Feeling is Believing: Teaching System Dynamics through Haptic Rendering
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Objective
Providing a cheap, engaging, and personalized laboratory learning experience is one of several challenges facing effective undergraduate education in STEM disciplines and has been identified as one of 14 Grand Challenges for Engineering in the 21st century by the National Academy of Engineering [1,2].

Overall Objective: Determining the impact that directed hands-on activity with haptic technology will have on engineering education is the ultimate goal of this study. Specifically, we are interested in discovering innovative ways to improve the modeling and design intuition of engineering students in a way that helps them relate theoretical systems seen in the classroom to physical systems found in everyday life, such as a raquet and ball.

Hypothesis: We believe that integrating haptic rendering into the traditional engineering curriculum will provide a learning experience that will help students relate mathematical modeling concepts to real life experience.

We will test this hypothesis using a novel apparatus that provides haptic information to the user to enhance their learning experience and engage their intuition.

The “Cigar Box”
The primary apparatus which enables the present experiment packages various electrical and mechanical components within a 6”x9” cigar box from which the device derives its name. Because we use a variety of cigar boxes (acquired from a local smoke shop) every kit is unique and appealing.

![Image of cigar box apparatus](image)

Components:
- Arduino® Uno microprocessor
- Motorized linear faders
  - Motorized linear potentiometers
- Switches
- Motor amplifiers
- Rotary potentiometers
- Battery-powered or standard outlet connection

Figure 1. Annotated views of the cigar box apparatus (open and closed).

Figure 2. Cigar boxes come in a variety of shapes and sizes.

Figure 3. Schematic diagram showing the link we are trying to establish between physical phenomena (interactions between a raquet and a ball, for instance) and mathematical equations using the box as an intermediary agent.

The cigar boxes can be programmed and used in a variety of activities ranging from haptic rendering course projects to musical instruments and more!

Figure 4. Cigar box assignments (top to bottom): haptic padsale, spring-mass-damper, frequency response.

Quantitative assessments (ten minute written quizzes) were administered to students following interventions using take-home assignments that integrated the cigar box (cigar box assignments). Qualitative feedback (in the form of a written survey) was collected at the study’s conclusion.

Methods

General Procedure:
- Class is divided into two groups (Groups A and B)
- With students in each category forming 3-4 person subgroups
- Assessment I is delivered to the class
- Intervention 1: Group A is given the cigar box assignment while Group B is given the complementary written assignment
- Assessment II is delivered to the class
- Intervention 2: Group A is given the written assignment while Group B is given the cigar box assignment
- Assessment III is delivered to the class
- Survey administered

Student Feedback
“I don’t think the ME dept. gave us enough exposure to physical systems so we can work on more real-world (not necessarily ideal) situations. I liked seeing the theory applied to a real thing instead of a vague set of variables.”

“Definitely incorporate the cigar box into the class, I found it very useful. If not lab classes, at least discussion after class covering what the code does and why unit conversion are needed.”

“I believe near the end of the semester I learned a great deal b/c I was forced to implement 461 ideas into the code.”

“I think most ME’s in this school have almost no diagnostic skill, this starts to build that experience.”

“Cigar box helped me learn frequency response easily.”

“It helped me to be able to understand the concept of feedback controls and haptic control.”

“I think the in class discussions pre & post cigar box were the best learning portion. It helped me visualize Bode plots.”

“I enjoyed working on the cigar box, it was a good supplement to the HW’s, & lectures. It could be taught in a separate cigar box lab section to supplement what we do in class.”

Figure 5. Mean test scores for quantitative assessment (quizzes) 1 and 2. Error bars +/- 1 standard deviation.

Figure 6. Screenshot of survey provided to students at conclusion of the study.

- Responses to Q4 and Q10 above neutral
  - Students thought it was relevant to the course material
- Big jump in mean responses between Q3 (mastery of frequency response before using the Box) and Q4 (mastery after using the Box)

Figure 7. Mean response score to Likert scale survey questions. Error bars +/- 1 standard deviation.

Conclusions
- More sensitive measures are needed to quantify impact
- Qualitative feedback indicates students largely appreciate hands-on activity
- Further refinement of methods and procedure is needed

Future Work
- Develop new assessments that are more sensitive to impact of cigar box
  - Incorporate physical object exploration with pencil-and-paper quizzes. Have students identify properties.
  - Continuous improvement of next generation cigar box models
    - Development of “frictionless” model
    - Incorporate flat voice coil motors
    - Improve weighting harness

Figure 8. Hybrid graphicCompare to students of conclusion of the study.

References