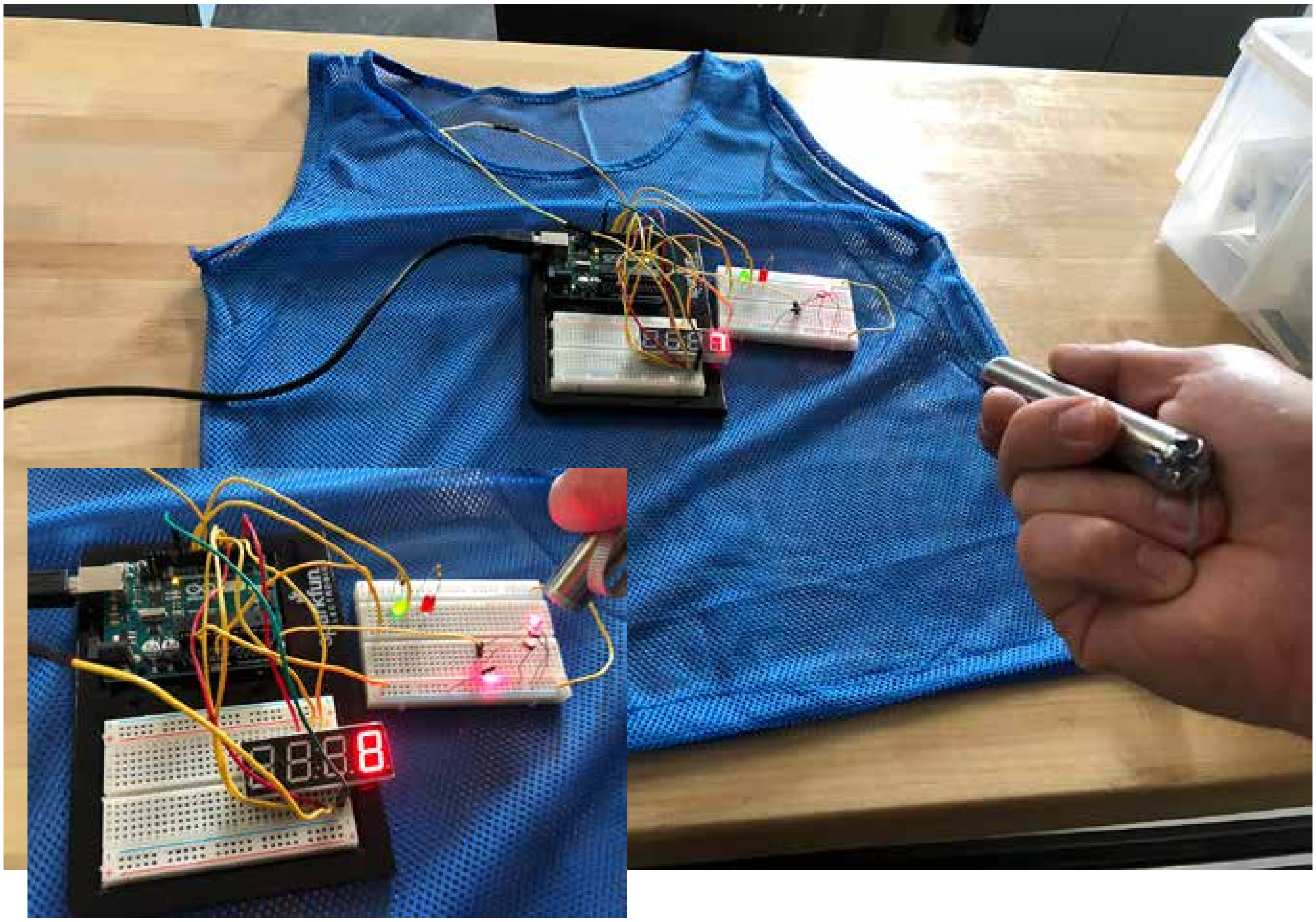
socially relevant contexts



teaching technology and engineering concepts through socially relevant contexts: promoting mind and body fitness by engaging students in active game design

An emphasis on intellectually stimulating and physically engaging opportunities for students through CT scenarios may be one path towards improving the overall wellness of our K-12 students.

by Scott R. Bartholomew and Liwei Zhang

Introduction

Although there are over 320,000 health and fitness apps available on major app stores, there is scant evidence that they actually promote a healthier lifestyle, assist users in exercising, or promote weight loss (Young, 2018). A healthy lifestyle includes multiple aspects of wellness such as physical, intellectual, social, and emotional health (Lyon, 2019). Two of these aspects, physical and intellectual, have recently come into focus. For example, in the United States the percentage of children and adolescents affected by obesity has more than tripled since the 1970s (Fryar, Carroll & Ogden, 2014). Although obesity can be caused by a variety of factors, consuming more energy from foods and bever-

Figure 1 (above). A prototype made by authors with an LCD screen and light switches when a tag is detected (when the laser pointer points at any LDR sensor).

ages than the body uses for growth, physical activity, and health functioning can lead to extra weight gain over time (Hill, Wyatt, & Peters, 2012). In turn, obesity has been linked with a variety of other health-related, and non-health-related, challenges. While maintaining an appropriate balance of physical activity, relaxation, and food consumption can assist in promoting a healthy lifestyle and combating obesity (CDC, 2019), policies, opportunities, and environments that encourage youth to eat fruits and vegetables and spend at least 60 minutes of physical activity a day are not widely available (CDC, 2019). Recommendations regarding dietary, physical, and educational activities, positive emphasis and environments in schools can assist youth in achieving and maintaining a healthy weight and lifestyle balance (U.S. Department of Health and Human Services, 2010).

Another aspect of overall health—intellectual wellness—revolves around creative, stimulating, and challenging mental activities (Lyon, 2019). Completing a Sudoku puzzle, finishing a crossword, or solving a particularly challenging riddle are all activities that may foster intellectual wellness. In short, thinking critically about challenging topics may foster a better overall wellness. Related to critical thinking is another recently popularized form of thinking: computational thinking (CT). With the ongoing technological revolution, CT is becoming essential in K-12 education to better prepare students for their future school and career opportunities that will involve an increasingly technological world (Wing, 2014). Outside of simply programming electronic devices, the development of computational thinking involves both problem-solving skills and systems design (Wing, 2006). These computational thinking skills are essential for students as they prepare for future opportunities and challenges (P21, 2015).

For decades, lessons in schools have focused on teaching students about physical activities and engaging them in simple CT opportunities (e.g., printing out phrases such as "Hello World," or computing math problems). However, research (Overmars, 2004) has shown that young students may be inclined towards activities that accomplish both physically and intellectually stimulating goals—*they want to program games!* Engaging students in programming games fosters engagement and excitement for students, as they can more readily connect with the content and context (Kafai, 2006, Van Rosmalen, et al., 2015). Further, programming games can engage students in a variety of computational thinking skills such as problem solving, systems thinking and design, and logic models. Inspiring students to pursue further education, training, and experiences with computational thinking may help them foster the necessary skills for their future schooling, employment, and interaction with the increasingly technologically connected world.

This article presents a lesson plan using an Arduino for integrating computational thinking and game design with middle school students who may have little or limited prior experience with text-based programming. Specifically, the authors believe that this lesson plan, which focuses on engaging students in both designing and playing an active laser-tag game (Figure 1, page 13), can help students learn basic programming principles, explore ideas related to circuits and sensors, develop teamwork and communication skills, participate in active physical play, and gain motivation in learning more programming in future game development and other applications.

Laser Tag

Laser tag is a game in which two or more players attempt to "tag" other players by "shooting" a laser at a sensor worn by the other individual. Unlike other forms of tag games (e.g., freeze tag) where players touch other players with their hands, laser tag does not normally have any physical contact. The idea of laser tag has existed for decades; "laser guns" were originally used by the United Stated Army in the 1970s as a training tool for soldiers. These laser guns, and the associated "games," were used to mimic real situations soldiers would potentially face. In these early models, a laser module was stored in a gun case, and sensors were mounted on the helmets and vests of soldiers. When a sensor detected a "hit," a noise was made to notify the soldier that they had been "hit."

In the late 1970s and early 1980s, laser tag game systems with toy guns and sensor targets began appearing in the toy and gaming industry with great success. Many of these early commercial products were inspired by *Star Trek* and *Star Wars* films, which featured similar technology. Multiple companies, each with their own varied laser tag game systems, accessories, and options, continue to market and sell these products (TagFerret, 2007). In recent years, this industry has totaled more than $400 million in sales each year (Lifschutz, 2017).

While the general term "laser tag" has been widely adopted, almost all laser guns manufactured in the toy industry today use infrared lights rather than actual lasers for safety reasons. These infrared lights, when directed towards a sensor, can trigger a variety of programming sequences built into the game system (Sanjeev, 2014). In this lesson plan, we use laser pointers with an output of less than 5 milliwatts to trigger a student-designed and produced laser tag vest. In this setting and all settings using lasers, we caution that safety rules be followed—especially related to not pointing a laser at an individual's eyes.

Computational Thinking and Game Design

The concept of "computational thinking," and the need for everyone to gain related skills and relevant experience, has been discussed a great deal in recent years (Grover & Pea, 2013; Mohtadi, et al., 2013; Weintrop, et al., 2016). Many educators (e.g., Lye & Koh, 2014) agree with Wing (2006), who posited that computational thinking should be one of the foundational skills for every student to learn in order to succeed in the increasingly technological world.

The process of designing an interactive game allows students to develop computational thinking skills through solving problems in a complex situation that can utilize sensors, hardware, and programming (Overmars, 2004). Games usually consist of multiple variables (e.g., players, resources, rewards, levels, etc.) that interrelate with each other, and designing games requires a combination of variables together that creates a complete system that is "playable" and entertaining (Fullerton, 2014). Research into computational thinking skill development through game design challenges has found that students can benefit through knowledge gained and positive attitude changes (Akcaoglu, 2014) as well as the development of core computational thinking skills and experiences.

Arduinos

Arduino is a microprocessor commonly used by many artists, hobbyists, and industry professionals to prototype electronic devices. The low cost and relatively modest learning curve make this a top choice for amateur and professional users (Kushner, 2011). The Arduino, which is open source and programmed in C language, is relatively easy to navigate and use, and related information, resources, and tutorials abound online. While a wide variety of microprocessors would suit the needs of educators working with students (e.g., LilyPad, Arduino Nano, TI LaunchPad), the authors chose to use Arduino Uno because it is relatively easy for beginners to wire circuits and sensors (Figure 2). Another potential option (LilyPad) designed for wearable devices would also be suitable.

Programming and Game Design Lesson Plan

In this lesson, students are placed in groups and provided with a computer, an Arduino kit, and other supplies for prototyping (supply list, pp. 17, 19), as well as the design challenge around laser-tag game design (p. 19). In this challenge, students design game rules, build game equipment, test game play, revise game design, and finally present their laser tag game to the class. Writing game rules for the game with instructions for users was intentionally highlighted to facilitate the development of skills related to delivering and describing technical information.

The lesson overview and lesson plan are included on the following pages. This lesson plan is intended to be an example of one way the integration of several topics could be used to foster computational thinking in students through game design. Teachers are encouraged to explore other games and programming platforms and adjust levels of difficulty to fit class needs.

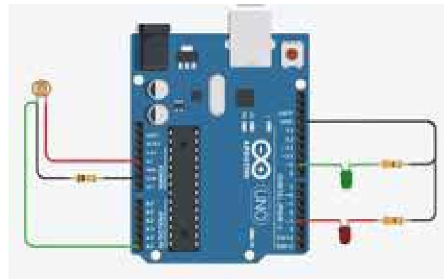


Figure 2. The schematic diagram showing the circuits of LDR and LEDs connecting to Arduino.

In addition to a variety of other games that could be adapted to follow a format similar to this lesson, variations of this lesson plan may include modifications such as removing the counter (for novice students), adding "start-up" or "warning" lights for various points in the game (for more advanced students), or building "targets" and "reset" stations for expanding the game and learning.

The authors contend that it is time for K-12 education to move past simply telling students to "eat your vegetables" and challenging students to program "Hello World." This article and lesson presents one potentially more engaging approach to combining computational thinking and physically stimulating educational opportunities. Allowing students the opportunity to engage in a familiar game-based task through computational thinking, design, and play is a positive way of encouraging the development of physical and intellectual skills, which may lead to improvement in their overall wellness and their future education and employment. An emphasis on intellectually stimulating and physically engaging opportunities for students through CT scenarios may be one path towards improving the overall wellness of our K-12 students.

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Supplies

Helpful links to buy sample supplies for student challenge:

Vests from: www.amazon.com/Scrimmage-Practice-Children-Basketball-Volleyball/dp/B014JZK0II

Laser Pointers from: www.amazon.com/Innozon-Pointer-Battery-Interactive-Training/dp/B077LTTVLW

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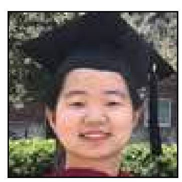

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This is a refereed article.

Ad Index

Lesson Overview

Lesson Title – Teaching Computational Thinking Through Active Game Design

Time: 10 hrs.

Lesson Overview/Purpose: Students will engage in an interactive challenge to design and build a laser tag game through programming electronics with an Arduino. This will require students to apply knowledge of circuits and sensors, program IF statements in C to handle input/output, and write game instructions.

Core Content Standards:

- *Standards for Technological Literacy,* Standard 12:
  Students will develop the abilities to use and maintain technological products and systems.
- *Next Generation Science Standards*:
  Students will use mathematics and computational thinking in science and engineering practices.

STEM Standards:

- *Next Generation Science Standards*: Use Mathematics and Computational Thinking
  - Create algorithms (a series of ordered steps) to solve a problem.
- *Standards for Technological Literacy,* Standard 12
  - Benchmark I. Use tools, materials, and machines safely to diagnose, adjust, and repair systems.
  - Benchmark J. Use computers and calculators in various applications.
  - Benchmark K. Operate and maintain systems in order to achieve a given purpose.
  - Benchmark L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.
- ELA/Literacy
  - Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
  - Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.
- Mathematical Practices
  - Reason abstractly and quantitatively; model with mathematics; use appropriate tools strategically.

Student Objectives:

Students will:

1. Program the Arduino microcontroller to apply if-then conditional statements.
2. Prototype complete circuits to build a light detector.
3. Design, develop, test, review, and present a laser-tag game.
4. Communicate with step-by-step instructions to explain the game rules.
5. Explore the roles of a game designer through writing a game story, designing game rules, and testing gameplay.

Enduring Understandings:

- The if-then conditional statements in programming act the same as the logic of game rules. (Computer Science)
- Sensors allow computers/microcontrollers to read energy changes in the physical world. (Science)
- Potential of applying electronics and programming in game design. (Engineering/Technology)

Driving Question: How can computer thinking be used to produce an entertaining and engaging game?

Career Connections:

- Electronics Engineer
- Digital Engineer
- Multimedia Programmer
- Game Designer
- Control and Instrumentation Engineer
- Telecommunications Engineer
- Computer Scientist
- Software Developer

Supplies:

- Arduino boards and power cable
- 9V battery and battery clip (to power Arduino board)
- Jump wires
- LEDs
- Photoresistors (LDR)
- Resistors
- Transistor
- Breadboards
- Switch buttons
- Laser pointers with battery
- Nylon mesh sports team practice vests (2 colors, see references for samples)
- Computers with Arduino IDE installed
- Construction paper

Full Lesson Plan

Lesson Title – Teaching Computational Thinking Through Active Game Design		

Design:
Enable students to create their own game story and rules of playing.
 	
2 Hours
	• Introduce the class to the Laser Tag game
	  ▪ Helpful Resources:
	    ◦ Family Laser Tag War: www.youtube.com/watch?v=0Rx4UMOX9p4
	    ◦ Laser Tag Briefing Video: www.youtube.com/watch?v=rV5A3uvxqQI
	    ◦ Laser Tag Museum: www.lasertagmuseum.com/
	• Introduce the class to the laser tag game design challenge
	  ▪ Day at Work: Video Game Designer: www.youtube.com/watch?v=c0o6BPYKBiA
	  ▪ Game Design & Theory 01: What is a game: www.youtube.com/watch?v=G2hQvfpAisI&t=1m55s
	• Students will work in groups and write their own game narratives
	  ▪ Where and when does this story take place? (setting)
	  ▪ Who is involved in the story? (characters)
	  ▪ What happens through the story? (plot)
		▪ Helpful Resources:
		  ◦ Three elements of game writing: www.youtube.com/watch?v=wNNXdoj7cCQ
		  ◦ How to write a good game story: https://paladinstudios.com/2012/08/06/how-to-write-a-good-game-story-and-get-filthy-rich/
		• Lead a discussion with the class to practice using if-then statements to describe game mechanics
		  ▪ If a player does …, then … will happen,
		    ◦ e.g., if a player is tagged 3 times, then their third light blinks twice and turns off.
		    ◦ e.g., if all 3 of a player's lights are off, then they are "dead" in the game.
		• Students will discuss and write down game mechanics in groups.
		  ▪ Goals/winning conditions
		  ▪ Effects of being tagged
		  ▪ Number of "lives," etc.
		• Each student group will submit a complete draft of game story and game mechanics design.

Build:
Enable students to build their own knowledge through building and reflecting.
 	
6 Hours
	Electronics – 2 Hours
	• Students will work individually and construct circuits on a breadboard:
	  ▪ To light an LED with a battery, resistor, and jump wires.
	  ▪ To light two LEDs in series and parallel circuits.
	• Think-Pair-Share, sharing reflections on questions students have in lighting up LEDs.
	• Discuss electricity, circuits, schematic symbols, and Ohms law.
	    ▪ Address students' misconceptions or questions.
		• Students will work in pairs and construct a light detector circuit using an LDR.
		  ▪ Helpful Resource: www.build-electronic-circuits.com/ldr-circuit-diagram/
		• Ask each student to explain to another why their circuit does or does not work.
		• Discuss problems students encountered with building circuits.

	Arduino – 2 Hours
	• Students will work in groups and practice programming with Arduino to:
	  ▪ Run the Arduino built-in example codes, Blink (Basic, Output) www.arduino.cc/en/Tutorial/Blink
	  ▪ Run the Arduino built-in example codes, Button (I/O, If-Then) www.arduino.cc/en/Tutorial/Button
	• Explain example codes, Button, to the class.
	  ▪ Go through each line of code, ask and explain its function.
		• Students will work in groups and practice programming with Arduino to:
		  ▪ Run the Arduino built-in example codes, If Statement-Conditional (If-Then, AnalogRead) www.arduino.cc/en/Tutorial/ifStatementConditional
		  ▪ Discuss how to modify codes and circuits and build a light detector with Arduino.
		  ▪ Program a light detector using an LDR on Arduino.
		• The groups that have completed the light detector can mentor other groups:
		  ▪ Building circuits
		  ▪ Writing
		• Lead discussion with the class to review and reflect on their Arduino experience.

	Prototype – 2 Hours
	• Discuss the game design challenge with the class.
	  ▪ Clarify student understanding of the requirements.
	• Discuss the importance of teamwork.
	• Students will use the materials provided to build a functional prototype of laser tag game set.
	• Students will test and revise their game design with the prototype.
		• Students will finalize game rules of their game and make an instruction sheet for the game.
		  ▪ Helpful Resources:
		    ◦ 6 Tips on writing board game rules: www.youtube.com/watch?v=BR1pg5Qsqkc
		• Each group will make a video demo to introduce and market their game.

Evaluate: Allow students to present, evaluate, and play the game they designed and built. 2 Hours	• Each group will play its video demo and present its gameplay to the class. • Students will vote for the game they most want to play. • The winning team will help other teams to get their gaming equipment ready for class competition.	• Upload the same code to every Arduino. • Students will work together to build a play arena for class competition.

Design Challenge: Laser-Tag Game

Description:
Time to design and build your own game! Imagine you are a game designer, working on a design challenge of a laser-tag game. During this challenge, you and your team will work together to design, build, and play a laser-tag game. Your task includes: (1) design the game play and write game rules/instructions, and (2) design and build game equipment for players to wear while playing. For each team, your final product will be a packaged game set for each team member and a video demo presenting the gameplay.

Caution: NEVER aim lasers at eyes!

Supplies:

Arduino board	Vests (2 colors)	A switch button	Transistors
Laser pointers	Resistors	Jump wires	Construction paper
LEDs	Breadboard	Photoresistors	

Criteria and Constraints:
1. Your game must have clearly written rules explaining how to play the game.
2. Your team must build two sets of game equipment (one for each team member).
3. Your game must be suitable for at least two players to play but may be extended to include more players.
4. The video demo must be no longer than 60 seconds.

Deliverables:
1. A packaged game set, including an instruction sheet and game equipment.
2. A video demo of how to play (imagine you are marketing your game).

Scoring Rubric:

Item	Score Level 3	Score Level 2	Score Level 1
Game Rules	Game rules are clearly written and easy to follow. A first-time player should know how to play the game after reading the instructions.	Game rules are included. Players may still have some minor questions regarding how to play the game after reading.	No game rules. Key instructions are missing or badly written, which would result in players not knowing how to play after reading.
Game Equipment	A set of game equipment is built for each team member, and all pieces function as stated in the game rules.	One set of game equipment is missing. Some pieces do not function as stated in the game rules.	Game sets, pieces, and parts are missing and/or do not function.
Video Demo	Video is well made and demonstrates the entire gameplay.	Video is made and demonstrates major elements of gameplay; longer than 60 seconds.	No video is made; or video is not relevant to the gameplay; or longer than 90 seconds.
Extra Credit: Class Competition	Game design is voted as the best gameplay for the class competition.		

Class Competition: Laser-Tag War

Some Guidelines for Setting up the Laser Tag Party

1. **FIRST step** – all should vote and agree on one set of game rules.
2. **Hardware** – to ensure everyone can participate in the class competition, each team will have to build each team member a vest. A laser pointer will be provided to each player.
3. **Software** – teachers make sure the same codes have been uploaded to Arduinos before playing.
4. **Playground** – everyone in the class will work together to design and build a play arena.
5. **Team Up and Play!**