the target population — who specifically experiences this problem or need?

3. What is the mission of the design team?

4. Who will benefit from it? Describe the geographic area and population to be served?

5. What are the project requirements?

6. What constraints have been placed on your team?

7. What immediate and long-range results are expected?

8. Will these results change people's lives, the educational community and/or the world?

9. By what criteria will the success or failure of this project be measured?

10. What techniques or tools will be used to evaluate your project before you turn it in?

11. How will evaluation results be used?

12. What is the anticipated total budget for this project in real terms (you may have to go online and look up the price of your equipment and materials)? Give a complete itemized budget breakdown.

Brainstorming Possible Solution

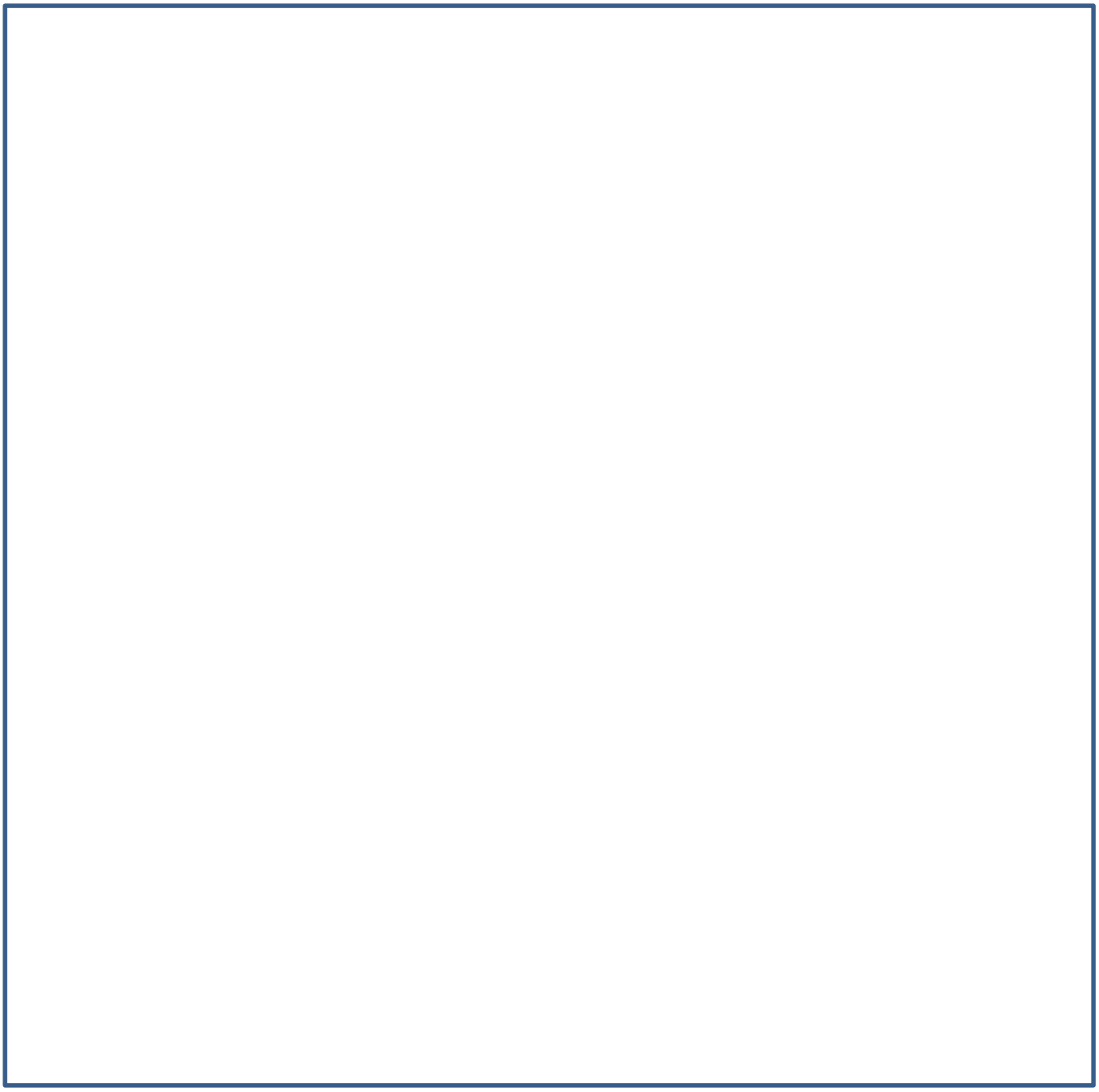
Instructions: Brainstorm 3 separate ideas pertaining to the design challenge. Include a rough sketch of each idea in addition to a brief description. Be clear as to what the idea is and how it would work.

1.

Description:

Brainstorming Possible Solution

2.



Description:

Brainstorming Possible Solution

3.

Description:

Generate Ideas

Developer Interview Worksheet

Names_____

Date _____

Work with your partners to conduct developer interviews. This information helps you determine if your design will meet your team's needs and also may help you find hidden needs.

1. **Gather raw data from your team. You may do research while answering these questions:**

   When will your product be used?

   Why is your product needed?

   What do you like about existing products that are similar to your product?

   What do you dislike about existing products that are similar to your product?

   What improvements would you make to the existing products?

2. **Fill in the following chart to document user feedback. (If you need more room, you may add rows.)**

Product Need	How Will Need Be Met	Rank

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3. Rank in order the highlights of your design.

Rank	Product Need
1	
2	
3	
4	
5	

Provide an updated sketch of your current product idea (this will not be your final detailed drawing):

Research Ideas and Explore Possibilities

Patented Existing Product Worksheet

Names_____

Date _____

Work with your partners to conduct research to answer the following questions.

- **What is the design challenge that you are working on?**

- **What are some possible products that relate to the design challenge?**

- **Give at least three examples of existing patents that relate to your design challenge.**

Product name: **Website/Resource:** **Brief description of product:** **How this relates to your design challenge:**
Product name: **Website/Resource:** **Brief description of product:** **How this relates to your design challenge:**
Product name: **Website/Resource:** **Brief description of product:**

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How this relates to your design challenge:

Reverse Engineering Worksheet

Names_____

Date _____

Work with your partner to reverse engineer one of the existing products you identified in the above assignment.

1. **Describe the product that you will reverse engineer. Where is it typically used? Who might use it?**

2. **What is the function of this product?**

3. **What are the major components of this product?**

4. **List the detailed procedures you used to reverse engineer this product.**

5. **What are the results and recommendations you have for your product design after reverse engineering this product?**

Specify Criteria and Constraints

Instructions: In the tables below, identify the criteria and constraints of the product you are designing.

Criteria:

1	
2	
3	
4	
5	
6	
7	

Constraints:

1	
2	
3	
4	
5	
6	
7	

Consider Alternate Solution

7. Provide a paragraph description of your backup plan in case your product design does not work:

2. Provide a drawing of your back-up plan:

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Select an Approach

1. Provide a brief description of why you chose your final design.
2. Provide a brief timeline of how your team plans on completing the project. When do you plan on each step being complete, building your project, and testing it?
3. What is the list of all the materials you use during this project? (NOTE: This question may be edited multiple time before being submitted).
4. List each member of the team and what his or her role is in the project. Be very specific as to what each person will be completing and/or helping with.
5. Provide a detailed, multi-view drawing of your product **including dimensions** (NOTE: you may need a separate sheet of paper. If you use CAD, then you may paste you image below or attach it):

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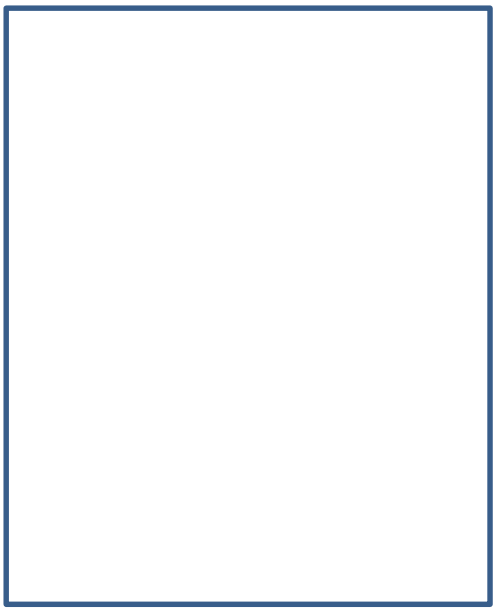
Make a Prototype

1. Provide 3 images of group research and planning



2. Provide 2 images of programming

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3. Provide 5 images of building the device





Testing and Evaluating

Provide a paragraph of how you tested you device, how your product performed, changes you had to make and why you had to make those changes.

Refine the Design

Provide a paragraph of improvements you would make, why you would make them, and how you would do so if you had additional development time.

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Rubric for Design Portfolio

Element	High Mastery (3)	Average Mastery (2)	Low Mastery (1)
Title Page	Title page is appropriate format with all required information (Team Member Names, Project Title, Device Name, and Due Date) centered in the page.	Title page is semi-appropriate format with bits of required information (Team Member Names, Project Title, Device Name, and Due Date) missing.	Title page is incorrect format with an abundance of missing required information (Team Member Names, Project Title, Device Name, and Due Date).
Table of Contents	Table of Contents is included with all required parts of the design portfolio and with page numbers.	Table of Contents is included but excludes required parts of the design portfolio and/or page numbers.	Table of Contents is missing and abundance of required parts of the design portfolio and/or page numbers.
Defining a Problem	Defining a Problem worksheet includes full, well though-out responses to questions and shows full understanding of the problem.	Defining a Problem worksheet includes though-out responses to questions but needs expanding upon to show more understanding of problem.	Defining a Problem worksheet excludes though-out responses to questions and requires much more detail. Little understanding of problem is evident.
Brainstorm Possible Solutions	Brainstormed solutions include 3 ideas accompanied with clear drawings and well defined explanations. Clear evidence of brainstorming.	Brainstormed solutions include 3 or less ideas accompanied with drawings and explanations with the need for more details.	Brainstormed solutions include less than 3 ideas accompanied with minimal drawings and explanations. Little evidence of brainstorming.
Generate Ideas	Group interview is complete with well thought-out responses. Highlights are ranked in order of importance. Evidence of clear ideas being generated.	Group interview is complete with responses. Highlights are identified. More details are needed to provide evidence of generating ideas.	Group interview is not complete with applicable responses. Highlights are not ranked or identified. Little Evidence of clear ideas being generated is provided.
Research Ideas and Explore Possibilities	Patent Search and Reverse Engineering Worksheets are complete with well thought-out responses. Evidence of successful research is provided.	Patent Search and Reverse Engineering Worksheets are complete with responses but need more details. Further evidence of successful research is required.	Patent Search and Reverse Engineering Worksheets are not complete with responses. Little evidence of successful research is provided.
Specify Criteria and Constraints	7 Criteria and 7 Constraints are appropriately identified.	7 Criteria and 7 Constraints are identified but need re-organization or further defining.	7 Criteria and 7 Constraints are not appropriately identified. Little understanding is present.
Consider Alternative Solution	Clear evidence of a back-up plan is provided	A back-up plan is evident but further details are needed.	Little evidence of a back-up plan is provided.
Select and Approach	Information on why the approach was chosen, timeline of development, materials list, and list of responsibilities is clear and well though-out.	Information on why the approach was chosen, timeline of development, materials list, and list of responsibilities is present but further details are required.	Little information on why the approach was chosen, timeline of development, materials list, and list of responsibilities is provided.

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Make Prototype	Team submits 10 or more images of research, programming, and product development.	Team submits less than 10 but more than 6 images of research, programming, and product development.	Team submits less than 6 images of research, programming, and product development.
Testing and Evaluating	Team provides clear evidence they tested and made changes to their device through a well though-out response to the prompt.	Team provides evidence they tested and made changes to their device through a response to the prompt, but further details are required.	Team provides little evidence they tested and made changes to their device through their response to the prompt.
Refine the Design	Team provides clear evidence they thought of improvements they could make, why they would make them, and how they would make them through a well though-out response to the prompt.	Team provides evidence they thought of improvements they could make, why they would make them, and how they would make them through a response to the prompt., but further details are required.	Team provides little evidence they thought of improvements they could make, why they would make them, and how they would make them through a response to the prompt.
Group Work	Group works as a team and each member takes on an identified role as well as helps eachother achieve each step of the design process.	Group works as a team and each member takes on a role to achieve each step of the design process.	Group does not work as a team and each member struggles with taking responsibility to achieve each step of the design process.
TOTAL: /39	COMMENTS:		

COMMENTS:

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Presentation Rubric

Element	High Mastery (3)	Average Mastery (2)	Low Mastery (1)
Images	Presentation has at least 6 meaningful images that show evidence of research, design, and final product.	Presentation has at least 6 images that somewhat show evidence of research, design, and final product.	Presentation 6 or less images that show little evidence of research, design, and final product.
Aesthetic Quality	Font is a readable size for all of audience and colors of slides do not make it difficult to read. Text is present in an appropriate amount but not overwhelming.	Font is a readable size for some of audience and colors of slides are okay. Text is present in an appropriate amount but not overwhelming.	Font is a readable size for some of audience and colors of slides are okay. Text is present but may be overwhelming.
Content Information	Includes Design Portfolio information that shows precise evidence of proper application of the Engineering Design Process.	Includes Design Portfolio information that shows evidence of application of the Engineering Design Process.	Includes Design Portfolio information that shows little evidence of application of the Engineering Design Process.
Time	Students present all relevant information within the 5 – 10 minute timeframe	Students present within the 5-10 minute timeframe but have gaps in time that could be used more productively	Students did not present within the 5-10 minute timeframe nor used their time effectively while presenting.
Demonstration	Students provide a successful and meaningful demonstration shows confidence in product and evidence of testing/practice.	Students provide a demonstration showing evidence of testing and practice. Some parts of demonstration are rough but product works.	Students provide little or no demonstration showing evidence of testing and practice
TOTAL: /15			

COMMENTS:

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FINAL GRADE:

	Design Portfolio:	**/39**
	Device Functionality	**/15**
	Ad Campaign	**/9**
	Information Poster	**/9**
+	**Presentation:**	**/15**
	Final Grade:	**/87**

NOTE:

87 = 100

78.3 = 90

69.6 = 80

60.9 = 70

52.2 = 60

43.5 = 50

COMMENTS:

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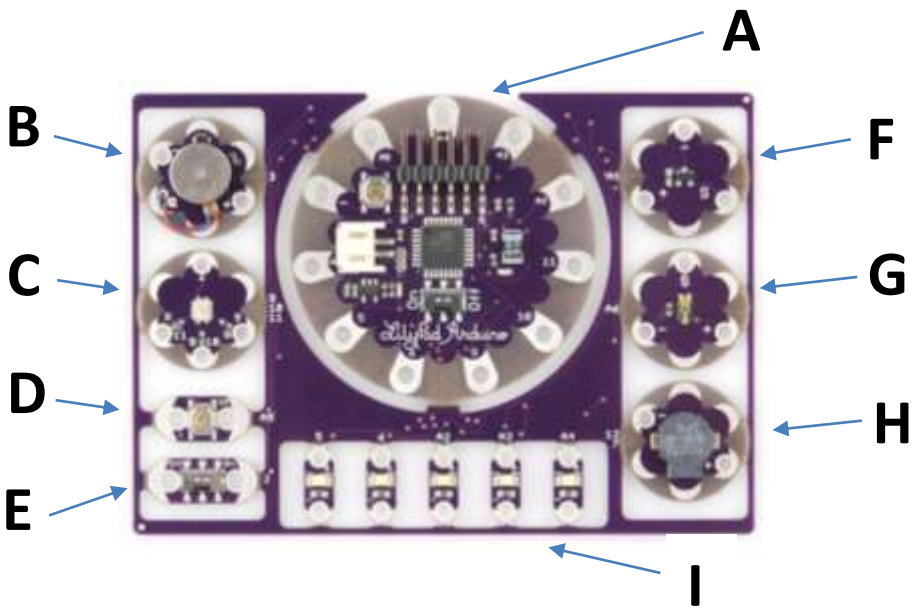
PARTS OF AN ARDUINO



A. Arduino LilyPad Simple Board – Holds the program for the device, has a battery connection that leads to the different digital and analog connections.

B. LilyPad Vibe Board - This output device vibrates. Many current game station controllers have Vibe Boards installed on them to provide motion feedback for when a character falls or when a vehicle hits an object. These Vibe Boards are typically in the handles of the controller, which fit in the user's hands and are easily felt when activated.

C. LilyPad RGB Tri-Color LED – This LED is an output device that can shine red, blue, or green. It can show one, two, or all three colors at once. When more than one of the colors is on, the colors mix to form different colors (when red and blue shine you see violet). These are in electronic billboards to show an array of colors and images.

D. LilyPad Button – Is an input device that completes a circuit and results in an action when pressed. Much like when you go to an elevator and select a floor to go to, you push a button that inputs information to the elevator that it needs to go to a certain floor. Another example is when you press a doorbell button.

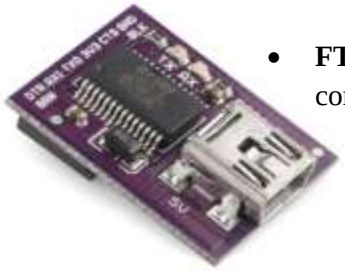
E. LilyPad Slide Switch – This input device is a simple switch that completes a circuit and results in an action. Similar to an on and off switch on a device. When you switch it on, the device turns on, and when you switch it off, the device turns off.

F. LilyPad Temp Sensor - This sensor is an input device that takes thermal energy, converts it to electrical energy, and uses that electrical energy to calculate a temperature. Many hospitals use electric temperature sensors to detect body temperature and get exact numerical temperature readings for better healthcare.

G. LilyPad Light Sensor – A light sensor is an input device that detects how much light is hitting the sensor. Much like how a solar panel produces electricity when hit with light, the light sensor produces a certain voltage depending on how much light is hitting it. This voltage can vary and show differences in light levels. Many streetlights have light sensors on them so when it light gets to a certain low amount, the streetlights will switch on.

H. LilyPad Buzzer – This is an output device that emits an audible tone. Smoke alarms use buzzers to emit a very loud alarming noise to communicate the presence of smoke and possibly fire.

I. LilyPad Bright White LED – The White Light Emitting Diode (LED) shines white when on and acts as an output device. LEDS use a low amount of energy and can shine very brightly (do not stare at them). Because they are a diode, they only work with electricity flowing one way through. Make sure to connect them correctly (positive to positive, negative to negative) in order for them to work. LEDs are used heavily is outdoor lighting. When the sun sets, the white LEDs will come on and illuminate the outside while using a low amount of energy.



- **FTDI Basic Breakout** – Connects the Arduino LilyPad Simple Board to the computer so that programs can be uploaded onto the board.

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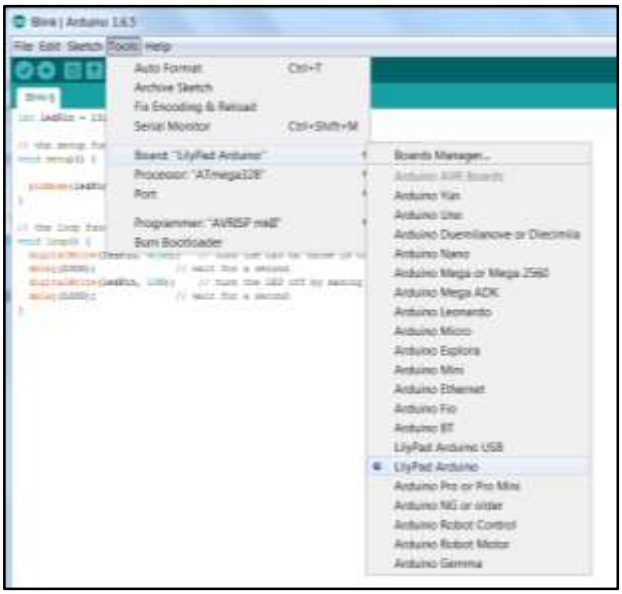
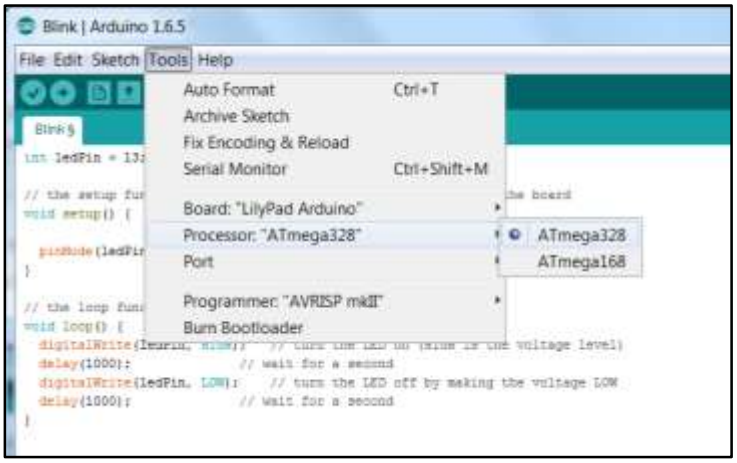
Programming with Arduino LilyPad

Programming an Arduino LilyPad takes practice and focus. The following is just for a quickstart information section. The Arduino LilyPad needs to be setup on the software in order to be properly accept the code. Refer to https://www.sparkfun.com/tutorials/308 for more detailed information on setting up the Arduino. It is important to remember that programming is a form of language that computers understand. It is comprised of various commands and values. When typing code, make sure you type everything out eactly as it should. Just like when you are writing a letter or text, if you misspell something or use an incorrect word, your message will not work just as if you misspell or use the wrong command while programming, your program will not work.

1. After installing the Arduino LilyPad on your computer and making sure all drivers are up to date, open the Arduino Software.

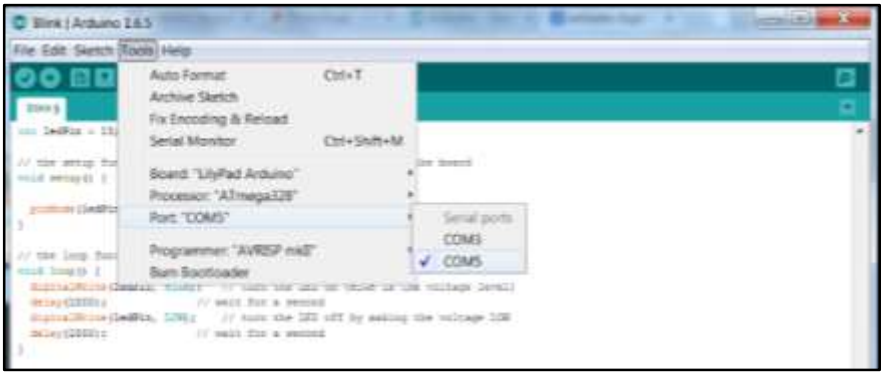
2. Go to the "Tools" Tab and locate the "Board" menu then select LilyPad Arduino (NOTE: If you choose another board, that your code may not upload successfully):



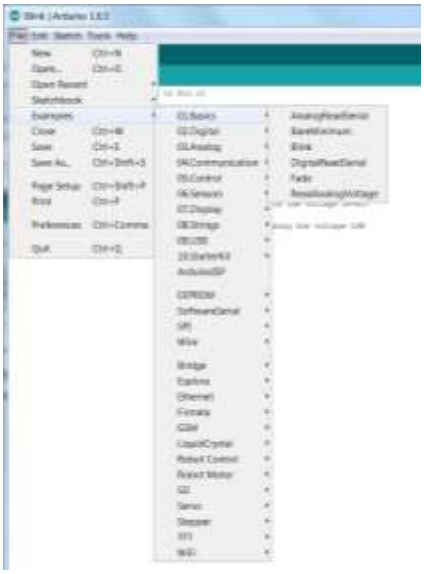


3. From the same "Tools" Tab, locate processor and select "ATmega328":

4. From the same “Tools” Tab, select “Port” and choose COM 5. (NOTE: **Your computer may use a different port for your board. It may take some investigation to identify the port.** Unplug your device from the computer, go to “Tools” tab, select “Port” and note the numbers that show up. Plug in your device, go to “Tools” tab, select “Port” and note the numbers that show up. Whatever new number shows up is likely the port your device is plugged into. Numerous times, it is the highest numbered port. Refer to online resources: https://www.arduino.cc/en/Guide/ArduinoLilyPad , https://www.sparkfun.com/tutorials/308 for more information):



5. Once your board is setup you can then begin programming. It is recommended you practice with example programs before writing your own program. Example programs can be found in the “File” tab under the “Example” menu (NOTE: Not all examples will function with the equipment you have initially).



6. When you open a sample program, you can copy lines of code or alter values to change settings on your board.

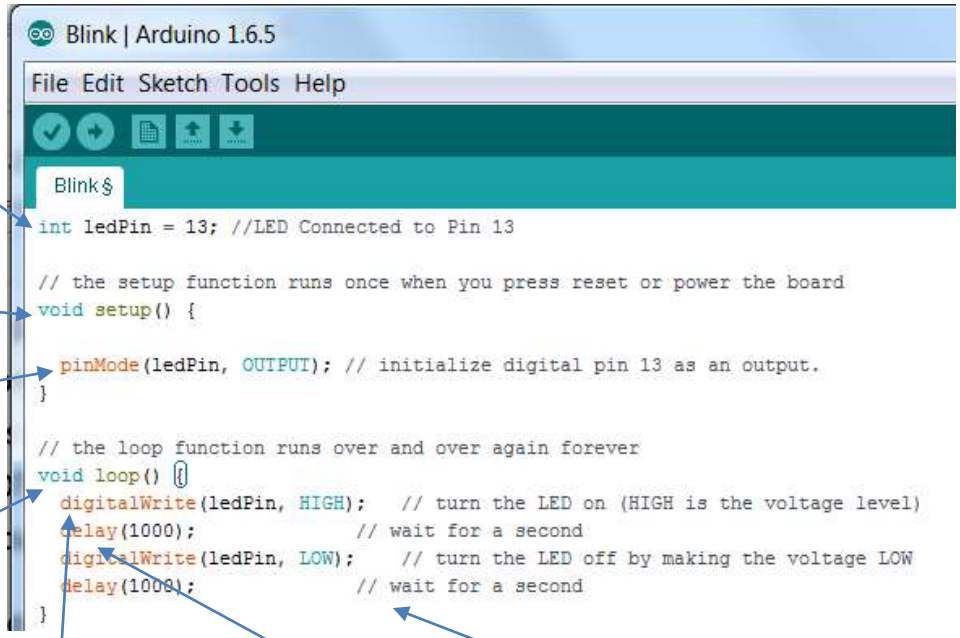
7. Type in the following code into your Arduino Software. You must type it ***exactly*** how it appears or else it will not work.

8. The program you just typed will cause the LED attached to Pin 13 to blink. The following diagram breaks down the commands you are programming into the board:

"int ledPin = 13" is declaring the LED is attached to pin 13 of the board. int stands for Integer.

"Void setup() { function" is called once when your program starts. Use it to initialize pin modes or begin serial. Note that a curly bracket } comes at the end of everything that needs setup.

"pinMode" sets a device as an "Input" or "Output"



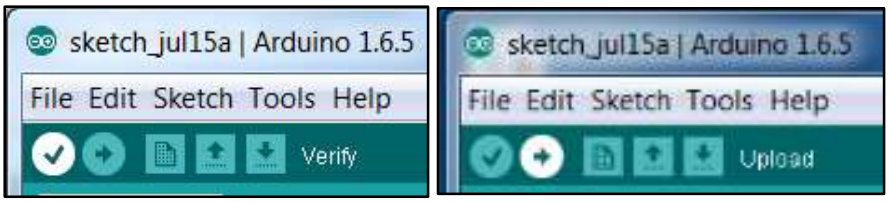
After calling the "setup() function", the "loop() function" does what its name suggests and loops consecutively, allowing the program to change, respond, and control the Arduino LilyPad. This is the main program the board will run repeatedly Note that a curly bracket } comes at the end of everything that needs setup.

"digitalWrite" action is where the program can turn "on" (HIGH voltage) or "off" (LOW voltage)

"delay" action pauses your program for the amount of time specified in milliseconds, where 1000 equals 1 second.

When you want to make a comment about a line but it isn't code, put in 2 forward slashes "//" then your comment.

9. When you complete your program or just want to check it, you may upload it to the board be pressing "Upload".



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10. Programming takes a lot of practice and attention to detail. Use the following links as resources to further your experience with programming:

    a. Arduino Programming Notebook: http://playground.arduino.cc/uploads/Main/arduino_notebook_v1-1.pdf

    b. LilyPad Development Board Sparkfun Tutorial: https://www.sparkfun.com/tutorials/308

    c. Intro to Arduino LilyPad Programming: http://lilypadarduino.org/?page_id=209

    d. Arduino LilyPad Blinking Program Guide: http://lilypadarduino.org/?page_id=212

    e. Arduino LilyPad Switch Program Guide: http://lilypadarduino.org/?page_id=216

    f. Arduino LilyPad RGB LED Guide: http://lilypadarduino.org/?page_id=548

    g. Arduino Input List: http://lilypadarduino.org/?cat=5