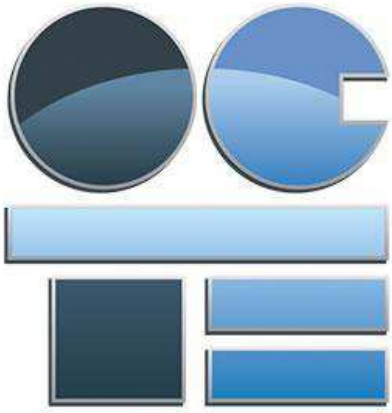

# TEJ4M

# Computer Engineering

## Data Acquisition and Analysis with Arduino


### Abstract

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# Table of Contents

# Project Overview

The Arduino microprocessor family is a cheap and efficient way to create a data acquisition system. Using a variety of sensors and communication devices, students will learn to develop a way to measure the physical world and send the data to be analyzed by computer. This is the basis for a wide variety of devices being developed as the “Internet of things” or IoT.

In this series of activities, students will design and build simple measurement systems leading to the design of a remote, fully automated weather station. The knowledge and skills developed here is the basis of more complex systems in the world of IoT devices, robotics and control systems and remote imaging.

| Project Challenge | Connections |
| --- | --- |
| The Arduino single board microprocessor is an ideal platform for obtaining data from electronic sensors of all types. In this project, students follow the design and build of a temperature/humidity sensor and store the data in a spreadsheet file for analysis. Students will then design and build a simple data logger, then a Wi-Fi enabled remote sensor device. Students are then challenged to investigate, design and build further instrumentation to collect and display local weather phenomenon. | Science: weather, measuring physical parameters, experimentation, data collection, physics<br><br>Mathematics: data analysis, spreadsheet manipulation, interpolation, linear equations, engineering unit conversion, statistics<br><br>Construction/Manufacturing: design and build structures to hold instrumentation, weather proof enclosures for electronics<br><br>Communications: data mining, data acquisition and analysis, robotic control and sensing, IoT device design, environmental monitoring and image and video collection |

| Project Criteria | Examples |
| --- | --- |
| Once students are shown how to design and build initial instrumentation, they then research other physical parameters to measure and propose a complete weather data collection system. The project is flexible…teachers can decide on extent of project, limitations on instrumentation or structures. Project can be simplified into measuring inside parameters instead of weather.<br><br>The project can be tailored to accommodate differentiated instruction by modifying level of proscribed physical parameters, varying amount of "handholding", or level of post collection data analysis. The important elements in the project are understanding the measuring of physical parameters and the collection of data using the Arduino microprocessor. | Simplified projects: measuring greenhouse, hydroponic or shop environments.<br>Enhanced projects include weather balloon instrumentation, connecting to Environment Canada or StatsCan projects, weather satellite downlinks, drone instrumentation, space simulation projects.<br><br>Teachers can give varying degrees of instruction to students to design their own systems, reduce or add additional physical parameters to measure, reduce or enhance amount of data analysis required (example: project completion when data is stored, or add statistical or trend analysis requirements. |

| Project Synopsis and Timelines | | | | | |
|---|---|---|---|---|---|
| **Act #** | **Activity Title/Name** | **Time (hrs.)** | **Curriculum Expectations** | **Assessment & Evaluation** | **Connections?** |
| 1 | Design and build of an Arduino based weather monitoring station. Measure temperature and humidity with the Arduino microprocessor. | 10 | A1.2<br>A3, A3.1, A3.2, A3.4, A3.5<br>B3, B5<br>B1.1, B1.2, B3.1, B3.2, B3.3 | □ K/U<br>□ T/I<br>□ C<br>□ A | ▪ Ontario Curriculum<br>▪ Growing Success<br>▪ DI<br>▪ SEF<br>▪ STEM<br>▪ Math Literacy<br>▪ Literacy |
| 2 | Collecting and analyzing data with an Arduino data logger | 8 | A1.2, A2.4, A3, A5.5, A5.6<br>B1, B2, B3, B5<br>B1.3, B2.3<br>B3.2, B3.4, B5.3 | □ K/U<br>□ T/I<br>□ C<br>□ A | ▪ Ontario Curriculum<br>▪ Growing Success<br>▪ DI<br>▪ SEF<br>▪ STEM<br>▪ Math Literacy<br>▪ Literacy |
| 3 | Sending and receiving data through Wi-Fi using the Arduino compatible ESP8266 microprocessor | 8 | A3, A5, A2.4,<br>B1, B2, B3, B5<br>B1.3, B2.1, B2.3<br>B3.1, B3.2, B3.3, B5.3<br>D3.3, D3.4, D3.5 | □ K/U<br>□ T/I<br>□ C<br>□ A | ▪ Ontario Curriculum<br>▪ Growing Success<br>▪ DI<br>▪ SEF<br>▪ STEM<br>▪ Math Literacy<br>▪ Literacy |

# Activity 1 – Understanding Data Sensors

## Minds On (Engaging Prior Knowledge)

### Activity 1 Project Research and Information Gathering

Activity Description:
To learn the basics of microprocessor based instrumentation and sensor technology, students will design and build an Arduino based weather station. This station will consist of a variety of remote location sensors to measure weather phenomenon such as temperature, humidity, rainfall, barometric pressure, wind speed and wind direction. The first section of activities will cover the principles of measure physical parameters through microprocessor based electronics, collecting and storing of data, and sending and receiving data. Later stages (beyond this phase of the project) include the design and actual build of the structures of the station.

In Activity 1, students learn to build a circuit to measure two properties; air temperature and humidity using the DHT22 sensor. They will use software to design and build a circuit, then build and program a physical one on breadboard. Next they will research and determine how to measure a list of other physical parameters that will be used later. An enhancing activity includes designing and building circuits for other sensors.

### Activity 1 Criteria and Instructions

1. The instructor describes the overall project that culminates in a group designed and fabricated remote weather station.

2. The instructor highlights the variety of physical properties (temperature, sound pressure, motion, etc.) and the electronic means of measuring these properties using the bases of changes in resistance, voltage or current.

3. The instructor introduces the DHT22 temperature and humidity sensor and describes pertinent details of data collection (sample rate, accuracy, range, Vcc, Vout and data/voltage conversions) and asks students to locate the DHT22 data sheet online (See Appendix 2).

4. Students in pairs research and discuss the details found on the data sheet in class. Student pairs initiate a team webpage to contain all information and design process details for the entire project. Students fill in Appendix 4, DHT22 Sensor Information sheet on their team webpage.

5. The instructor then discusses Arduino libraries and necessary programming details for the DTH22 sensor (and the process of adding libraries.

6. Students (individually) then design and construct a working DHT22 temperature and humidity circuit online in Fritzing (see Appendix 5 and 6) (note: at this point simulation site 123D Circuit does not have a DHT sensor in the catalog).

7. Students present their design to the instructor and class.

8. Upon approval by the instructor, students (individually or in pairs) build the circuit on breadboard. (See Appendix 5 and 6 for design). Students then program the Arduino (see Appendix 7 sketch). Instructors approve the design and the students run their circuits and present their results. Students add to their web page the portfolio of their work and their analysis for marking.

9. Students are given a list of other physical parameters and individually (or in pairs) research and describe the corresponding sensors and the details of how the sensors work.

NOTES

- All work to be recorded online for continual referencing.
- Work is completed individually or in pairs.
- Instructors must approve students to move on to building circuits when they are satisfied the student(s) can describe the electronics and programming aspects as well as demonstrating safe and clean shop and wiring practices.

| Activity 1 Prior Knowledge | Connections |
|---|---|
| Students should have:<br>• basic understanding of the Arduino microprocessor, pinouts and voltage, current requirements<br>• knowledge of Arduino programming concepts and terminology and the techniques of building sketches.<br>• Basic knowledge and practice in electronic design or simulation software (Fritzing or 123D Circuit)<br>• Knowledge and practice in electronic breadboard design and testing<br>• Knowledge of safe practices in electronic circuit building and static electricity handling.<br>• Knowledge and practice in basic web page design | There is a large variety of free resources on the Arduino and electronic sensor circuits. Students are encouraged to lookup sample circuit designs on the simulation software libraries, YouTube how-to videos and forums on Arduino and circuit designs.<br>All integrated circuits and sensors will have data sheets online that describe measurement parameters and pinouts. |

| Activity 1 Planning Notes | Connections |
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| Before initiating this activity, teachers should prepare instrumentation and circuit building materials. Using self-contained numbered project boxes that incorporate all necessary materials is suggested to help inventory control, reduce cleanup and preparation time and help control individual team's progress.<br><br>Posting assessment resources such as rubrics and to-do lists around the classroom, and online, can help student's focus on the important learning goals.<br><br>Students should be provided a means such a classroom clipboard to list any equipment damage or flaws, missing components, etc.to help plan preparation and for inventory control. | Examine sample circuits available at 123D Circuits and/or Fritzing.org. (Note: some user posted circuits may contain errors or complicating additions, make sure students are aware).<br><br>See Appendix rubrics for example criteria for discussion<br><br>**Ontario Skills Passport**<br>Implement the Ontario Skills Passport at the beginning of the project |

## Action (Introduce or Extend Learning)

| Activity 1 Instructional Strategies | Connections |
|---|---|
| Introduce topic of measuring information through sensors by opening discussion on types of physical parameters (weather in particular) (i.e. temperature, humidity, air pressure, solar incidence, etc.).<br><br>Introduce types or electronic measuring (resistive, capacitive, inductive) used by sensors. Describe and discuss scale of voltage readings, range, accuracy and engineering unit conversions.<br><br>Students download information sheet for DHT22 Temperature/Humidity Sensor for class discussion. (See Appendix 2) Students fill out a Sensor Information Sheet on the DHT22 (see Appendix 3 template and Appendix 4 DHT22 sample)<br><br>Students post types of weather phenomenon that can be measured with a remote weather station for class discussion. The class decides what components will make up eventual remote sensing weather station.<br><br>Students research and fill in sensor information sheets for each of the phenomenon to be measured and corresponding sensors, using the DHT22 Info Sheet as a template.<br><br>Reflection on research and design brainstorming is initiated with students deciding on sensors required for the station. Students are assigned groups that will each design and build their idea for a remote station.<br><br>Students are then given the task to design and program a simple DHT22/Arduino circuit. Students individually first design virtual circuit on Fritzing (or other software). Students demonstrate their circuit with the teacher for approval before continuing.<br><br>Students then continue to design and build further test circuits for each of the sensors required. Students develop reports on | DI: the number of sensors studied can be varied by teacher, lesser numbers and deeper concentration for some, greater number for others.<br>DI: students can work in pairs on the design and build of each circuit, or experienced students can be assigned to help individuals on any aspect of the project. |

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| their website on each of the sensor including any calibration work that may be required as well as their personal research observations. | |
| Activity 1 Assessment and Evaluation | Connections |
| Students complete pages of their research and circuit information on their individual websites. Teachers evaluate accuracy and completeness of information throughout project, including evidence of understanding of terminology and circuit design basics.<br><br>Students use Appendix 1 Rubric as a guide to the requirements of their work.<br><br>At each design stage, including at each sensor circuit designed and built, the teacher must assess the student work and approve the students moving forward.<br><br>In all electronics work, clean circuits and safe procedures and tool use must be assessed on an ongoing basis. | Appendix1 Rubric<br><br>OCTE toolSAFE project<br><br>Existing designs on Fritzing, 123Circuit, YouTube or supplier websites |
| Activity 1 Accommodations | Connections |
| Teachers are to be familiar with exceptional students' Individual Education Plans (IEPs) for legislated accommodations, and consult with the appropriate staff. By doing this, teachers will be aware of and can implement prescribed modifications accommodations and/or alternative program goals.<br><br>Teaching Strategies for students with special needs may include:<br><br>● grouping design teams with varied abilities to allow for peer support. The teacher may choose or modify the teams depending on individual strengths and weaknesses<br>● providing a list of websites and resources that will assist with finding specific research materials | **SEF Component 1 Assessment for, as and of Learning Connections**<br><br>Indicator 1.1: Assessment is connected to the curriculum, collaboratively developed by educators and used to inform next steps in learning and instruction.<br><br>Students are supported and assessed in the ongoing development of learning skills and work habits. |

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| • pairing experienced students with those who are not yet familiar with the work<br>• the use of a support staff to assist students in reaching their IEP goals | In this activity, a variety of assessment strategies and tools are used to improve learning and inform instructional decisions (e.g., teacher observations, notes and website reports, brainstorming, rough drafts and sketches, regular conferencing, final reports and initial designs and plans). |

## Consolidation & Connections (Provide Opportunities for Reflection)

| Activity 1 Reflection Paper/Exit Card | Connections |
|---|---|
| At the completion of the activity, students are given the opportunity to demonstrate their work (logged on their website) in a classroom basis.<br><br>Each student pair or group is designated to present research info on sensors they researched from the Appendix 8 Sensor List. Each team should describe a different sensor in order for all students to take advantage of the gained knowledge.<br><br>Each design group is then asked to develop a preliminary design for the remote weather station, noting sensors to be used, construction of the tower and infrastructure, and suggestions for possible placement around the school campus. Sketches and ideas should be posted around the classroom for review and idea generation. | **SEF Component 1 Assessment for, as and of Learning Connections**<br><br>**Indicator**<br><br>1.2 A variety of relevant and meaningful assessment data is used by students and educators to continuously monitor learning, to inform instruction and to determine next steps. |

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| | Students:<br>• Provide explicit feedback about their engagement and learning to educators.<br>• Advocate for what they need as learners.<br><br>**Differentiated Instruction**<br>Teaching strategies may need to be changed based on student feedback and observation of student's learning capabilities. |

## Materials, Tools and Resources

| Activity 1 Websites |
|---|
| Autodesk 123D Circuits (Circuit simulation and training, Arduino resources and code)<br>http://www.123dapp.com/circuits<br><br>Fritzing (Circuit simulation and training, Arduino resources and code)<br>http://fritzing.org/home/<br><br>Adafruit: source of products, code and lessons<br>https://www.adafruit.com/<br><br>Adafruit videos: ideas, DIY lessons<br>https://www.youtube.com/user/adafruit/videos<br><br>Arduino: the mothership, news, tutorials, forums<br>https://www.arduino.cc/ |

Arduino Libraries: extension libraries
https://www.arduino.cc/en/Reference/Libraries

Adafruit Github: use search function for particular Arduino libraries
https://github.com/adafruit

Adafruit Github DHT library files
https://github.com/adafruit/DHT-sensor-library

Adafruit DHT tutorial
https://learn.adafruit.com/dht

Github: temperature/humidity Arduino Sketch
https://github.com/futureshocked/arduino_sbs/blob/master/Temperature%20and%20Humidity/DHTtester/DHTtester.ino

Element 14's Arduino forums: helpful community on everything Arduino
https://www.element14.com/community/groups/arduino

Weather Station DIY design: suggested starts
https://www.wired.com/2016/04/diy-weather-station/
http://www.ciese.org/curriculum/weatherproj2/en/index.shtml

Make Magazine: making Arduino weather stations
http://makezine.com/2015/11/20/build-your-own-arduino-weather-station/

Instructables (Number one website for Maker/DIY ideas, including electronics)
http://www.instructables.com/

Abundance of informational sites, tutorials, ideas upon Google search or YouTube or Wikipedia

## Activity 1 Publications

Make Magazine: leading Maker publication (online and print)
http://makezine.com/

Arduino Workshop, a Hands-on Introduction with 65 Projects
John Boxall, No Starch Press, San Francisco, 2013, ISBN 1-5593227-448-3

See Amazon, Chapters for latest publications on Arduino and weather sensing information

## Activity 1 Computer Software

Fritzing circuit design
123D Circuits web based simulation software
Arduino IDE
Adobe Illustrator or CorelDraw
Fusion 360
AutoCad
Web design software such as Wix

## Activity 1 Human Resources

Local Maker, DIY or Makerspace Community
Robotics clubs
Local College or University electronics, weather science groups
Environment Canada

## Activity 1 Other

Online tutorials are an excellent up-to-date way of learning electronics, programming and software use. Several individual lessons are available free on YouTube.

Lynda.com: (free with library card!)
https://www.lynda.com/

Udemy (excellent video tutorials, wait for $10US specials for courses)
https://www.udemy.com/courses/

## Activity 1 Appendices

Appendix1_CircuitDesignRubric.docx
Appendix2_DHT22_ProductDataSheet.pdf
Appendix3_SensorInfoSheet_Template.docx
Appendix4_DHT22TempHumidity_SensorInfoSheet.docx
Appendix5_Fritzing_DHT22Sensor.jpg
Appendix6_DHT22Sensor_schem.jpg

Appendix7_Sample_DHT_Temperature_Humidity_Arduino_Sketch.docx
Appendix8_SensorListSheet.docx

# Activity 2 – Collecting and Analyzing Data with a Data Logger

## Minds On (Engaging Prior Knowledge)

### Activity 2 Project Research and Information Gathering

Activity Description:
In this activity students will conduct a series of circuit design and programming activities to demonstrate data collection and analysis. The weather station will eventually collect data from the variety of sensors. This data must be collected, stored, collated and analyzed. In this activity, students will learn to collect data from a temperature and light sensor and store the data on an SD card or connected computer. Students will also learn basics of data types and methods of analyzing data.

### Activity 2 Criteria and Instructions

1. The instructor will introduce the concept of file storage of data collected from instrumentation. Data can be collected by an attached computer or a data logger shield connected to the Arduino, or by Wi-Fi connectivity (Activity 3). Students learn to program and connect computers and data loggers and learn how to open, add data and close sequential files.

2. The instructor ensure students are familiar with the various data types used in data collection and analysis (See Appendix9_ArduinoDataTypes). Instructors initiate

discussion of data types and possible uses. Instructors may want to use Appendix 9, remove information, and require students to fill in the information for homework or as a test.

3. Students are then introduced to the data logger shield and its operation. (See https://learn.adafruit.com/adafruit-data-logger-shield). Note that it may be necessary to solder header pins if the data logger has not been prepared previously. See the Adafruit website for instructions and refer to the OCTE toolSAFE soldering video under Computer Engineering.

4. Instructors lead discussion on the concept of the Real Time Clock or RTC. Data coming from instruments such as a weather station need to be timestamped for analysis. Note that a CR1220 3V coin battery is needed for the RTC. (Note also that all circuitry is limited to 3V). Using Apendix10_ArduinoDataLoggerPinoutDiagram, describe the breakout pads, the SD Card Detect (CD) and Write Protect (WP) pins, the available RTC square wave pinout (SQ) and the 3.3V, 50mA available voltage source pins.

5. The RTC is an i2C (two wire) interface and requires installing the RTC library. See the Adafruit data logger site for detailed info on reading the clock, testing the clock and setting the time to current computer time. (See https://learn.adafruit.com/adafruit-data-logger-shield/using-the-real-time-clock)

6. Instructors point out the Serial Peripheral Input (SPI) interface and describes how it works (A clock signal synchronizes communications between master (microprocessor) and slave components). Note that older data loggers may not have SPI communications and will require different protocols and library calls. (See https://learn.adafruit.com/adafruit-data-logger-shield/for-the-mega-and-leonardo) A brief comparison of types of communication buses can be introduced here (I2C, SPI, USB, etc.).

7. Instructors discuss the SD/microSD card, formatting and limitations. Instructors illustrate the CardInfo sketch included in the Arduino and ask students to run the sketch. Discuss and poll students about any errors encountered.

8. Students are given a design brief (Appendix10_ArduinoDataLogger) outlining a project to design and build a sensor package that will illustrate the data collection and analysis process. This project is based on Adafruit's example of a refrigerator temperature and light sensor, used to determine energy use when a refrigerator door

is opened. This device can also be used to record the temperature and light variation of the classroom in a 24 hour period. See https://learn.adafruit.com/adafruit-data-logger-shield/light-and-temperature-logger for details.

9. Instructors go over the design brief criteria, and lead a class discussion on designing a pseudo code for the data logger. Students are then tasked in teams to design, build and test the relevant circuit, virtually first, then upon instructor approval, the actual physical circuit.

10. After the data collection test procedure, students are asked to download the data from their SD cards and to import the data (which will be in a .csv (Comma Separated Values) file) into a spreadsheet for analysis.

11. Instructors then guide students to graph the test data for visualizing. Instructors review the functions of a spreadsheet and illustrate the procedures for graphical analysis.

12. Students program their data loggers for the required time period and conduct the actual recording, importing data and graphing the results. Instructors initiate a class discussion on the results and ask students to describe how a data logger can be used in the case of the proposed weather station project.

NOTES

- All work to be recorded online for continual referencing.
- Work is completed individually or in pairs.
- Instructors must approve students to move on to building circuits when they are satisfied the student(s) can describe the electronics and programming aspects as well as demonstrating safe and clean shop and wiring practices.

| Activity 2 Prior Knowledge | Connections |
|---|---|
| • Simple data types used in Arduino programming (reinforced here, see Appendix 9)<br>• Programming the Arduino through the IDE<br>• Pseudo code generation<br>• Arduino programming code structures<br>• Designing and testing a virtual circuit through | There is a large variety of free resources on the Arduino and electronic sensor circuits online. Students are encouraged to lookup sample circuit |

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| Fritzing or 123Circuits<br>• Installing and referencing simple instrumentation such as temperature or temperature/humidity probes (see Activity 1)<br>• Basic spreadsheet operation (reinforced here) | designs on the simulation software libraries, YouTube how-to videos and forums on Arduino and circuit designs and in this case, Adafruit's sample instructions on their data logger shield.<br><br>Students should have been exposed to spreadsheet concepts in mathematics and/or science. Instructors should highlight the uses of spreadsheets and databases in the scientific, mathematical, engineering and financial realms. |
| Activity 2 Planning Notes | Connections |
| Before initiating this activity, teachers should prepare instrumentation and circuit building materials. Note that this project will require battery power sources, prepare AA or other power sources for Arduino card<br><br>Reference sites and documents should be placed in student's docs.<br><br>Posting assessment resources such as rubrics and to-do lists around the classroom, and online, can help student's focus on the important learning goals.<br><br>Students should be provided a means such a classroom clipboard to list any equipment damage or flaws, missing components, etc.to help plan preparation and for inventory control. | Examine sample circuits available at Adafruit, 123D Circuits and/or Fritzing.org. (Note: some user posted circuits may contain errors or complicating additions, make sure students are aware).<br><br>See Design brief and Appendix rubrics for example criteria for discussion<br><br>Make connections with math, science and business teachers for spreadsheet operations and information to determine student's prior knowledge. |

## Action (Introduce or Extend Learning)

| Activity 2 Instructional Strategies | Connections |
|---|---|
| Start from first principles to structure knowledge. Students need to understand:<br>1. data types<br>2. data communications buses such as SPI, IC2, and asynchronous serial such as USB<br>3. use of RT clocks for synchronous communications<br>4. protocol for opening files and storing data on SD/microSD cards.<br>5. Using spreadsheets and graphical tools for analysis<br><br>Students should also be encouraged to look at the wide variety of uses for remotely collecting data such as security systems, environmental monitoring, sequential photo gathering, robot operations and data mining.<br><br>Students should build on the knowledge from this simple monitoring project to the weather station concepts. | DI: the number of sensors and the types of additional sensors can be added for further knowledge and experience.<br><br>DI: students can work in pairs on the design and build of the circuit, or experienced students can be assigned to help individuals on any aspect of the project.<br><br>DI: Additional spreadsheet analysis can be added for advanced students such as trend analysis.<br><br>Math, science or business teachers can be brought in to help with the understanding of spreadsheet operations. |
| **Activity 2 Assessment and Evaluation** | **Connections** |
| Students complete pages of their research and circuit information on their individual websites throughout the activity. Teachers evaluate accuracy and completeness of information throughout project, including evidence of understanding of terminology, circuit design and data logging/spreadsheet basics.<br><br>The Design Brief (Appendix 10) lists the criteria for assessment and evaluation of each stage of the activity.<br><br>Students use Appendix 13 Activity 2 Rubric as a guide to the | Design Brief (Appendix 10) is a typical description of the design requirements and criteria of an engineering design problem. Analyzing a problem and determining an optimal solution through the design process is an important skill for students to master, and understand. |

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| requirements of their work.<br><br>At each design stage, including at each sensor circuit designed and built, the teacher must assess the student work and approve the students moving forward.<br><br>In all electronics work, clean circuits and safe procedures and tool use must be assessed on an ongoing basis. | Understanding spreadsheet and database concepts is very important in today's word where much of the economy is determined through data mining and statistical analysis. Many careers require this knowledge and students should be made aware of the transferable skills developed here. |
| Activity 2 Accommodations | Connections |
| Teachers are to be familiar with exceptional students' Individual Education Plans (IEPs) for legislated accommodations, and consult with the appropriate staff. By doing this, teachers will be aware of and can implement prescribed modifications accommodations and/or alternative program goals.<br><br>Teaching Strategies for students with special needs may include:<br><br>● grouping design teams with varied abilities to allow for peer support. The teacher may choose or modify the teams depending on individual strengths and weaknesses<br>● providing a list of websites and resources that will assist with finding specific research materials<br>● pairing experienced students with those who are not yet familiar with the work<br>● the use of a support staff to assist students in reaching their IEP goals | **SEF Component 1 Assessment for, as and of Learning Connections**<br><br>Indicator 1.1: Assessment is connected to the curriculum, collaboratively developed by educators and used to inform next steps in learning and instruction.<br><br>Students are supported and assessed in the ongoing development of learning skills and work habits.<br><br>In this activity, a variety of assessment strategies and tools are used to improve learning and inform instructional decisions (e.g., teacher observations, notes and website reports, brainstorming, rough drafts and sketches, regular conferencing, final reports and initial designs and plans). |

## Consolidation & Connections (Provide Opportunities for Reflection)

| Activity 2 Reflection Paper/Exit Card | Connections |
|---|---|
| At the completion of the activity, students are given the opportunity to demonstrate their work (logged on their website) in a classroom basis.<br><br>Each student pair or group presents their spreadsheet information and graphs and shares any issues or problems and solutions that may have occurred. The class engages in a discussion on comparing each team's data and resulting graph, noting similarities, differences and potential problems. | **SEF Component 1 Assessment for, as and of Learning Connections**<br><br>**Indicator**<br><br>1.2 A variety of relevant and meaningful assessment data is used by students and educators to continuously monitor learning, to inform instruction and to determine next steps.<br><br>Students:<br><br>• Provide explicit feedback about their engagement and learning to educators.<br><br>• Advocate for what they need as learners. |

| | |
|---|---|
| | **Differentiated Instruction**<br><br>Teaching strategies may need to be changed based on student feedback and observation of student's learning capabilities. |

## Materials, Tools and Resources

| Activity 2 Websites |
|---|
| Adafruit data logger shield information (PDF)<br>https://cdn-learn.adafruit.com/downloads/pdf/adafruit-data-logger-shield.pdf<br><br>Adafruit Data Logger Shield<br>https://www.adafruit.com/product/1141<br>https://learn.adafruit.com/adafruit-data-logger-shield<br><br>Serial Peripheral Interface (SPI)<br>https://en.wikipedia.org/wiki/Serial_Peripheral_Interface_Bus<br><br>Github RTC library<br>https://github.com/adafruit/RTClib<br><br>Adafruit's Temperature and Light Data Logger Project<br>https://learn.adafruit.com/adafruit-data-logger-shield/light-and-temperature-logger<br><br>Open Office Tutorial on Spreadsheets<br>http://www.tutorialsforopenoffice.org/tutorial/Spreadsheet_Basics.html<br><br>Microsoft Excel video tutorial on Excel basics<br>https://www.youtube.com/watch?v=exxBmHaWSLs |

## Activity 2 Publications

Make Magazine: leading Maker publication (online and print)
http://makezine.com/

Arduino Workshop, a Hands-on Introduction with 65 Projects
John Boxall, No Starch Press, San Francisco, 2013, ISBN 1-5593227-448-3

See Amazon, Chapters for latest publications on Arduino and weather sensing information

## Activity 2 Computer Software

Fritzing circuit design
123D Circuits web based simulation software
Arduino IDE
Adobe Illustrator or CorelDraw
Autodesk Fusion 360
Web design software such as Wix
Microsoft Excel, Open Office Calc or similar spreadsheet

## Activity 2 Human Resources

Local Maker, DIY or Makerspace Community
Robotics clubs
Local College or University electronics, weather science groups
Environment Canada
Math, Science and Business Studies teachers

## Activity 2 Other

Online tutorials are an excellent up-to-date way of learning electronics, programming and software use. Several individual lessons are available free on YouTube.

Lynda.com: (free with library card!)
https://www.lynda.com/

Udemy (excellent video tutorials, wait for $10US specials for courses)
https://www.udemy.com/courses/

## Activity 2 Appendices

Appendix9_ArduinoDataTypes.docx
Appendix10_ArduinoDataLoggerDesignBrief.docx
Appendix11_ArduinoDataLogger_PseudoCodeSample.docx
Appendix12_ArduinoDataLoggerSampleCode.docx
Appendix13_Activity2Rubric.docx
Appendix14_Arduino_DataLoggerShield.jpg

# Activity 3 – Wireless Communications with Arduino Compatible ESP8266 Wi-Fi

## Minds On (Engaging Prior Knowledge)

### Activity 3 Project Research and Information Gathering

Activity Description:
In this activity, students will design and build an Arduino based data collector that utilizes a vey inexpensive ESP8266 Wi-Fi module to directly upload measured data to a computer through the Internet. The ESP8266 is a self-contained microprocessor that is programmable through the Arduino IDE. This allows for remote instantaneous (live) data collection and the ability to remove the data collection and analysis computer from possible harsh environmental conditions. It also allows for quick error correction and repair problems with equipment or systems, as one does not have to go and physically retrieve the data after a period of time.

In this activity, students will design a simple Arduino based, Wi-Fi enabled temperature/humidity sensor. This will form the basis for learning how to transmit information to and from remote stations or robots.

### Activity 3 Criteria and Instructions

1. Students are asked to review their ideas and designs for the weather station in a class discussion. The instructor leads the discussion on how to gather data or send commands to remote computers. Discussion should generate ideas in radio communications, Wi-Fi, Bluetooth, NFC (Near Field Communications), laser and fibre optics.

2. Instructor illustrates the ESP8266 board and describes it functions and pinouts.

Instructors describe the project to read temperature and humidity from a DHT22 from Activity 1 and send the data remotely to a computer for collection and analysis.

3. The instructor starts off a class design of pseudo code for the project by introducing the necessary include libraries. Students are asked to build the pseudo code by recalling requirements from Activity 1 and adding the necessary routines for the ESP8266.

4. Students proceed to design the virtual circuit in Fritzing and build the necessary code for testing. Students add their work to Google Docs and their websites for discussion and evaluation.

5. Students are placed in teams to build the physical circuit and to program the device through the Arduino IDE over USB. (Note the wiring requirements for the circuit in Appendix 15, the wiring diagram of the ESP8266/DHT22 circuit.

6. Students run the circuit, collect the data and enter the resulting data into a spreadsheet and graph for presentation and evaluation. Students record their results in their Google Docs or equivalent as well as their website. Problems and issues are to be recorded as well.

7. Students present their results to the class and describe any problems or issues they encountered along the process.

| Activity 3 Prior Knowledge | Connections |
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| • Simple data types used in Arduino programming<br>• Programming the Arduino through the IDE<br>• Pseudo code generation<br>• Arduino programming code structures<br>• Designing and testing a virtual circuit through Fritzing or 123Circuits<br>• Installing and referencing simple instrumentation such as DHT22 temperature/humidity probes (see Activity 1)<br>• Basic spreadsheet and graphing operation | There is a large variety of free resources on the Arduino and electronic sensor circuits online. Students are encouraged to lookup sample circuit designs on the simulation software libraries, YouTube how-to videos and forums on Arduino and circuit designs and in this case, |

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| | Adafruit's sample instructions on their ESP8266 Huzzah module.<br><br>Students should have been exposed to spreadsheet concepts in mathematics and/or science. Instructors should highlight the uses of spreadsheets and databases in the scientific, mathematical, engineering and financial realms. |
| Activity 3 Planning Notes | Connections |
| Before initiating this activity, teachers should prepare instrumentation and circuit building materials. Note that this project will require a maximum of 3.3V power sources.<br><br>There is a wide variety of form factors of ESP8266 modules, many requiring soldering pins. There is an ongoing technological innovation every day, rendering earlier problems and issues moot. Be aware that older modules may have tricky issues that have to be addressed. Instructors need to prepare and test the operation of the project to ensure smooth student involvement.<br><br>Reference sites and documents should be placed in student's docs. Note especially the Adafruit site that uses this project in the tutorial on the ESP8266.<br><br>Posting assessment resources such as rubrics and to-do lists around the classroom, and online, can help student's focus on the important learning goals.<br><br>Students should be provided a means such a classroom clipboard to list any equipment damage or flaws, missing components, etc.to help plan preparation and for inventory control. | Examine sample circuits available at Adafruit, 123D Circuits and/or Fritzing.org. (Note: some user posted circuits may contain errors or complicating additions, make sure students are aware).<br><br>See Appendix rubric for example criteria for discussion<br><br>Make connections with math, science and business teachers for spreadsheet and graphing operations |

## Action (Introduce or Extend Learning)

| Activity 3 Instructional Strategies | Connections |
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| As in Activity 2, start from first principles to structure knowledge. Students need to understand:<br>1. data types<br>2. data communications buses such as SPI, IC2, and asynchronous serial such as USB<br>3. protocols for Wi-Fi communications<br>4. Using spreadsheets and graphical tools for analysis<br><br>Students should also be encouraged to look at the wide variety of uses for remotely collecting data such as security systems, environmental monitoring, sequential photo gathering, robot operations and data mining.<br><br>Students should build on the knowledge from this simple monitoring project to the weather station concepts. Students should be required to research other remote communications devices such as XBee and radio as well as use of cloud based platforms for IoT (Internet of Things) such as ThingSpeak or | DI: students can work in pairs on the design and build of the circuit, or experienced students can be assigned to help individuals on any aspect of the project.<br><br>DI: Additional spreadsheet analysis can be added for advanced students such as trend analysis.<br><br>Math, science or business teachers can be brought in to help with the understanding of spreadsheet operations.<br><br>DI: Students can reach ahead by investigating a full fledge remote weather station in anticipation of the major project. Students can also investigate robotic two way communications through the use of WI-Fi and other communication techniques and devices. |
| **Activity 3 Assessment and Evaluation** | **Connections** |
| Students complete pages of their research and circuit information on their individual websites throughout the activity. Teachers evaluate accuracy and completeness of information throughout project, including evidence of understanding of terminology, circuit design and data logging/spreadsheet basics. | Understanding remote monitoring, robotic two way communications, spreadsheet and database concepts is very important in today's word where much of |

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| Students use Appendix 18 Activity 3 Rubric as a guide to the requirements of their work.<br><br>At each design stage the teacher must assess the student work and approve the students moving forward.<br><br>In all electronics work, clean circuits and safe procedures and tool use must be assessed on an ongoing basis. | the economy is determined through data mining and statistical analysis. Many careers require this knowledge and students should be made aware of the transferable skills developed here. |
| Activity 3 Accommodations | Connections |
| Teachers are to be familiar with exceptional students' Individual Education Plans (IEPs) for legislated accommodations, and consult with the appropriate staff. By doing this, teachers will be aware of and can implement prescribed modifications accommodations and/or alternative program goals.<br><br>Teaching Strategies for students with special needs may include:<br><br>● grouping design teams with varied abilities to allow for peer support. The teacher may choose or modify the teams depending on individual strengths and weaknesses<br>● providing a list of websites and resources that will assist with finding specific research materials<br>● pairing experienced students with those who are not yet familiar with the work<br>● the use of a support staff to assist students in reaching their IEP goals | **SEF Component 1 Assessment for, as and of Learning Connections**<br><br>Indicator 1.1: Assessment is connected to the curriculum, collaboratively developed by educators and used to inform next steps in learning and instruction.<br><br>Students are supported and assessed in the ongoing development of learning skills and work habits.<br><br>In this activity, a variety of assessment strategies and tools are used to improve learning and inform instructional decisions (e.g., teacher observations, notes and website reports, brainstorming, rough drafts and sketches, regular conferencing, final reports and initial designs and |

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| | plans). |

## Consolidation & Connections (Provide Opportunities for Reflection)

| Activity 3 Reflection Paper/Exit Card | Connections |
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| At the completion of the activity, students are given the opportunity to demonstrate their work (logged on their website) in a classroom basis.<br><br>Each student pair or group presents their spreadsheet information and graphs and shares any issues or problems and solutions that may have occurred. The class engages in a discussion on comparing each team's data and resulting graph, noting similarities, differences and potential problems.<br><br>Students discuss next steps in their weather station design projects. | **SEF Component 1 Assessment for, as and of Learning Connections**<br><br>**Indicator**<br><br>1.2 A variety of relevant and meaningful assessment data is used by students and educators to continuously monitor learning, to inform instruction and to determine next steps.<br><br>Students:<br><br>• Provide explicit feedback about their engagement and learning to educators.<br><br>• Advocate for what they need as learners. |

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| | **Differentiated Instruction**<br><br>Teaching strategies may need to be changed based on student feedback and observation of student's learning capabilities. |

## Materials, Tools and Resources

| Activity 3 Websites |
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| ESP8266 Forum<br>http://www.esp8266.com/index.php<br><br>Adafruit ESP8266 Huzzah Breakout Board<br>https://www.adafruit.com/products/2471<br><br>Make Magazine: Installing and Building an Arduino Sketch for the $5 ESP8266 Microcontroller<br>http://makezine.com/2015/04/01/installing-building-arduino-sketch-5-microcontroller/<br><br>Instructables List of Automated Weather Station Projects<br>http://www.instructables.com/howto/Automatic+Weather+Station/<br><br>ThingSpeak Cloud based data collection<br>https://thingspeak.com/<br><br>Blynk: cloud based app for IoT communications<br>http://www.blynk.cc/ |
| Activity 3 Publications |
| Make Magazine: leading Maker publication (online and print)<br>http://makezine.com/ |

Arduino Workshop, a Hands-on Introduction with 65 Projects
John Boxall, No Starch Press, San Francisco, 2013, ISBN 1-5593227-448-3

See Amazon, Chapters for latest publications on Arduino and weather sensing information

## Activity 3 Computer Software

Fritzing circuit design
123D Circuits web based simulation software
Arduino IDE
Adobe Illustrator or CorelDraw
Autodesk Fusion 360
Web design software such as Wix
Microsoft Excel, Open Office Calc or similar spreadsheet

## Activity 3 Human Resources

Local Maker, DIY or Makerspace Community
Robotics clubs
Local College or University electronics, weather science groups
Environment Canada
Math, Science and Business Studies teachers
Local businesses involved in IoT projects

## Activity 3 Other

Online tutorials are an excellent up-to-date way of learning electronics, programming and software use. Several individual lessons are available free on YouTube.

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## Activity 3 Appendices

Appendix15_ESP8266WiFi_DHT22.jpg Fritzing sketch
Appendix16_PseudoCode_ESP8266_DHT22_Project.docx
Appendix17_ESP8266_DHT22_WiFi_Code.docx
Appendix18_Activity3_ESP8266_Rubric.docx