Smart Buildings and the Internet of Things

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Lesson Focus

'Smart buildings' meld environmentally responsible design with cutting-edge computing technology. This lesson explores the practical, scientific, ethical, and environmental issues that emerge in building 'smart buildings' that rely on 'the internet of things'. Students work in teams using resourced technology to design and perhaps later implement, smart building solutions to make their school a better place in which to live.

Age Levels

Intended for ages 11 – 17

Objectives

Introduce students to

- the concepts 'smart building' and 'the internet of things'
- design principles and technologies that are used to create smart buildings
- how computing solutions can support solutions for the common good
- how sensors, message passing, and event handling implement 'smart building' technology

Anticipated Learner Outcomes

Students will be able to

- explain what makes a building 'smart'
- explain how sensors, event handling, and message passing are used to support 'the Internet of things'
- design experiments to collect data on the environmental and social needs of a physical environment
- develop a proposal for a solution to an identified need in a physical environment

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- Designing Smart Building Environments: Exploring Careers in Engineering and Technology: http://ieeetv.ieee.org/careers/designing-smart-building-environments-exploring-careers-in-engineering-and-technology?
- Video on Smart Buildings - https://www.youtube.com/watch?v=j3LrU-CK5YU
- Video on Internet of Things - https://www.youtube.com/watch?v=LVlT4sX6uVs

Optional sensor resources:

- Electronic sensor kits such as SparckFun - https://www.sparkfun.com/products/12862
- First Robotics League sensors - http://www.robotshop.com/en/sensors.html
- The Finch Robot from BirdBrain Technologies - http://www.finchrobot.com/
- Arduino sensors - http://www.instructables.com/id/ARDUINO-TEMPERATURE-SENSOR-LM35/

Recommended Reading

- Smart Buildings - http://www.buildingefficiencyinitiative.org/articles/what-smart-building
- The Internet of Things - https://en.wikipedia.org/wiki/Internet_of_things
- Temperature sensing - https://www.intorobotics.com/pick-best-temperature-sensor-arduino-project/comment-page-1/
- Message passing - https://en.wikipedia.org/wiki/Message_passing

Optional Writing Activity

As a team you identified an environmental or social need in your school that could benefit from ‘smart building’ technology that works through concepts from ‘the internet of things’. Summarize your identified problem and proposed solution and discuss how you would ‘sell’ the project to your school administration.

Smart Buildings and the Internet of Things
For Teachers:
Teacher Resources

◆ Lesson Objectives
Introduce students to
- the concepts 'smart building' and 'the internet of things'
- design principles and technologies that are used to create smart buildings
- how computing solutions can support solutions for the common good
- how sensors, message passing, and event handling support 'the internet of things'

◆ Materials
This lesson is designed to be flexible in showing how to implement the details. As discussed below, you can use found technology resources from your STEM classrooms depending on your own expertise in using those devices. Options are listed below.

The simplest activity involves collecting information on light and heat usage in at least four classrooms in your school (or building). Room thermometers range in cost from about $4.00 to $10.00 each. The ScienceProjectStore.com has a 10 unit digital thermometer pack for $49.00. Walmart offers a 10 unit pack of Learning Resources Boiling Point Thermometers (mercury) for $20.

More sophisticated data gathering can occur depending on the found resources in your school. These include:
- electronic sensor kits such as SparckFun
- First Robotics League sensors
- The Finch Robot from BirdBrain Technologies
- Arduino sensors

◆ Procedure
Overview
The procedure described here assumes that (1) the only sensing technology you have at your disposal is room thermometers that have to be read by hand, and (2) you can only devote a total of 2 class hours to this activity. Opportunities to expand these activities are via homework assignments, classroom experiences of longer duration, and the use of found resources is included where appropriate.

Regardless of how simple or complex you make this lesson, please make sure you understand the technology you will be using. For example, if your school has a First Robotics League (firstinspires.org) team, its members will have access to a variety of sensors depending on the grade level of your team. These students (as well as their coaches) can offer advice on how to actually program sensors so that data gathering can be automatic. Please bear in mind that if neither you nor your class have experience with a particular sensor, then stay with the basic, off-computer activity. On the other hand, if you, or colleagues or students, have expertise in robotics (First Robotics, Finch Robot) or micro controllers (Arduino, electronics kits), then please do expand the basic procedure described here to meet your needs. The example resources listed above is not a complete list, but contain resources that are well-established. Others, such as the BirdBrain

Technologies Hummingbird, the LilyPad for e-Fashion and Raspberry-PI may also provide suitable ‘found resources’. Finally, if you have App Inventor experience and appropriate Android phones or tablets, you can program those to sense temperature.

You may want to do some background reading on the details of how ‘the internet of things’ works based on the recommended readings. The essential idea is that sensors, such as light and temperature sensors, send messages via the network backbone to devices that can change the state of the environment.

Procedure During First Hour

1. Watch the IEEE Career video with your students, then use Worksheet 1 to provide focus questions. Discuss the following important points in the video on Sohaib Sheikh:
    a. Smart buildings can reduce energy consumption and enable a flexible and more productive environment.
    b. Mr. Sheikh’s job is to focus on future trends and technologies to the experience of the building occupants.
    c. Smart building technology is aware of the occupant as an individual, can analyze usage patterns, and provide occupancy data.
    d. The technology creates a workplace in which it can perform functions such as recognizing who is entering the building, the worker’s preferred lighting and temperature, and what level of security access individuals are allowed.

2. Watch the remaining videos on ‘Smart Buildings’ and ‘The Internet of Things” and discuss how
    a. sensors are critical to building smart building technology
    b. network communication provides the backbone through which the internet of things processes information and makes decisions
    c. algorithms (procedures) that respond to events generated by sensors are at the heart of how the Internet of things supports smart buildings.

3. Divide your class into teams of 3 - 5 members. Challenge them to discuss how smart building technology could improve their school using Worksheet 1, and the Student Resource sheet. At a minimum, have them consider how temperature could be controlled based on individual needs and preferences. The worksheet asks them to describe two smart technologies that will improve their school environment. Then ask them to identify what kind of sensors they will need, which other devices will be needed to send messages when the sensor detects a change, and what information will have to be given to the device that makes a change in the environment.
4. In the second hour, ask them to plan a test (simulation) of how their technology will work. If you have sensors other than thermometers, encourage your students to include these in the design if they know how to use them. If you only have thermometers, then choose carefully among potential sensors they may use. Or simply let them pick the sensors. If your students have programming expertise, challenge them to write a program to do the sensing, then report appropriate changes before the second session. However, remember that the challenge is in the design, not implementation. They may find the implementation task harder than they or you imagined. But encourage them to be imaginative in their design.
5. Spend the last 10 minutes of class having your teams give a ‘lightning talk’ explaining their idea.

Procedure During Second Hour

1. Using Worksheet 2, have students simulate the procedures they defined in the first hour. They should have notes on
   a. the smart technology
   b. at least one device that sends messages based on sensor data
   c. at least one device that receives messages and directs a reactive device, such as a thermostat or light switch, to make a change
   d. rules for the method that will send the message
   e. rules for the method that receives the message
   f. reasonably precise information in the message
2. Give students about 20 minutes to experiment with their technology solutions. If you are using optional sensors, have them experiment with what kind of data is actually generated. 'Play computer' and walk through the directives in the methods they created. Depending on the self-motivation in your class
   a. have each team experiment with their solution and refine it
   b. have two teams share solutions and 'debug' each other's solutions
   c. pick one solution from everyone's first hours' work and have all the teams experiment with that solution.
3. Leave time for a full class discussion about
   a. did the designs 'work' – what might need to be refined?
   b. whether the designs actually proved to be useful – for example do you really need to have the temperature automatically detected?
   c. what are the social and ethical ramifications of the internet of things? Are the solutions convenient and helpful, or somewhat controlling? (Have they created butlers or nagging parents?)
   d. how could the technology be 'gamed', that is, how could a smart human thwart the sensed data – for example, by deliberately cooling down or heating up the thermometer.

◆ Time Needed

- 2 sessions, at most 1 hour each. Watch the IEEE Career video and design the fact finding activity in the first hour. Gather your data and design a solution in the second hour.

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Student Resource:

Smart buildings are buildings with computer systems imbedded in them that support the workers' personal comfort in an environmentally sustainable way. List three kinds of 'smarts' you saw in the videos you were shown.

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The internet of things is a term used for a computing system that allows a collection of devices to communicate with each other to support personalized services for human beings. A user does not need to initiate a task: rather, sensors that detect changes influence how small computing devices, not humans, send messages to each other to handle tasks. List three examples of the internet of things you saw in the videos or that you've observed in your daily life:

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Devices that engage in the internet of things: There are two kinds of devices that make up the internet of things:
1) **Devices with imbedded sensors** contain algorithms (rules) that determine what other devices need to be informed about a function that was 'sensed'. List three examples of devices that sense something then report information to other devices. List three devices with imbedded sensors.

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2) **Devices that react to detected change** contain algorithms that determine what the device should do based on the detected change. For example, a device connected to a heater will turn it on when it receives a message from a sensing device that contains a thermometer. List three devices that react to a detected change.

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Sensors monitor natural phenomena such as heat, light, and motion. Sensors can also be more sophisticated. For example, a camera or video camera can be used by a face-recognition algorithm to determine who has entered a room. List six sensors:

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Event driven message passing is a type of algorithm. Rather than have a single controller, the algorithm is made up of a collection of *methods*, each of which can send and receive messages. They can all be part of the software on a single computer, or a collection of computers can use their methods to send messages to other computers via a *communications network.*

The Internet is the network that spans the entire globe allowing humans to communicate with each other, but increasingly it is allowing devices to communicate without human intervention. Methods can *broadcast* information and they can be attuned to *receiving* broadcasts. Methods on devices with sensors monitor the data coming from the sensors, then make decisions based on that data, and broadcast information that other devices receive. Methods that receive that information make their own decisions about how to use that data. Methods on computers connected to mechanical devices can decide to open or lock doors based on the data received, change lighting and temperature, and do a multitude of other functions.

The event model of algorithm design focuses on events (such as a temperature change) that a method reacts to. The method doesn't know what to do with the information, only that it is responsible for sending out the message. Other methods are listening for specific messages that cause them to react and set in motion even more events, some of which are broadcast back, and some of which are used to operate *reactive* devices such as thermostats and light switches.

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Smart Buildings and the Internet of Things

Student Worksheet 1:

This worksheet guides you through the preparation of a design for Internet of Things devices that will turn your school into a smart building.

1) Brainstorm with your team about how your life at school could be improved with smart building technology. On separate paper, or using a word processor, take notes on at least three ideas.

2) Designing devices:
    a. What sensing devices will you need?
    b. What reactive devices will you need?
    c. What kind of data will your sensing device produce?
    d. What kind of information will the methods attached to your sensors broadcast?
    e. What rules will your methods associated with sensors need to determine what to broadcast? For example, a rule might be ‘if the temperature in the room goes about 70 degrees Fahrenheit broadcast the message to lower the temperature in the room.
    f. What kind of information will the methods attached to reactive devices need to receive? For example, a device attached to a thermostat (or directly to a heater) is waiting for a message to raise or lower the room temperature.
    g. What kind of rules will your methods associated with reactive devices need to listen for?

3) Your teacher will give you a list of sensor devices and reactive devices that you can use to design **two** smart building solutions. At a minimum, you will be asked to design something involving a thermometer and a thermostat. Write down a description of your design, making sure you identify both the sensor and reactive device needed. Also write down
    a. the method in the sensor device that broadcasts the message
    b. the message(s) being sent
    c. the method in the reactive device that is listening for a message.

4) Plan a simulation of your smart solution: what happens when your sensor causes your algorithm to send a message to other methods.

5) Be prepared to have your group do a ‘lightning talk’ at the end of the hour. This is a 2 minute description of one of your smart building solutions.

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Student Worksheet 2:

This worksheet guides you through experimenting with at least one of your smart building designs.

1. Get everything organized; set up the scene with your sensors, methods, and messages. You should have at least one real sensor – a thermometer. Review how to read data from it. If you have other sensors this is the time to explore how they actually work. What kind of data can you get from them? How can you manipulate the environment to get a reading that will help you test your design?

2. Make a list of the data that impacts the smart building technology. For example, is there a temperature threshold that causes a sensor device method to spring into action and broadcast messages? Conversely, given the messages that reactive devices are listening for, what data will start the process. Be prepared to experiment with this sort of range of data. (It is called a testing suite.) Also think about 'bad' data – data that might appear and that will gum up the works. Professional testers relish this part of their jobs. You can too.

3. The instructions for running a test are pretty straightforward, but the process itself is rather complicated. You have to pretend you are a computer and follow the rules exactly. Divide the tasks so that one person is the 'sensing device' and the other person is the 'reactive device'. A third person is responsible for manipulating sensor artificially to produce desired data. If you have more than three people on you team, the other(s) are referees who call out if the methods are not being precisely followed.

   Start the test by manipulating the sensor to produce useful data. This should set the device simulator people loose. Take notes as things go as expected, and when things go wrong. Change your methods and your message and retest.

   Make sure you leave time to experiment with bad data. Do your methods fail? How can you fix them so they can either react well or simply ignore bad data?

4. You will be asked to report back to the class about how your test went. Prepare what you will say, be sure to be brief and to the point. If you have time, brainstorm within your group about the ethical ramifications of your design: is it truly helpful or could it be put to inappropriate use? Does it protect an individual, or does it have the potential to do harm?

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Teacher Resource:
Alignment to Curriculum Frameworks

Note: All lesson plans in this series are aligned to the Computer Science Teachers Association K-12 Computer Science Standards, the U.S. Common Core State Standards for Mathematics, and if applicable also to the National Council of Teachers of Mathematics' Principles and Standards for School Mathematics, the International Technology Education Association's Standards for Technological Literacy, and the U.S. National Science Education Standards which were produced by the National Research Council.

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Understandings about science and technology

◆National Science Education Standards Grades 9-12 (ages 14-18)

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As a result of activities, all students should develop

- Understandings about science and technology

◆Next Generation Science Standards & Practices Grades 6-8 (ages 11-14)

Practice 1: Asking Questions and Defining Problems

- Ask questions to clarify and/or refine a model, an explanation, or an engineering problem

Practice 2: Generating and Using Models

- Evaluate limitations of a model for a proposed object or tool.

Practice 5: Using Mathematics and Computational Thinking

- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations

MS-ETS1-1 Engineering Design

- 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-ETS1-4 Engineering Design

- 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.

◆Next Generation Science Standards & Practices Grades 9-12 (ages 14-18)

Practice 1: Asking Questions and Defining Problems

- Ask questions to clarify and refine a model, an explanation, or an engineering problem

Practice 5: Using Mathematics and Computational Thinking

- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations

Practice 6: Constructing Explanations and Designing Solutions

- Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.

◆ **Standards for Technological Literacy – All Ages**

The Nature of Technology

- Standard 2: Students will develop an understanding of the core concepts of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Design

- Standard 9: Students will be able to develop an understanding of engineering design.

Abilities for a Technological World

- Standard11: Students will develop the abilities to apply the design process
- Standard 13: Students will develop the abilities to assess the impact of products and systems.

The Designed World

- Standard 14: Students will develop an understanding of and be able to select and use energy and power technologies.

◆**CSTA K-12 Computer Science Standards Grades 3-6 (ages 11-14)**

5.1 Level 1: Computer Science and Me (L1)

- Community, Global, and Ethical Impacts (CI)

  2. Identify the impact of technology (e.g., social networking cyber bullying, mobile computing and communication, web technologies, cyber security, and virtualization) on personal life and society.

◆**CSTA K-12 Computer Science Standards Grades 6-9 (ages 11-14)**

5. 2 Level 2: Computer Science and Community (L2)

- Collaboration (CL)

  3. Collaborate with peers, experts, and others using collaborative practices such as pair programming, working in project teams, and participating in group active learning activities.

CSTA K-12 Computer Science Standards Grades 9-12 (ages 14-18)

5.3. A Computer Science in the Modern World (MWJ)

- Computational Thinking (CT)

  8. Use modeling and simulation to represent and understand natural phenomena.

◆**CSTA K-12 Computer Science Standards Grades 9-12 (ages 14-18)**

5.3. B Computer Science Concepts and Practices

- Computational Thinking (CT)

  8. Use models and simulations to help formulate, refine, and test scientific hypotheses.