A Heat Conduction iPhone and iPad App for Engineering Education

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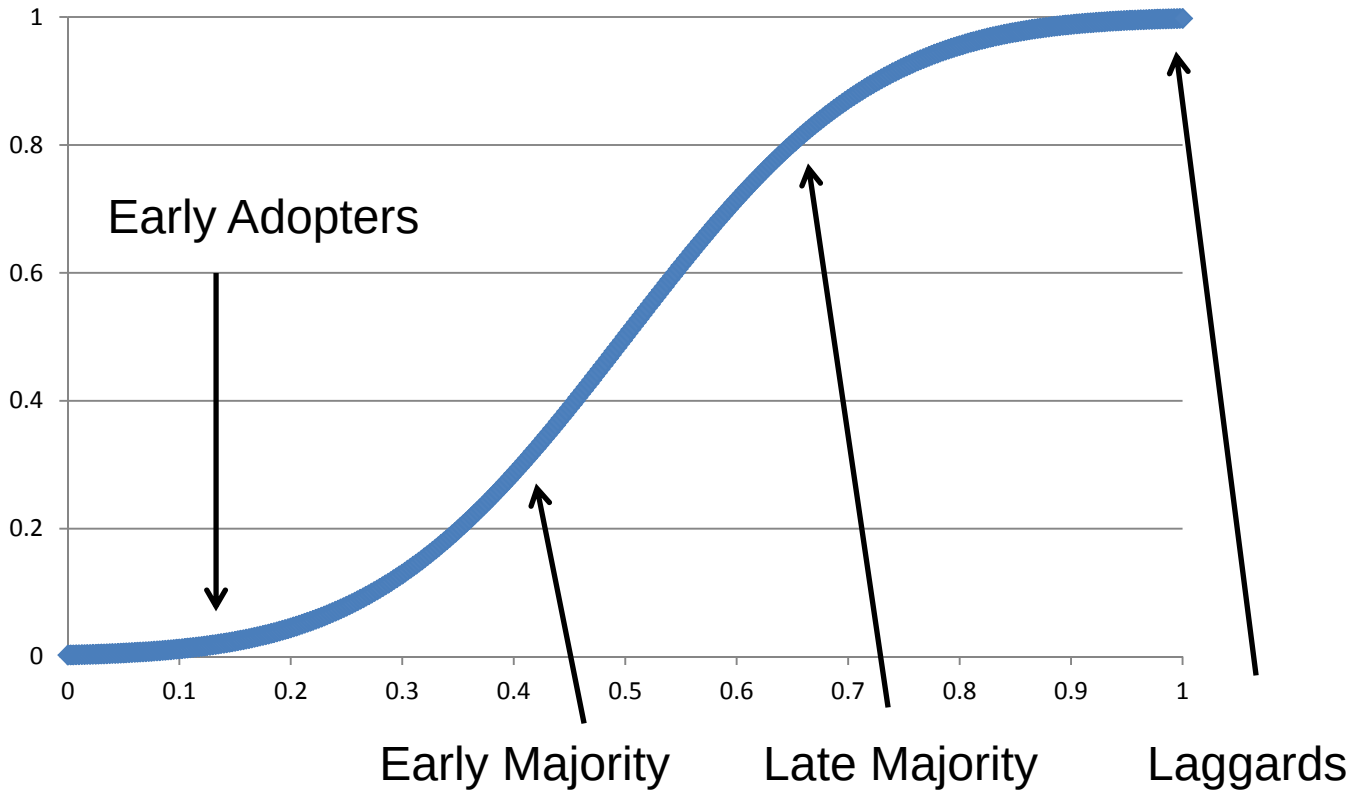
Background

- Students learn best by doing
- More and more important to use active learning as student learning styles have shifted over the past generations
- Today's students are visual learners
- Students are always on their phones
- Education apps can have positive learning benefits

Introduction

- Use of consumer products follows the diffusion of innovation



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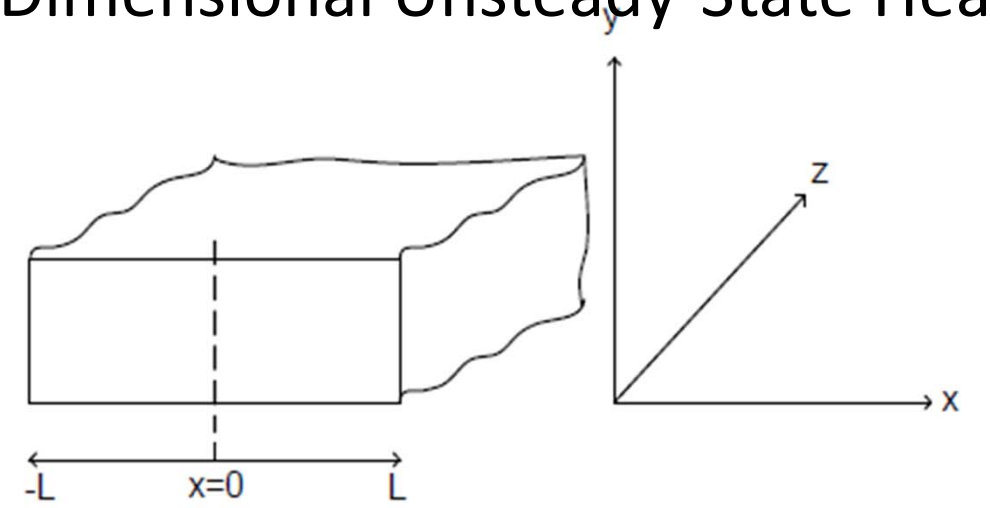
Diffusion of Innovation Concepts

- Recycling
- Portable CD players
- Sustainability
- Smart Phones
  - Opportunity to develop apps to improve student understanding / learning

Mathematical Background

- Fundamentals
  - Heat Conduction $$q_c = -k\frac{\partial T}{\partial x}$$
  - Convection $$q_h = h(T - T_f)$$
  - One Dimensional Unsteady-State Heat Conduction



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Mathematical Background

- Governing Equation $$\rho C_p \frac{\partial T}{\partial t} = k \frac{\partial^2 T}{\partial x^2}$$

  - **Boundary Conditions**: No flux at x = 0 $$\frac{\partial T}{\partial x} = 0$$

  - Conduction = Convection at x = L $$-k \frac{\partial T}{\partial x} = h(T - T_f)$$

  - **Initial Condition**: at t = 0, T = T_0

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Solution

- Infinite series

$$T = T_f + (T_0 - T_f)\sum_{n=1}^{\infty} A_n \cos\left(\frac{\lambda_n x}{L}\right)\exp\left(-\frac{\lambda_n^2 kt}{\rho C_p L^2}\right)$$

  - Recursion relation for λ, with *Bi = hL/k*

$$\lambda_n \tan\lambda_n = Bi$$

  - A_n depends on initial condition, such that:

$$A_n = \frac{\frac{\sin\lambda_n}{\lambda_n}}{\frac{1}{2} + \frac{\sin 2\lambda_n}{4\lambda_n}}$$

App Development - CS

- "*Heat Transfer for Students*" – **Free download!**
- Target platform iOS and Apple devices
- MacBook Pro for all algorithm development and testing as well as user interface design and optimization
- iPhone 4S running iOS 5.1 as a test bed
- Software coded in XCode 4.2 (Free)
- Development in Objective C
- 120 lines of code

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App Development - CHE

- Core Plot (Free) graphing library to develop plots of temperature vs. position at different times
- Plot displays 201 points
  - Invoke symmetry about x-axis
- Value of λ is needed for program
  - Computations are very fast on the iPhone!
  - Transcendental equation solved for first 50 roots
- Animation at 10 frames / second

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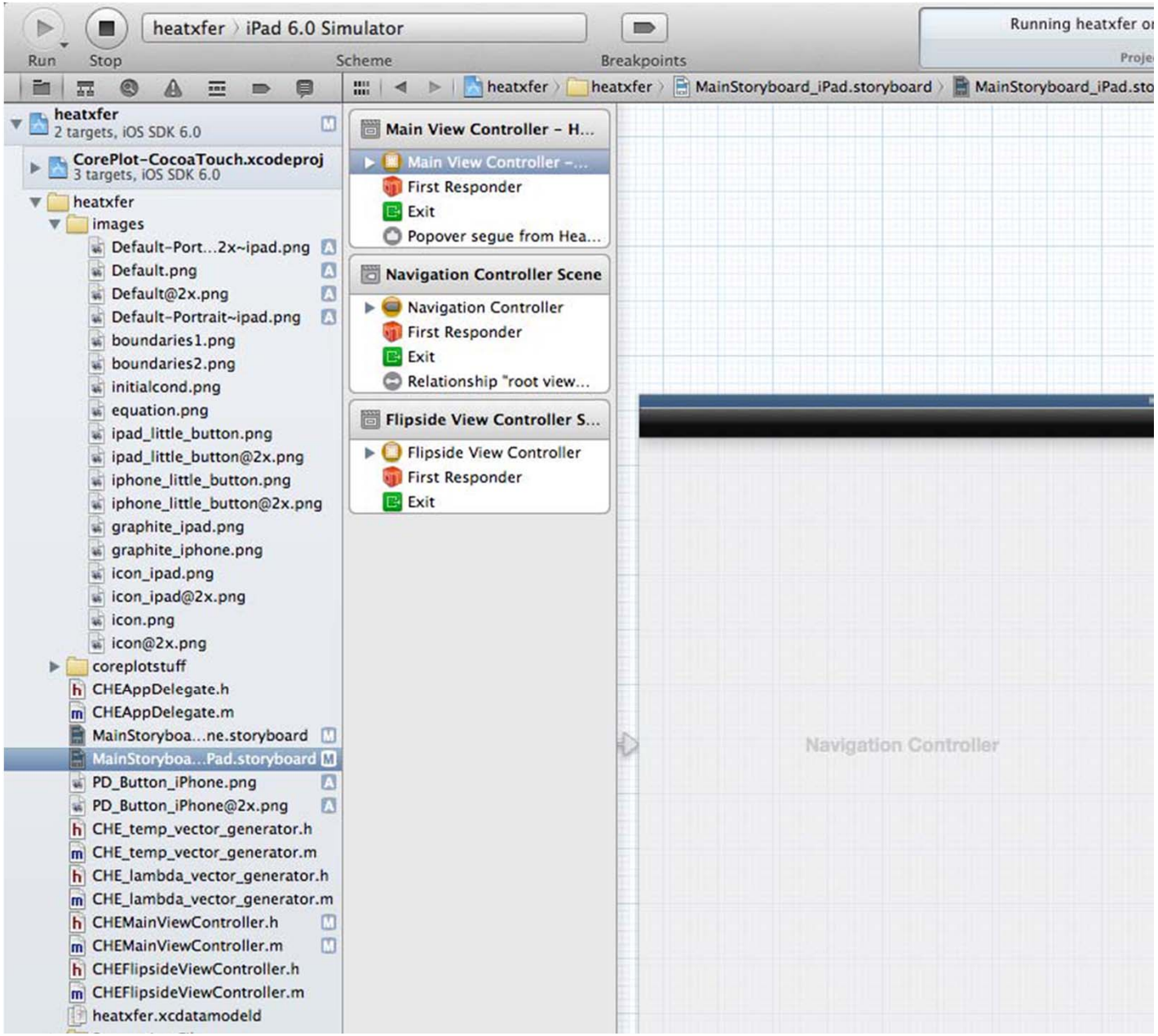
App Development - Images



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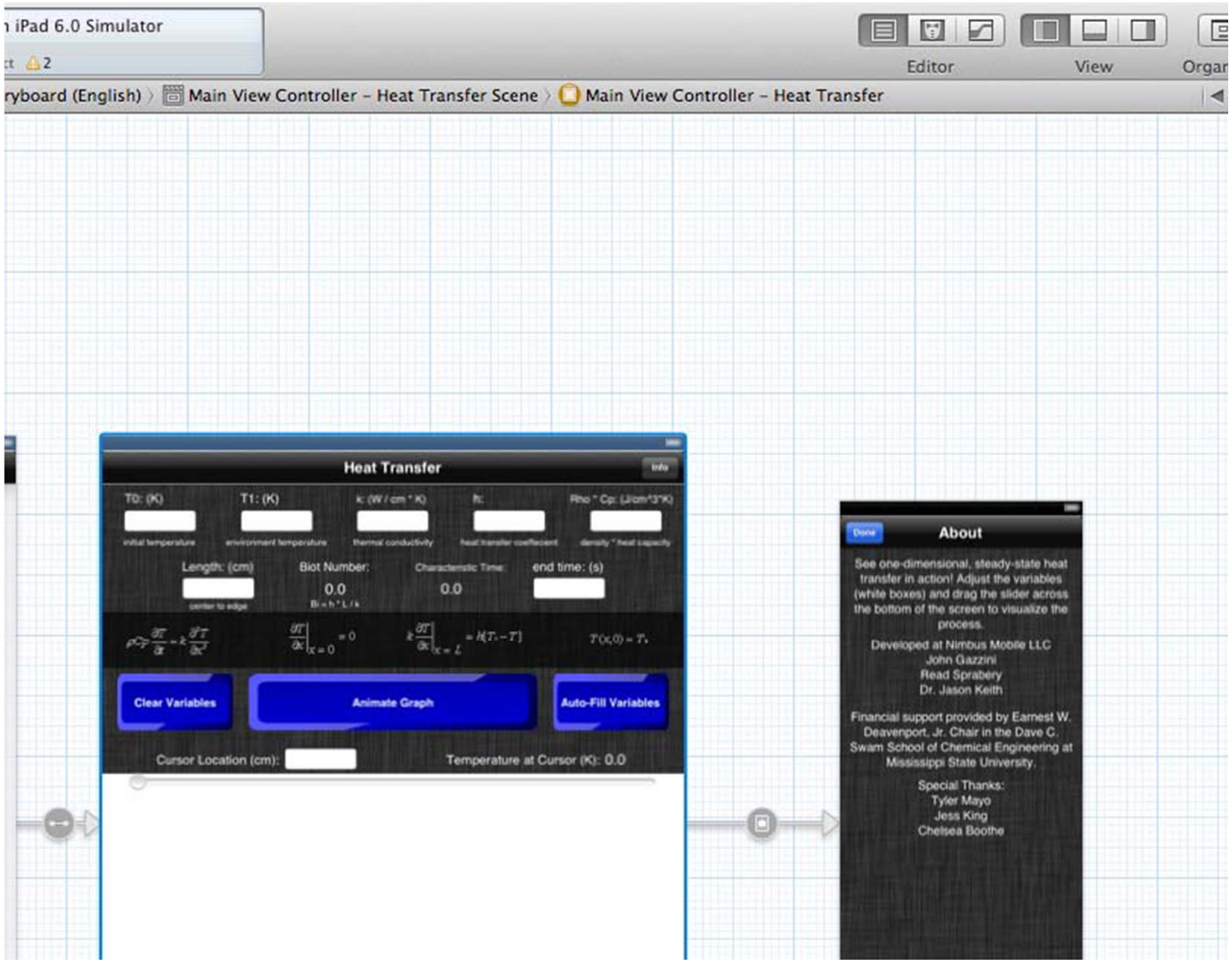
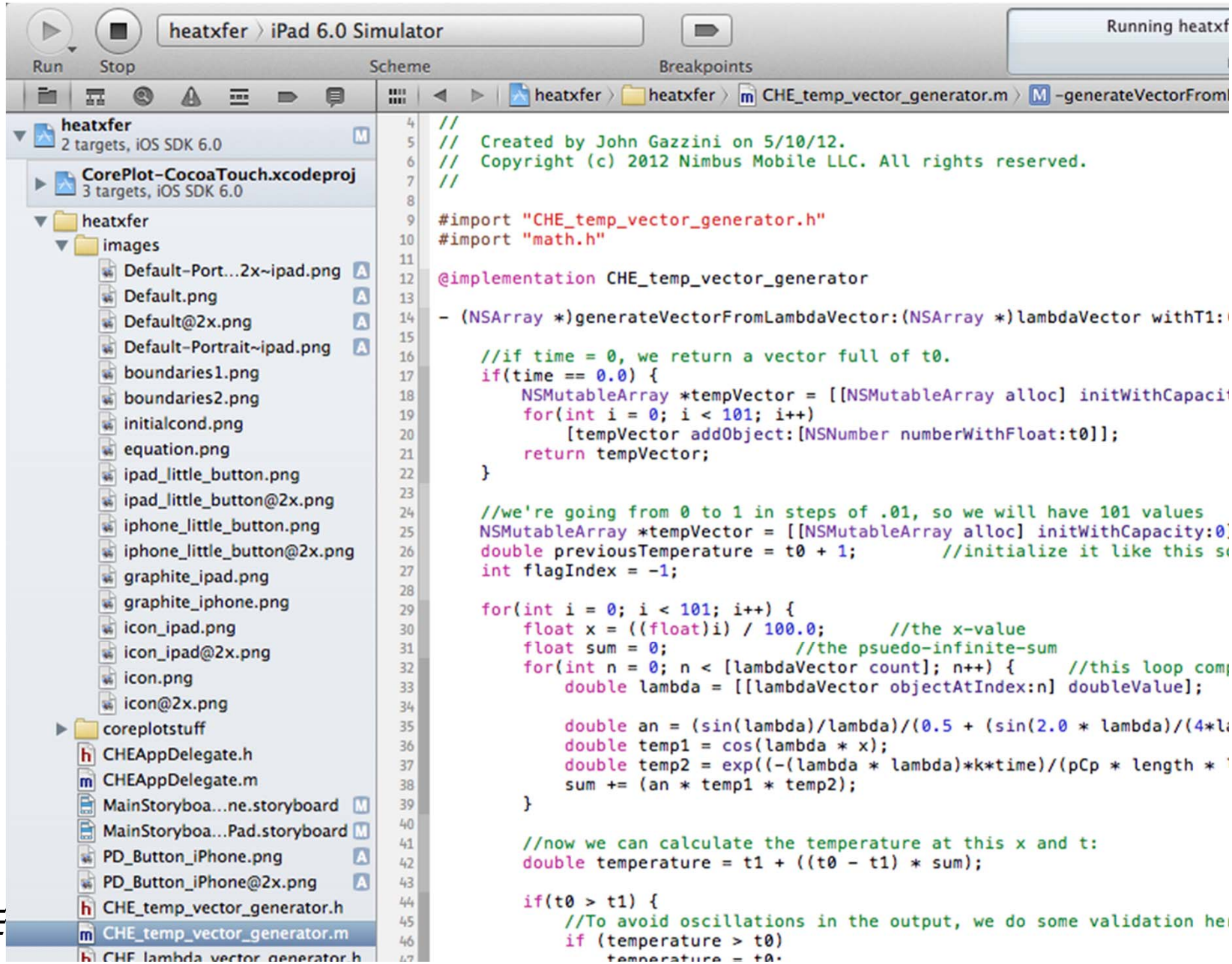
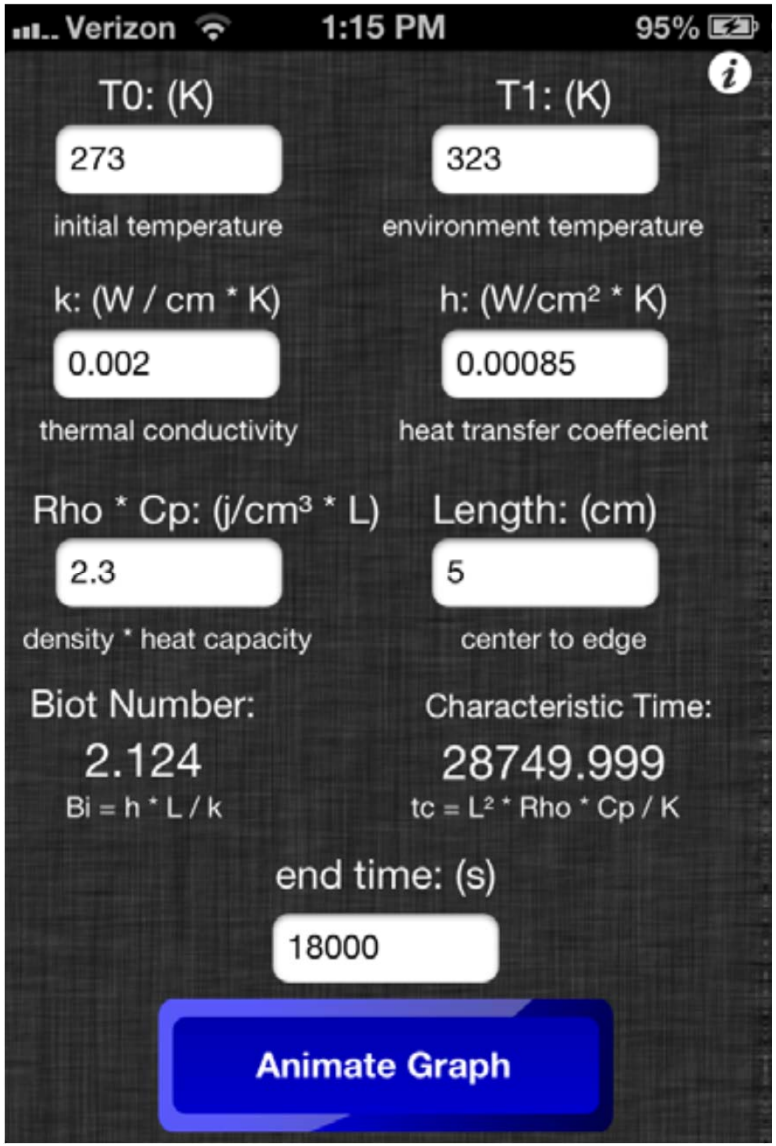
App Development - Images

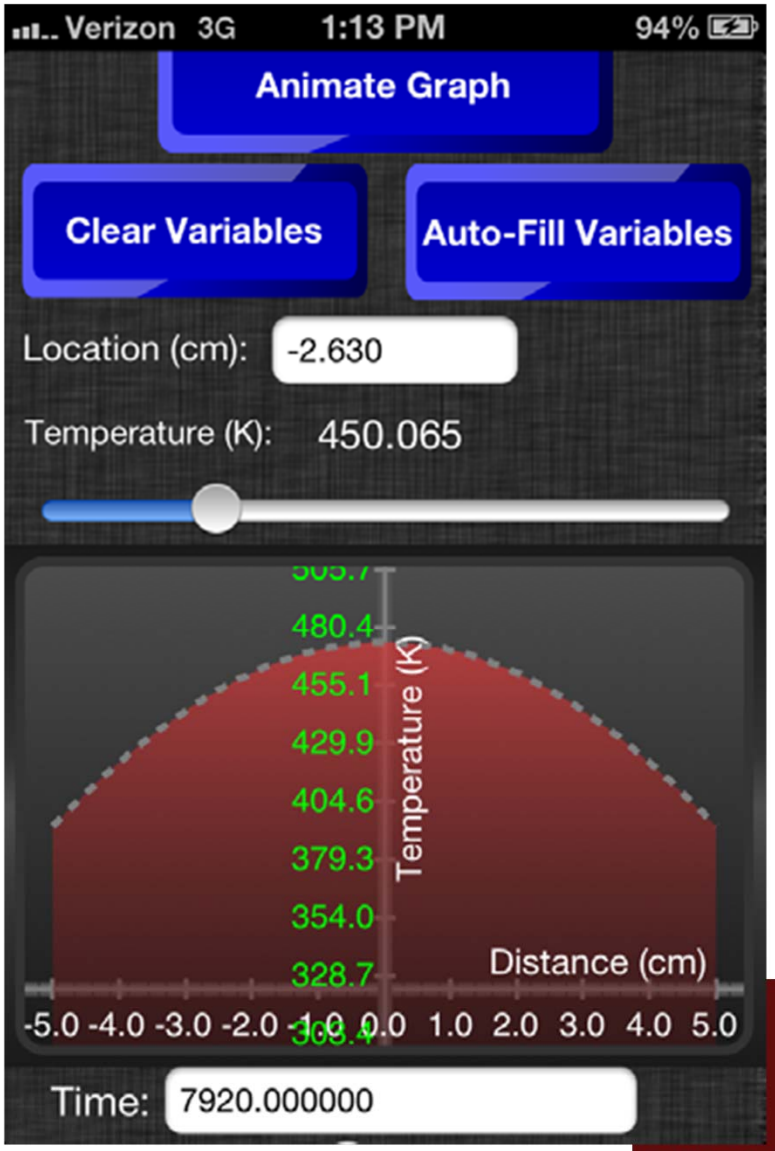


App Development - Code



App Development – iPhone Screenshots





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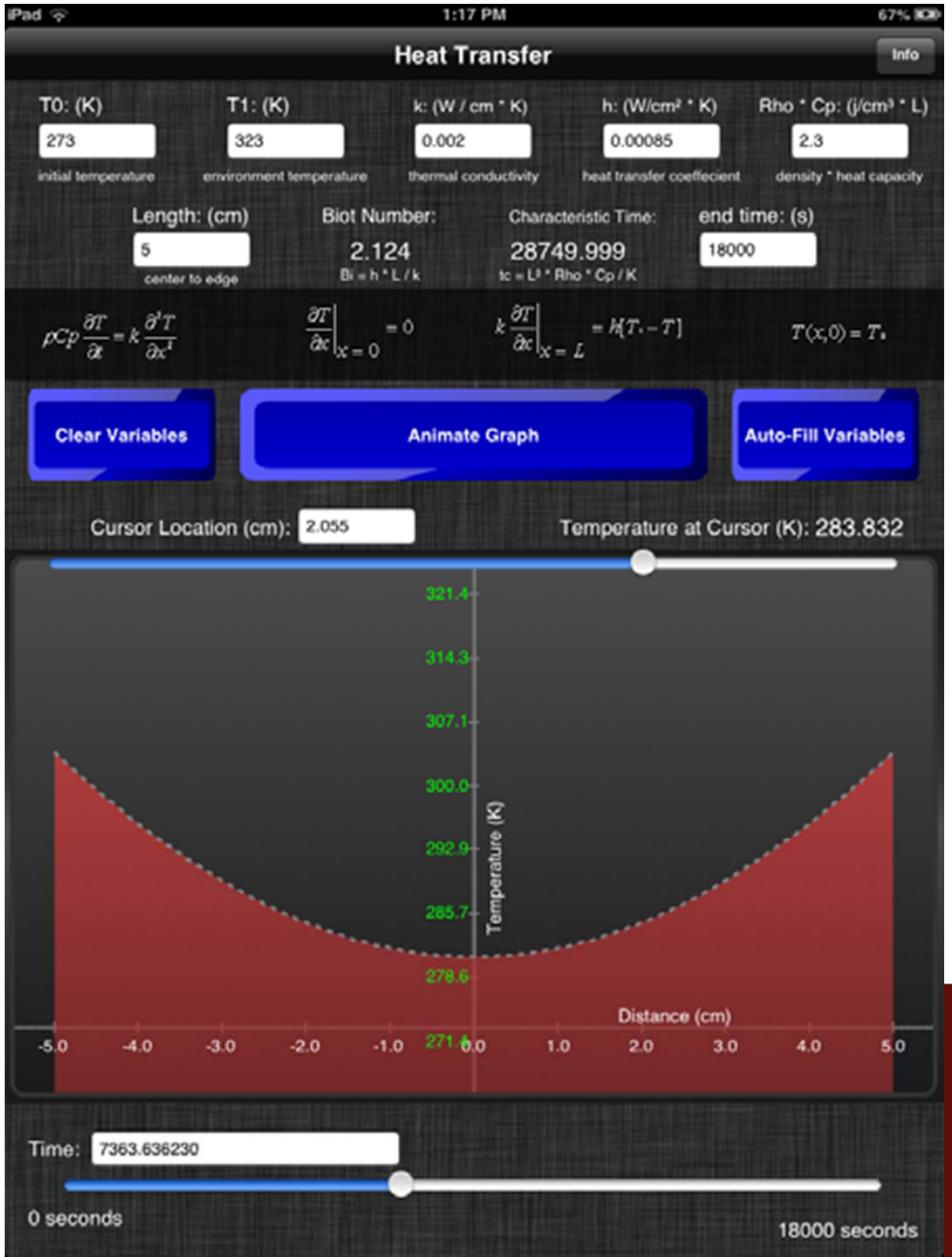
App Development – iPad Screenshots



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Implementation

- Reproduce example 5.3-2 of Geankoplis
  - Heat transfer in a slab of butter
  - Initial temperature, T_0 = 277.6 K
  - Fluid temperature, T_f = 297.1 K
  - Convection coefficient, h = 8.5 W/m^2K
  - Thermal conductivity, k = 0.2 W/mK
  - ρC_p = 2300 kJ/m^3K
  - Half thickness, L = 4.6 mm

Implementation

- Reproduce example 5.3-2 of Geankoplis
  - Results
  - Biot number = 1.95
  - Heat conduction time t_c = 23000 s
  - Simulation time t = 5 hours
  - Temperature results match very well
  - App appeals to a wide range of learning styles
  - Inspires students to "learn the math"

Total Downloads

- **Total Downloads: 2651**
- USA: 1165
- UK: 146
- Canada: 101
- Thailand: 135
- India: 63
- Mexico: 67
- Turkey: 69
- Saudi Arabia: 60
- Italy: 51
- Brazil: 54
- "Others": 740

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Summary

- This work has demonstrated an iPhone / iPad app called “Heat Transfer for Students”
  - Available for free from the app store
- Anecdotal evidence suggests that students have improved visualization of unsteady-state heat transfer by using this app
- Acknowledgments
  - James Worth Bagley College of Engineering
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  - Nimbus Mobile

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