Darwin builds better cars
Lessons evolving online vehicles

NABT 2012
Anne Royer, Elizabeth Schultheis, Louise Mead
Evolution & Engineering

• Introduce a program that incorporates evolutionary and engineering principles to build cars best adapted to their track

• Designing vehicles is a great hook to get students thinking about adaptation and evolution
You as an engineer:
Create a car that is best adapted to its environment
(a car’s “fitness” is dependent on how far it can travel in the environment)
Evolution & Engineering

• Introduce a program that incorporates evolutionary and engineering principles to build cars best adapted to their track
• Designing vehicles is a great hook to get students thinking about adaptation and evolution
• Start with Lego cars to get them engaged
• Move into working with online program Testing convergent evolution and adaptation
• Extend the lesson to combine natural selection with design
You as an engineer:
build the best Lego car you can

YOU CAN USE:
• Up to four wheels (0-4)
• One platform (gray piece)
• Up to four additional parts (0-4) (any other color)

Trial runs: the goal is to get your car to go as far as possible
– write name and best time on the board

After everyone has their starter pieces, you can pick up
more pieces (or remove them!) to engineer a faster car
Integrating evolution and engineering:
Using biological concepts to solve problems

Leonardo da Vinci
Evolution as a process:
How can we use principles from evolution to improve our Lego cars?

- Variation
- Inheritance
- Selection
- Time
Evolution as a process:
How can we use principles from evolution to improve our Lego cars?

• **Variation**: the fuel for natural selection
Evolution as a process:
How can we use principles from evolution to improve our Lego cars?

• **Selection:** acts on variation in a non-random way, leaving behind individuals with beneficial traits
Evolution as a process:
How can we use principles from evolution to improve our Lego cars?

• **Inheritance**: individuals with beneficial traits will survive better and pass on more genes to future generations
Evolution as a process:
How can we use principles from evolution to improve our Lego cars?

• **Time:** over many generations, the beneficial adaptations will spread through the population
Evolution and Engineering: BoxCar2D

• Computer program for vehicle evolution developed by Ryan Weber
• Virtual environment including the effects of gravity, friction, collisions, motor torque, and spring tension
• Each car represents an individual in a population
• Each generation the cars move along a track, with distance traveled considered their “fitness”
• To produce the next generation, cars mate - their traits recombine, and some mutation adds additional variation to produce offspring
Open web browser and go to:

www.BoxCar2D.com
BoxCar 2D

Computation Intelligence Car Evolution Using Box2D Physics (v3.2)

Time: 3:58  Score: 1.4  Torque: 317
Keep this round of evolution running in the background

Don’t close the window or open new tabs – only open new windows!!
Observing evolution in BoxCar2D
Evolution & Engineering:
How does BoxCar2D use principles from evolution to develop better performing cars?

• Variation
• Inheritance
• Selection
• Time
Evolution as a process:
variation

Each car is represented by one chromosome, with 40 variables on each chromosome.

All of the car’s traits are coded on the chromosome: how many wheels, angles, length, speed...
Evolution as a process: variation

- Where does the variation come from?
- Initial variation from randomly-generated cars
- Chromosomes undergo mutation at a user-set rate each generation; mutated traits are marked by a color change
Evolution as a process: variation

Each population contains 20 unique individuals
Evolution as a process: selection

At the end of each generation, cars are paired up to “reproduce”

Cars that move the furthest get “mated” most often, so they contribute most to the next generation
A lot like meiosis...

Parent chromosomes “cross over” twice to produce offspring that are a mixture of traits
Evolution as a process:

time

over many generations, adaptations will spread through the population; traits that work less well will dwindle.
Evolution as a process: time

• Keep the program running for many generations, and watch the cars evolve over time!
Evolution as a process:

• Variation
• Inheritance
• Selection
• Time (generations)
• Design??
BoxCar allows you to add design into your vehicles along the way

- How does this differ from evolution by natural selection?
- What are potential issues to address when using BoxCar to reinforce principles of evolution in your classroom?
COPYING A CAR OUT OF THE POPULATION:
- Click on the row in the table representing the car you want
- Click “copy selected”
- Paste into a new population on a new track, or back into the designer
Evolution with hand-engineering in BoxCar2D
(excerpted from boxcar2d.com/about.html)
Evolution with hand-engineering in BoxCar2D
(excerpted from boxcar2d.com/about.html)
INSTRUCTIONS WILL STAY ON THE SCREEN- DON’T COPY THEM DOWN!

• Importing your designed car into the program:
  – In the Derp Bike Designer, click “copy to clipboard”
  – Go to the main page, click “input seed/choose terrain” – keep on the same track
  – Click in the box that pops up and hit control-V to paste your car’s code
  – Click “input seed car” to start running

• Your car will show up first; the next ones in the population will be mixtures of your design and random cars
BoxCar2D Design Worksheet: beginning

Name ___________________ Date ______

Track__________

Draw your design

Score and time of hand-designed car:

Observe the population - record interesting points (not everything!)

<table>
<thead>
<tr>
<th>Generation</th>
<th>Car #</th>
<th>Score</th>
<th>Time</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• Share some of the cars that are evolving
• Do different populations on the same track look similar? Would we expect them to?
• What traits (features of your successful cars) do you think might be adaptations to your track?
Convergence

• Independent evolution of a similar solution to the same kind of natural selection (looks the same, but took a different path to get there)
• Engineering: different ways to solve the same problem
• Brainstorm – examples? (Engineering or biology)
Extensions

• Testing predictions about manipulating population size and/or mutation rate
• Tree thinking: building evolutionary trees, saving code or images of cars at nodes as “fossils”
• Invasiveness: in reciprocal transplants, do cars evolved on track “A” ever do better on track “B” than cars evolved on track “B”?
• Full-circle inquiry exercises
  – Students come up with their own questions
  – Emphasizing replication
  – Statistical testing – t-test or ANOVA using fitness
Cool cars!

- eNqzfxySMo1Vbqf9z +ZNZoJaFvYrZ4LALAe2A6tOmD2ot3+mphD6/7a1/Rt5N+dpTU/s72gu3Xo/Pt/+n6zx9Q0xn +DqORjAwP4aU/eM5xGP7H+sXDij4rCX/Ytsq8cv59213wlRh64eCFgdGDnUSTmUJtnf4YlqyTvTAjbnhsL8aKVdy+wPe1uGeEv/AAox2v92+Hcgu83F/qb9lSLVMj6gGIgDz9OcMrNVTvaPQ0IsZpf+/g8E9g++PdaMDu2w/wGxACz2MyJ6gm9HH8wdQGFm+28XHp36n8MEUwcWu/bXMTxRewZc3el//xiQAYh/+t9phtMzGBiAFAQDxfi5rRj+VTcyJM7jZtipKcHwhNuO4XKuClAHEwAUb5JX
Acknowledgements

Ryan Weber
Tom Getty
Mike Wiser
Bjorn Ostman
BEACON HS Institute students

QUESTIONS, FEEDBACK?