

# STORM EVADER

## Using an iPad to Teach Kids about Meteorology and Technology

BY AMY MCGOVERN, ANDREA BALFOUR, MARISSA BEENE, AND DAVID HARRISON

Children learn how to interpret weather information through an engaging game where they simultaneously route multiple planes around severe weather using radar and model output.

**G**iven the national shortage of workers in science, technology, engineering, and mathematics (STEM) fields, it is important that we engage more children in STEM skills with the goal of having more STEM majors. This has been made a priority at multiple national levels (National Academy of Engineering 2004; Olson and Riordan 2012).

Although video games are often seen as simply a form of entertainment, they are increasingly used in education at all levels. Such “serious games” can engage children and teach them concepts, sometimes without them even realizing that the game is meant to be educational. The growing impact of games in education is seen by their frequent appearance in the popular press (e.g., Olsen 2009; Mackay 2013; Tack 2013). Other recent examples include Cateté et al.

(2014), who introduced games to middle school students to help engage them in learning STEM skills, and Martínez-Arocho et al. (2014), who introduced middle school students to “big data” through games.

The literature on gaming in education is just beginning to grow. McClarty et al. (2012) provide a comprehensive review of the literature with a focus on the need for studies on the long-term impact of games in the classroom. Current studies focus primarily on increased engagement of students using games but not necessarily on the transfer of the skills from the digital world to the real world or on the long-term retention of the skills.

We have developed and released an iPad game, called Storm Evader, that teaches children meteorological concepts in real-world situations. This paper describes the game and our studies of children playing Storm Evader. We conclude with a discussion of future games aimed at teaching meteorological concepts to children.

Although there are a few meteorological games, we are not aware of other studies about their efficacy. Our game is unique in its focus on teaching children meteorological concepts through a real-life application. Players learn how radar data affect flights in a way that provides them instant feedback, which is critical for learning (Fink 2003; Dickey 2005). By using a game, any failures are safe and players can immediately retry for better solutions in situations that the game presents.

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**STORM EVADER.** Storm Evader teaches players to safely route planes across the United States during severe weather events. Users must route planes from the originating airports to the destination airports while avoiding weather hazards and minimizing fuel usage.

The main data used for the game are historical national radar mosaics of the contiguous United States, downloaded from the archives at the National Center for Atmospheric Research. We created composite images of the 2D data every 15 min for a variety of severe weather days from the spring and summer of 2013. Users can route planes for the full 24-h day. Figure 1 shows an example of planes being routed for 31 May 2013. This day was an interesting one for routing because of significant storms in the Midwest.

The game gives a reward based on how many planes landed safely and their fuel level at arrival. The plane takes damage based on a linear function of the radar reflectivity values that it flies through. Flying through more intense precipitation (generally shown

as red in the radar images) causes more damage. If the plane flies through an area with tornadoes or severe hail, it has to make an emergency landing.

*Embedded uses of technology.* In addition to teaching children about radar images, we had a second goal to demonstrate that computational and artificial intelligence (AI) could be used effectively in a real-world situation. Our approach was to embed information already used by forecasters in the game for players to use in their routing. We also designed an intelligent routing system that they could activate and modify if needed.

The radar images represent the truth of what really happened on a given day. A traffic controller routing planes would not have access to the future data so we do not allow the users to scroll through upcoming radar images. However, they do have access to the forecasts, provided every 12 h by the National Climatic Data Center's National Operational Model Archive and Distribution System (NOMADS)



FIG. 1. Planes being routed for 31 May 2013.

division. Figure 2 shows an example of the forecast data available for 31 May. If users choose to examine this data, they can route their planes in the forecast screen or they can pause the game and scroll back and forth through the forecasts.

The daily outlook summaries provided by the Storm Prediction Center (SPC; [www.spc.noaa.gov](http://www.spc.noaa.gov)) are the second source of data provided to users. These summaries are provided as a single image for each day, as shown in Fig. 3. Although the summaries are not dynamic, they provide information about the general region of atmospheric instabilities that are likely to be problematic for planes to fly through.

The intelligent routing system uses A\* (Hart et al. 1968; Russell and Norvig 2009) to route the planes around the storms depicted in the current radar images. A\* is an optimal path-finding technique designed for discrete and static environments. To adapt it to the task of routing planes, we discretize the radar image over the continental United States (CONUS). Because of the processing limitations on

the iPad itself, the discretization is fairly coarse. A\* also assumes that the environment is static, which is not true of weather. One way to address this would be to give the algorithm access to the radar images for the future time periods, but we wanted the routing algorithm to be feasible in a real-world scenario, so we did not allow the AI access to future states. Another way to address this would be to give A\* access to the forecast data but this proved too computationally intense for the iPad processor. It may be feasible in the future. A\* is able to provide suggested routes to the users and the users can then modify those routes as needed. Figure 4 shows an example of the route suggested by the A\* algorithm.

*Career mode and free play.* There are two main approaches for playing the game. The first is career mode and the second is free play. Career mode gives the user a series of stories and tasks that grow more challenging over time. Users gradually learn what types of radar reflectivity images planes should not fly

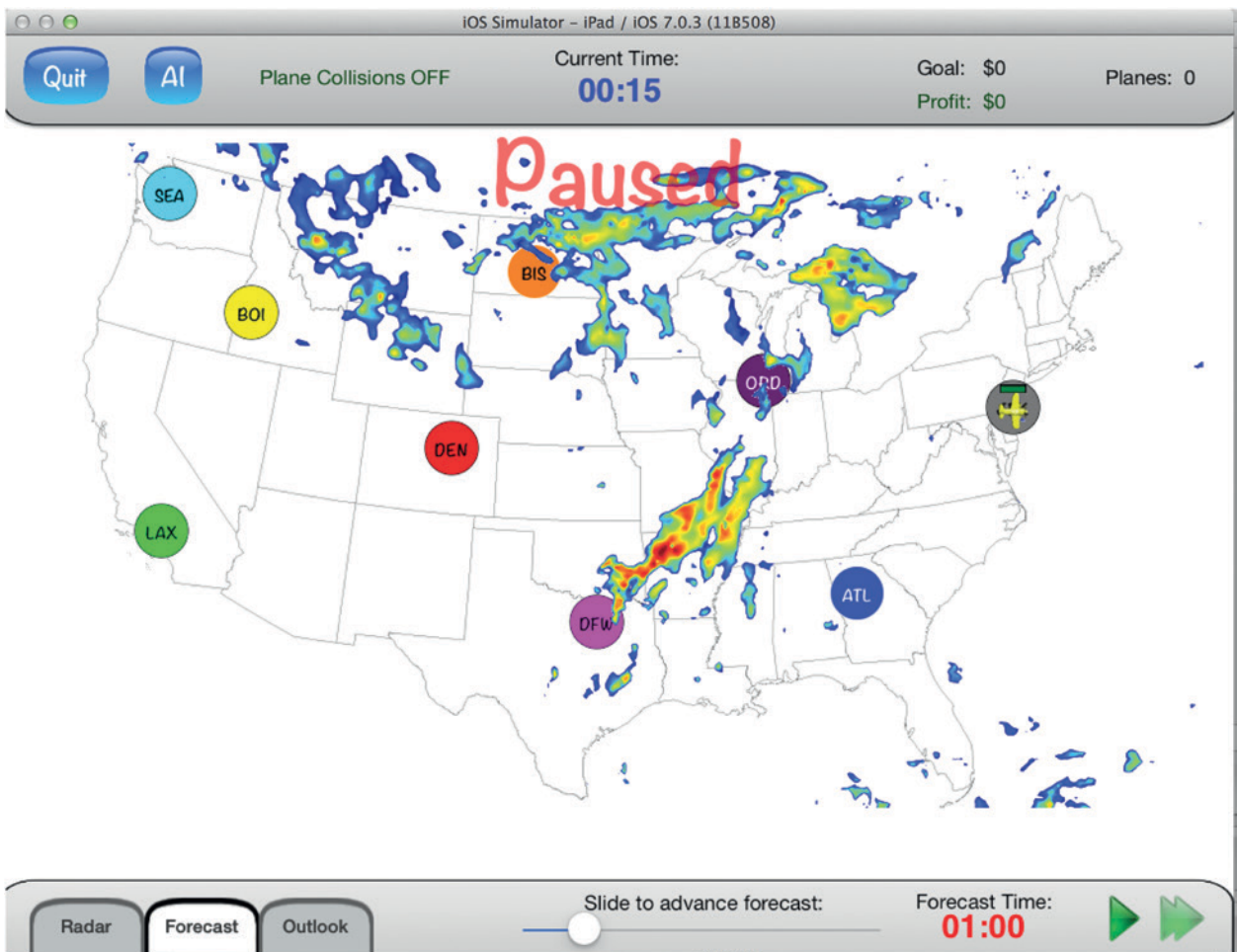


FIG. 2. Forecast data available for 31 May 2013.

through and how to fly efficiently around the storms. To progress to the next level, the user must earn a specified amount of money. For example, the first level of career mode tells the student the following:

Level 1: Welcome to your first day on the job! If you haven't already, we recommend you take a look at the tutorial located on the Main Menu. Let's get started, then! The weather may look calm now, but our meteorologists are predicting storms this afternoon. Be sure to watch out for bad weather when planning your routes! Start by looking at the latest forecast and route planes to the airport with the same color as the plane. You can then modify the routes once storms start forming. Remember no forecast is perfect so use your best judgment. Good luck!

Levels 5 and 6 train the user to use the SPC outlooks.

Level 5: We are on high alert today as it looks like there could be some very bad storms across parts of the country. To better focus on the storms, we are dividing the country into regions. You are in charge of planes flying in the central United States and will be covering Bismark (BIS), Chicago (ORD), Denver (DEN) and Dallas (DFW). The national Storm Prediction Center is forecasting very strong storms and possibly tornadoes across the Southern Plains this afternoon. Avoid these storms if at all possible! Planes that fly through the dark red region of a storm may be instantly lost. Avoid flying through the center of a storm.

Level 6: The strong storm system is continuing to cause havoc across the country. Since you did so well keeping our planes away from earlier storms, you've been assigned to continue routing planes that will be in storm paths. In addition to the central airports, you will also be working the

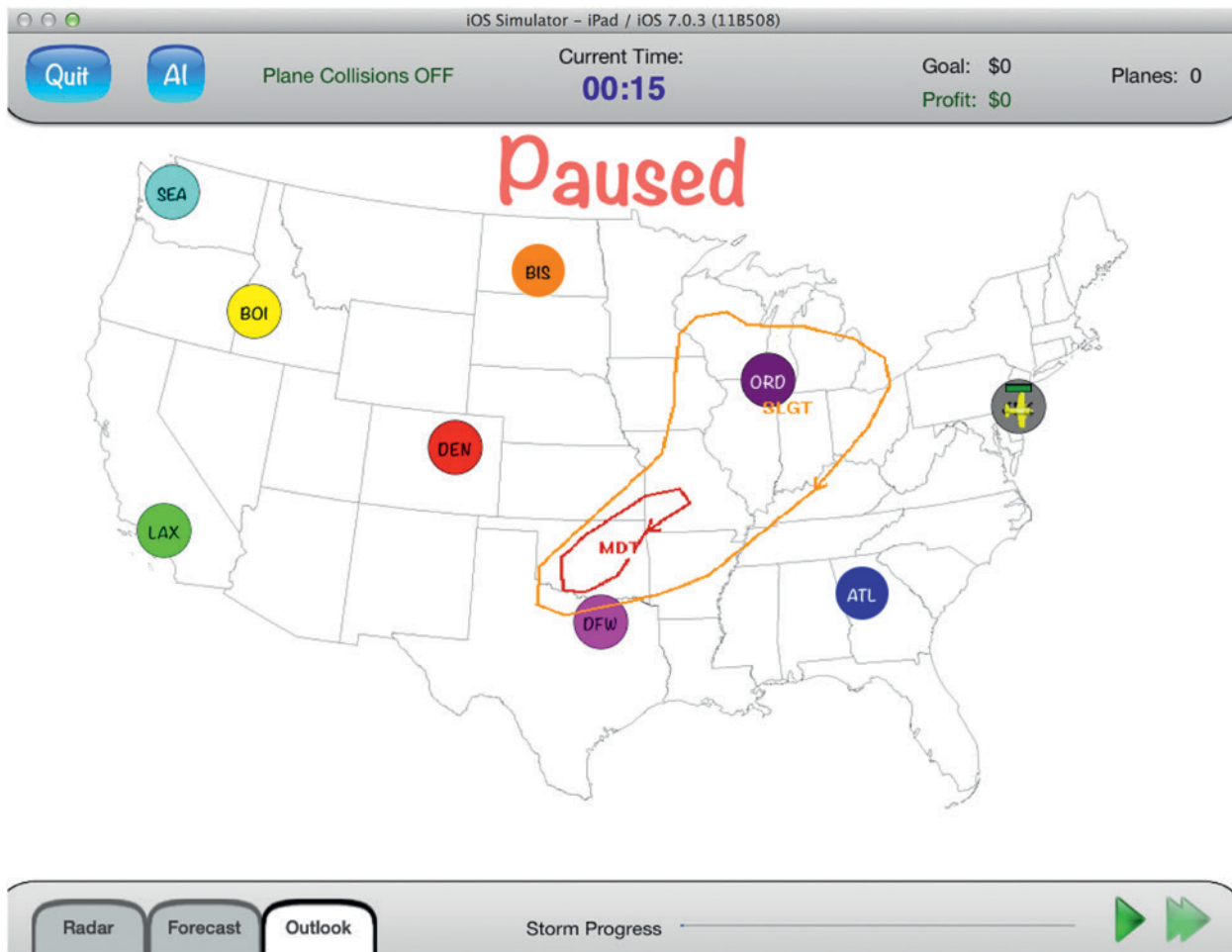


FIG. 3. Storm Prediction Center outlook for 31 May 2013.



eastern part of the country (New York, JFK and Atlanta, ATL). Good luck! Use the 'Outlook' tab to get a general idea of where the worst weather will be. There are three categories: SLGT (slight), MDT (moderate), and HIGH (high). Each increasing category indicates a greater risk for severe weather.

Near the end of career mode levels, the tasks become much more difficult. For example, level 17 focuses on a day where severe weather covered much of the Midwest, making routing across the country very tricky.

Level 17: A large and very dangerous line of storms has developed across the country this morning and is causing mayhem with air traffic. You've been assigned all long distance flights today. Try to find a way through the storm line if possible, but beware, these storms may strengthen without

warning. With large lines of storms, you must decide whether to fly all the way around the line or to look for a weakness to fly through. Each option has its risks and benefits.

Free play mode allows the user to choose any day from the list in which to play. There is also an endless mode where each day is looped back to back with the next day.

**EVALUATION.** We evaluated the game with small groups of children and then expanded our evaluations to several large public events. The smaller groups of children provided focused evaluations before we released the game. The children in the focus groups ranged from ages 4 to 13. They provided feedback on the gameplay and suggestions on the game itself. The children suggested many features such as allowing the user to customize the colors for each airport. Although this feature was originally envisioned to

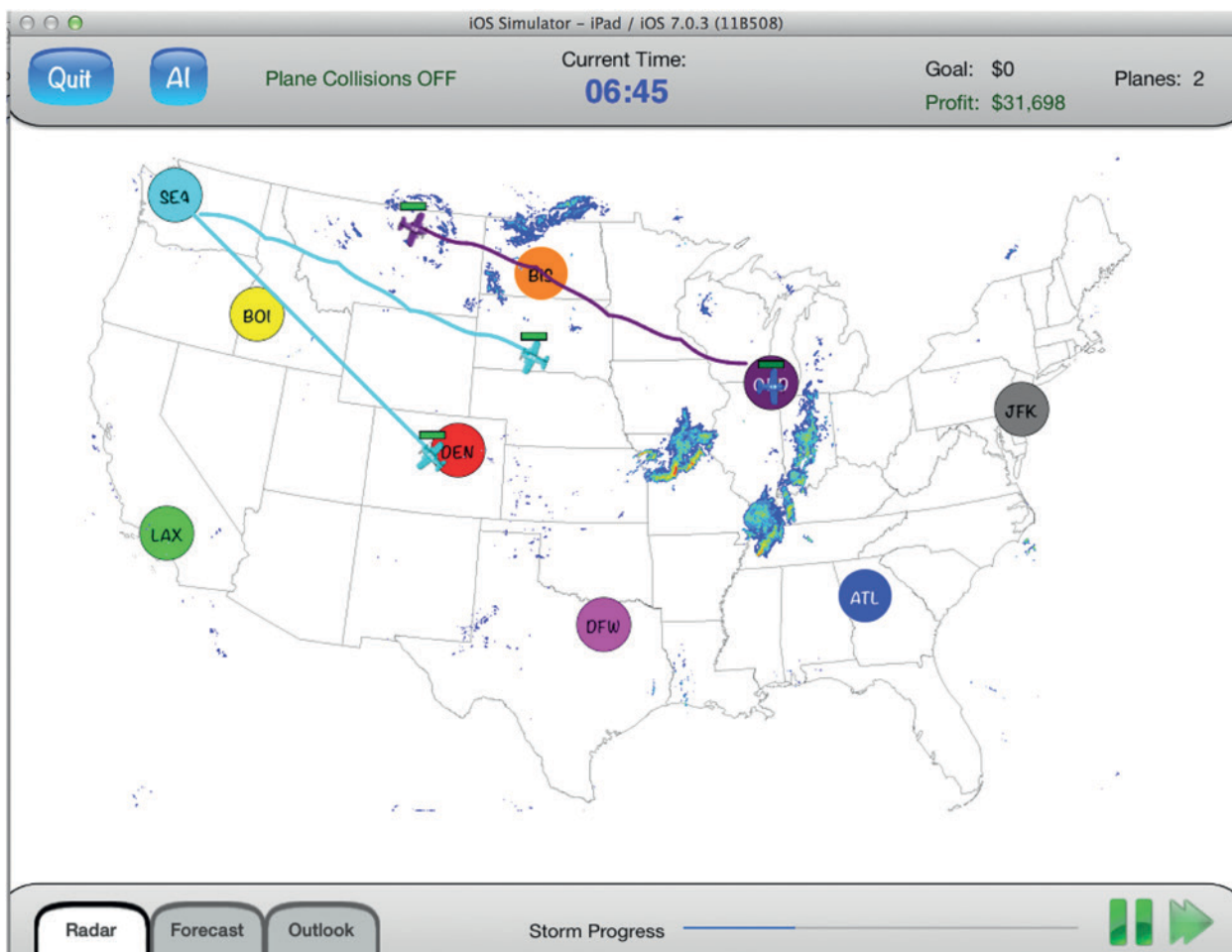


FIG. 4. Routes provided by the AI for 31 May 2013. The AI provides routes for the planes from their current location (which can be midflight) to the target airport.

accommodate color blind users, the children enjoyed the customizations and some even used it to make the game more challenging by making the airports all the same colors. The children also suggested the feature of allowing the user to choose the number of airports, although the older children wanted even more airports than we could reasonably accommodate on the screen. The younger children had trouble identifying the destination airports, which inspired us to create the feature of making the destination airport animate when the user touches the airplane.

We also demonstrated the game at several large public events. These events included the Geographic Information Systems (GIS) day and the National Weather Festival, which was held in November 2013 at the National Weather Center in Norman, Oklahoma. This annual event draws several thousand members of the general public to learn about weather. Storm Evader's demonstration was housed with other children's events. Many of the approximately 700 children who came by our area stopped by the table to play the game. We quickly learned not to allow the children at demos to play in endless mode because this mode does not have a natural end and the children will gladly play for a very long time. We often had to ask a child to stop playing so that another child could begin to play. Informally, the evaluations were all very positive with the children saying "this is cool" and "really fun."

We had University of Oklahoma Institution Review Board approval (3447) to survey some of the children about the game. In addition to asking them about their experience with iPad games and about the game itself, we asked them if they had learned what the different colors of the radar meant. In general, they agreed that they had learned this. We also asked them to imagine other applications of intelligent computers. Their answers were focused on weather applications.

**DISCUSSION AND FUTURE WORK.** We introduce a unique game, Storm Evader, that teaches children about radar reflectivity and applications of technology to routing airplanes. Although the game was developed for children, it has proven to be engaging to both children and adults. The game was developed using National Science Foundation funding and is available for free. The game is available at <https://itunes.apple.com/us/app/storm-evader/id778806405?mt=8>.

In future versions, we intend to incorporate aircraft turbulence into Storm Evader. This will take two forms. First, we will add a term about passenger

comfort to the score. Second, turbulence forecasts will be provided to the user from ongoing collaborations with the National Center for Atmospheric Research (Pinto et al. 2010; McGovern et al. 2011, 2014; Williams 2014).

We are currently developing a new game focused on tornado formation and safety. This game has two main goals: to teach the players how tornadoes form and to teach the players about public safety during severe weather. The players will learn how weather ingredients can be properly combined to make individual tornadoes as well as tornado outbreak days. When the severe weather ingredients for a season have been chosen, the players prepare a city for the severe weather. In this mode, they learn when to sound tornado sirens, how to provide easily accessible public shelters, and how to effectively manage emergency management funds. This version of the game also encourages the public to strengthen their homes for storm mitigation and make a designated safe room. As with Storm Evader, the players will learn to effectively read the radar in order to decide when to issue a tornado alert. When a tornado strikes, there is a tornado mini-game where players control a tornado's movement through regions of moist, warm, cool, and dry air. Depending on which regions the tornado passes through, it grows or shrinks. The players must also steer the tornado to avoid houses and emergency responders.

We are also planning a future game focusing on synoptic scale weather systems in the United States. In that game, players will learn how to create fronts, rain and snow storms, and tornado outbreak days. Players will learn about weather phenomena and how they differ across the United States. For example, players will learn that creating a rainy day in Chicago requires different weather ingredients than creating a rainy day in Phoenix.

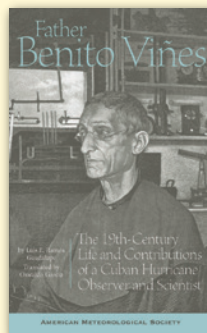
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