DOING THE DATA WALK

Ticker tapes for the 21st-century physics student

Steve Cogger

Ready, set, go! The traditional Run the Football Field physics activity—in which students are timed as they move at different speeds on a football field to investigate displacement and velocity—has been updated for the 21st century. Nowadays, GPS-enabled tablets and smartphones replace the stopwatches and yard markers of the past, allowing students to collect real data and learn about the concepts of motion.

This article describes a two-day lesson in which students use a free Android app called Data Walk to log their positions over time. Students upload the app's data output to a web platform called the Internet System for Network Science Experimentation (iSENSE), allowing them to view their motion in pictures and numbers. Visual representations and accurate position-time data enhance student learning and improve the outcome of the traditional run-the-field activity. I call this updated lesson the "Human Ticker Tape" lab because the data resemble the carbon paper dots of traditional motion labs.

Improved accuracy

Position, velocity, and their relationship to time are often difficult for students to grasp. Analyzing data that is highly dependent on the accuracy of student timers and on *data flips,* in which students have to swap the dependent variable (i.e., time) with the independent variable (i.e., the timer's position), does not improve student understanding. The traditional run-the-field lab ends with students trying to qualitatively analyze dubious data, so the activity often amounts to mostly a fun period outdoors with a bit of physics on the side.

The use of the technology described in this article preserves and enhances an engaging physical activity by improving the accuracy of the data and by reinforcing the concepts of position, velocity, and time in a human contextual scale. "Creating investigations that allow students to see physics in their everyday world and to be kinesthetically active outside of the traditional physics classroom can be incredibly engaging and effective" (Whitworth, Chiu, and Bell 2014). The lab is mostly qualitative; however, the data students collect will let advanced students engage in more involved numerical analysis as this data is also available. This article includes student work samples and outcomes that will help teachers implement this project in their own classrooms.

Essential questions

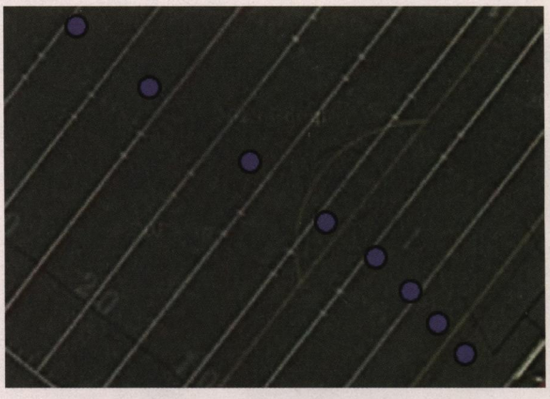
At the conclusion of the lab, students will be able to

1. Interpret patterns of motion and draw the corresponding qualitative position-time, velocity-time, acceleration-time graphs.
2. Analyze how a change in speed relates to the spacing of dots by measuring and discussing what they see with their partners or by making calculations using the data analysis capabilities of the software.
3. Develop a physical context for changes in motion by walking or running in a familiar location marked by known units.

FIGURE 1

Screenshots from the iSENSE Data Walk web page.

Students analyze dot patterns to determine different groups' motions. They can examine the dots on their own or superimpose the dots on a map of the local area.



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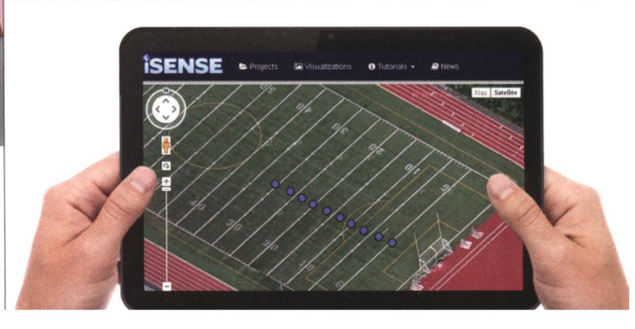

Materials

The Human Ticker Tape lab requires Android tablets or smartphones with GPS capabilities and the iSENSE Data Walk app, available for free online (see "On the web"). Using GPS tracking, the app allows students to record their position while walking or running outdoors. The GPS coordinates are then saved and uploaded to the Data Walk Project page on the iSENSE website. Students will need access to the school's wireless network so they can upload their data when they return to class. They will also need computers to analyze their data on the iSENSE website (see "On the web").

Day 1: Data collection and preliminary analysis

On the first day of the lab, teachers activate prior knowledge by reviewing the concepts of position, velocity, and time in the context of previous labs. I briefly describe actual paper ticker tapes, explaining how people would measure the spaces between the dots and make calculations to study motion. Qualitatively, the faster the motion, the larger the space is between the dots. In my classroom, this is an important clarification because prior labs use computer-based lab equipment (i.e., motion detectors) to draw position-time and velocity-time graphs based on ultrasonic sensor data. As students sometimes have problems interpreting data from "non-computer based equipment" (Steinberg 2003), the app and software retain the familiarity of computers while requiring students to analyze unfamiliar patterns, representing their motions.

Teachers instruct students how to use the app and hand out the lab data sheet (see "On the web"). Students are split into their regular lab groups and are assigned a specific motion. For example: "Start recording at the back of the end zone. Walk at a steady pace to the 30-yard line. Stop the recording after you cross the 30-yard line." If a football field is not available, any open space allowing motion between a start and end point will work.

Before students go outside, they discuss their assigned motions with their partners. They talk about how to create the motion and write down ideas, using such words as *steady, increasing, decreasing, stop, start, fast,* and *slow.* Teachers instruct students not to share their motions with other groups; part of the lab is to analyze other groups' dot patterns from the Data Walk web page and determine the assigned motion of the other groups.

Once outside, all members of the lab group perform their motion. Students can coach their partners while they record the motion and keep them on track if space is an issue. If time permits, students can record their own ideas for movement (e.g., running in circles) to provide data for additional classroom discussion. When students have finished recording their assigned motions, the class goes back inside to upload the data.

FIGURE 2

Examples of student ticker tapes.

Students analyze and describe the motion that created dot patterns.

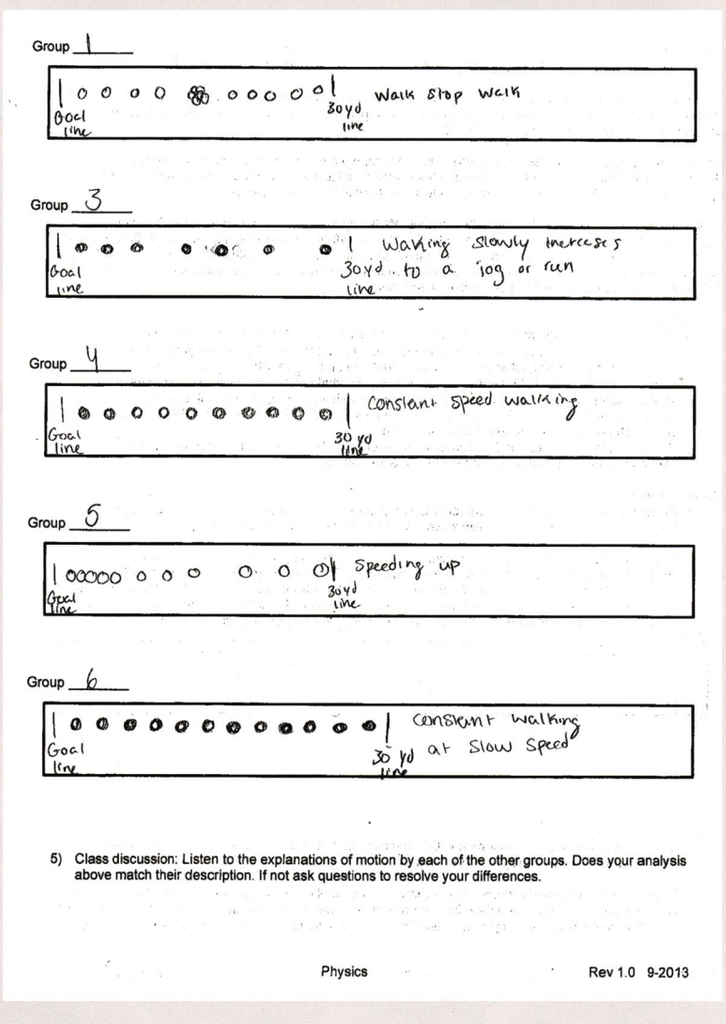

FIGURE 3

Connections to the standards.

Next Generation Science Standards (NGSS Lead States 2013).

HS-PS2: Motion and Stability: Forces and Interactions

Performance Expectation

The materials/lessons/activities outlined in this article are just one step toward reaching the Performance Expectation listed below. Additional supporting materials/lessons/activities will be required.
HS-PS2-1. Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

Science and Engineering Practices

Analyzing and Interpreting Data

- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

Obtaining, Evaluating, and Communicating Information

- Communicate scientific and technical information in multiple formats (including orally, graphically, textually, and mathematically).

The Human Ticker Tape lab provides numerous opportunities for data analysis using tools and models, and students must obtain, understand, and communicate information as they evaluate the validity of their classmates' claims. Students see visual data of their motions and analyze it in the context of their motions. They calculate results from numerical data and compare those results with peer data.

Disciplinary Core Idea

PS2.A: Forces and Motion

- Newton's second law accurately predicts changes in the motion of macroscopic objects.

In my class, students conduct a sequence of position-time, velocity-time, and acceleration-time labs that lead to the concept of force, which segues into Isaac Newton's laws of motion. Once students understand position-time and velocity-time concepts, the notion of unbalanced forces and Newton's laws of motion follow naturally. Standard PS2.A on Forces and Motion requires students to analyze data to support Newton's laws, stating "examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force."

The Human Ticker Tape lab precedes our labs on Newton's Laws and reinforces the idea that forces cause change in motion. In this activity, students analyze their own position-time data, using a representation that is different from what they see in the computer-based motion labs. The alternate representation and the physical act of performing the motion helps students activate prior knowledge and construct a deeper understanding of position, velocity, and acceleration.

Crosscutting Concept

Patterns

- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

In the Human Ticker Tape lab, students examine data patterns that they created and collected. After the outdoor activity, they analyze patterns created by their lab group and the other groups in class. Students can observe different patterns and provide evidence for causality in their explanations of their data.

After students have uploaded their data, they open the Data Walk Project page on the iSense website to find it. The website superimposes the data on a bird's-eye view of the location where the activity took place (e.g., Figure 1, p. 44). Students transfer the dot pattern of their motion from the web page to a representation of a ticker tape strip on their lab worksheet and explain the relationship of their dot patterns (i.e., spaces between the dots), to their motions.

Once groups have analyzed their own motions, they examine the dot patterns of the other lab groups and perform a similar analysis (Figure 2, p. 45). While students are analyzing the data, teachers can circulate, asking students to explain what they are seeing and justify their conclusions. The Day 1 activity usually takes an entire 56-minute classroom period.

Day 2: Continuing analysis and social context

The next day, students complete their data analyses before we discuss each group's dot pattern, which I project from the web page. Students complete a worksheet (see "On the web") that has exemplar data and requires further analysis of dot patterns of motions they haven't seen. The worksheet includes qualitative graphing of the exemplar dot patterns for velocity-time and acceleration-time. These grids are the same graph grids we use to record the data generated by computer-based motion sensors.

Once students have completed the worksheet, we discuss the results, answer questions, and talk about the devices' ability to accurately track location. Since most students have devices with tracking capability, it is important to discuss the social aspects of the technology. I ask students such questions as "How would you feel if you received a coupon for a store as you walked past it?" "Would you like it if the store recognized your identity and previous purchases?"

Conclusion

The Human Ticker Tape lab teaches physics concepts using new representations of student-created data as students engage in a fun learning activity. The social nature of the activity and the novelty of the lab experience (Moll 2011) provide new opportunities for students to learn. The Data Walk mobile app and its supporting, web-based software transform a dated activity to a modern lab using familiar technology. By generating their own data in a familiar environment, students feel more engaged and are more willing to challenge each other. The activity also aligns with the *Next Generation Science Standards* (Figure 3).

During my four physics classes, students were fully engaged and interested in the lesson. My department chair observed and participated in one of the classes and noted, "Students at lab benches are readily discussing data with one another." My colleagues and I performed this lab over three days with more than 200 11th-grade physics students.

We assessed student learning through individual and group conversations during the activity. The lab data sheet and the exemplar worksheet served as formative assessments. My assessment was primarily focused on correct interpretation and completed work. I addressed conceptual issues and discussed them with students when returning their materials.

Students were familiar with the idea of observing motions, making predictions, defending their predictions, and collecting data to test their predictions. The Human Ticker Tape activity is a complementary lab activity to cart-based motion labs. Many of the motions that students perform in the outdoor lab are comparable to the motions that they have seen with the carts. Repeating these motions on a human scale with data analysis provided by the app and web page reinforces the concepts of motion and addresses learning needs of all students. Students make qualitative graphical representations on the same graph grids as their cart labs to reinforce the motion concepts in a familiar context. ■

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On the web

Data Walk Project web page: *http://isenseproject.org/projects/156*
Download iSENSE Data Walk app: *http://bit.ly/12tpJGn*
iSENSE website: *http://isenseproject.org*
Human ticker tape review worksheet and physics investigation #X human ticker tape worksheet: *www.nsta.org/highschool/connections.aspx*

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