Best Practices for Teaching Haptics

This pdf file consists of five sections:

1. Introduction to the tutorial (pages 2-7)
2. Haptics curriculum design (pages 8-25)
3. Introducing haptics to students* (pages 26-32)
4. Haptics education resources (pages 33-38)
5. Small group discussion results (pages 39-45)

*not presented at the tutorial

Best Practices for Teaching Haptics

Allison Okamura, Stanford University
Sonny Chan, Stanford University
Karon MacLean, University of British Columbia
Blake Hannaford, University of Washington
William Provancher, University of Utah

2012 Haptics Symposium Tutorial

Slides are available at:

http://2012.hapticssymposium.org/workshops-and-tutorials-materials

The presenters' best practices have been informed by haptics education collaborations with:

Jake Abbott	University of Utah
Federico Barbagli	Stanford University
J. Edward Colgate	Northwestern University
Francois Conti	Stanford University
Mark Cutkosky	Stanford University
John Hollerbach	University of Utah
Lynette Jones	Massachusetts Institute of Technology
Katherine Kuchenbecker	University of Pennsylvania
Camille Moussette	Umea Institute of Design
Marcia O'Malley	Rice University
Jacob Rosen	University of California at Santa Cruz
J. Kenneth Salisbury	Stanford University
Ganesh Sankaranarayanan	Rensselaer Polytechnic Institute

... and our students and teaching assistants

Objectives of this tutorial

By the end of the morning, we hope participants will:

- Understand the current landscape of haptics teaching worldwide
- Identify the range of technical content that could be included in a haptics course
- Have learned about strategies for conducting haptics course laboratories and projects
- Have access to useful haptics teaching resources (books, published tutorials, software, hardware, etc.)
- Participate actively in a small group activity to define and communicate their own best practices for teaching haptics

Audience

Are you interested in:

- Developing a course on haptics at your own institution
- Improving an existing haptics course
- Exchanging haptics teaching strategies with other instructors
- Writing tutorials or textbooks on haptics
- Developing software and hardware platforms for haptics education
- Identifying which core concepts a haptics researcher/ practitioner should know

Schedule

8:30-9:00	Allison	Haptics curriculum design
9:00-9:30	Sonny	Teaching haptic rendering
9:30-10:00	Karon	Teaching interaction design
10:00-10:30	Small group activity: Challenges and best practices in teaching hands-on haptics courses	
10:30-10:45	Break	
10:45-11:15	Blake	Devices for teaching haptics
11:15-11:45	Will	Teaching haptics through course projects
11:45-12:00	Panel Q&A and Discussion	

Haptics Curriculum Design

Allison Okamura

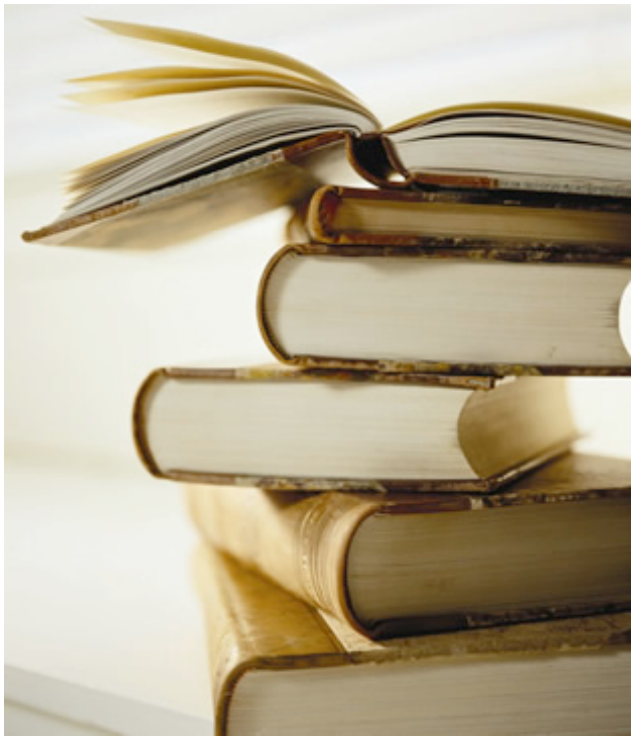
STANFORD UNIVERSITY

JOHNS HOPKINS UNIVERSITY

Student Populations

Disciplinary Background

Mechanical Engineering
Electrical Engineering
Computer Engineering
Bioengineering
Computer Science
Neuroscience
Psychology
Art
... and more



Student Populations

Level of Education

K-12 students

K-12 teachers

Lower-level undergraduate students

Upper-level undergraduate students

Masters-level graduate students

Ph.D.-level graduate students

Researchers/Faculty members

Non-academics

Potential Topics

- Human haptics and psychophysics
- Performance evaluation
- Device design and building
- Control systems
- Virtual environments
- Teleoperation
- Interaction design
- Application domains
- Haptics research

There are some choices to be made!

For example...

Human Haptics vs. Technology vs. Interaction Design

For engineers, an introduction to human haptics is necessary to motivate system design and evaluation

For scientists, haptic interfaces are transformational instruments

Interaction design informs useful and compelling haptic experiences

Kinesthetic vs. Cutaneous

Most commercially available haptic devices are kinesthetic (force-feedback) devices

There exist a large number of resources for developing control systems and virtual environments for kinesthetic devices

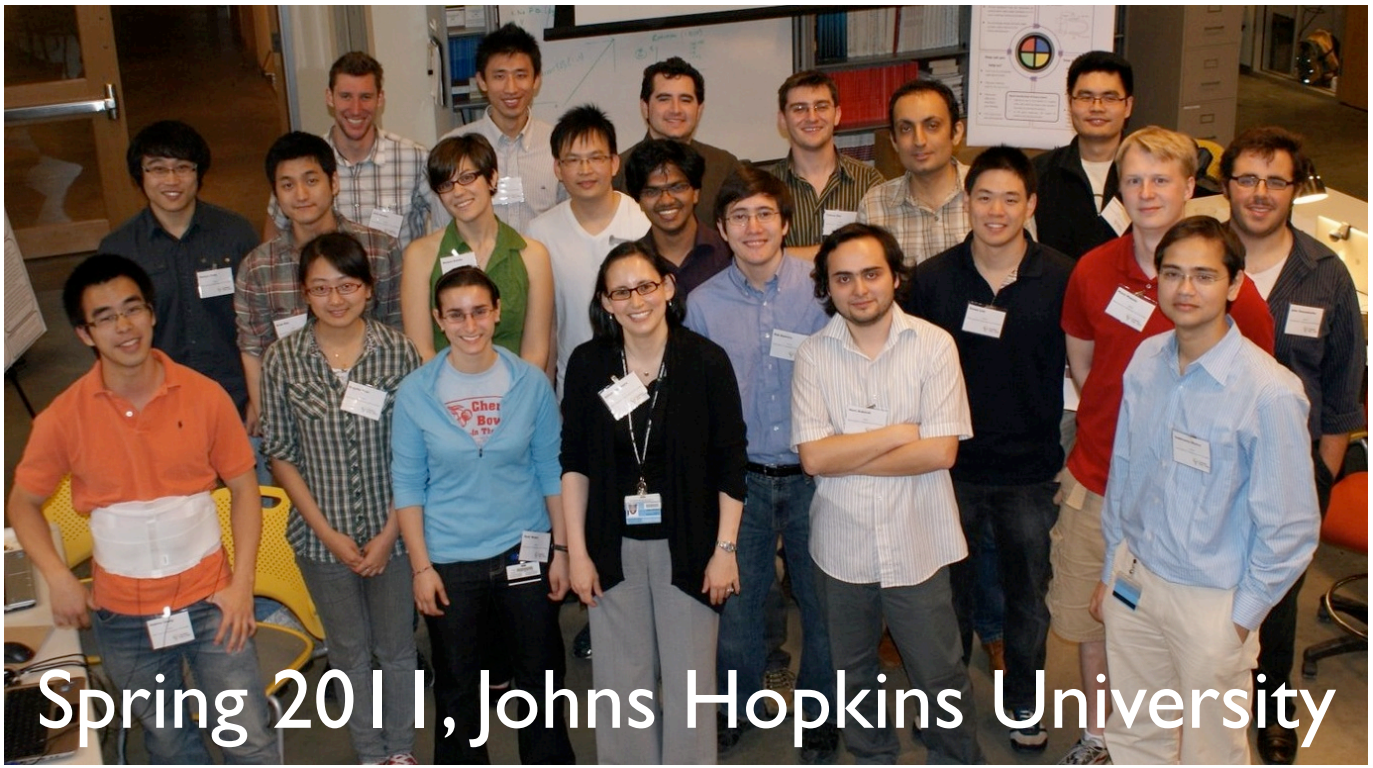
Many interesting psychophysical results are related to cutaneous sensing

There exist a wide variety of types of cutaneous devices

What is the best way to prepare students for haptics research?

Fundamentals
Guided implementation
Open-ended projects
Writing proposals
Reading papers

An example course



https://www.lcsr.jhu.edu/Education/Courses/530_651

Course Objectives

By the end of my course, students should be able to:

- Identify the primary mechanisms of human haptic sensing
- List and understand methods for sensing the position of and actuating haptic devices
- Develop the kinematic and dynamic equations for a haptic device
- Describe the differences between grounded and ungrounded force feedback
- Identify the salient features of a haptic device design
- List a a variety of different types of haptic interfaces
- Haptically render a rigid surface
- Haptically render several different surface properties
- Know how to model a deformable surface
- Create a simple dynamic haptic virtual environment
- Describe and implement basic telemanipulation controllers
- Understand the causes of instability in virtual reality and teleoperation systems
- Design a psychophysical or perceptual test
- Describe a number of applications of haptic feedback
- Read, evaluate, and critique research papers
- Identify a well posed research question and investigate it
- Design and deliver a research presentation
- Write a scholarly research paper

Course Content

	Topic	Weeks
Part 1	Intro. and human haptics	2
Part 2	Haptic devices	2
Part 3	Haptic rendering	3
Part 4	Teleoperation	2
Part 5	Student paper reviews	4

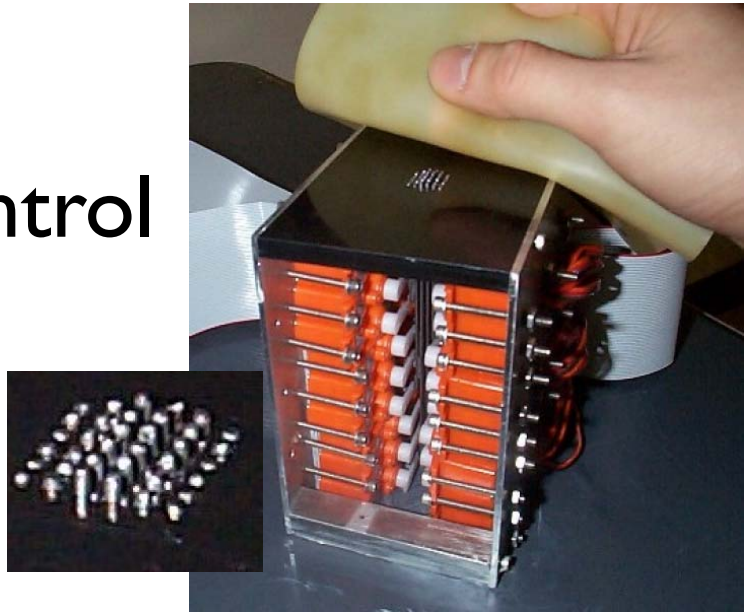
plus a research project... in 13 weeks

Part 1: Introduction and Human Haptics

- Importance of haptics
- Applications of haptics
- Human kinesthetic sensing
- Human cutaneous sensing
- Basics of human motor control
- Human subjects experiments (and IRB approval)
- Psychophysics
- Statistics

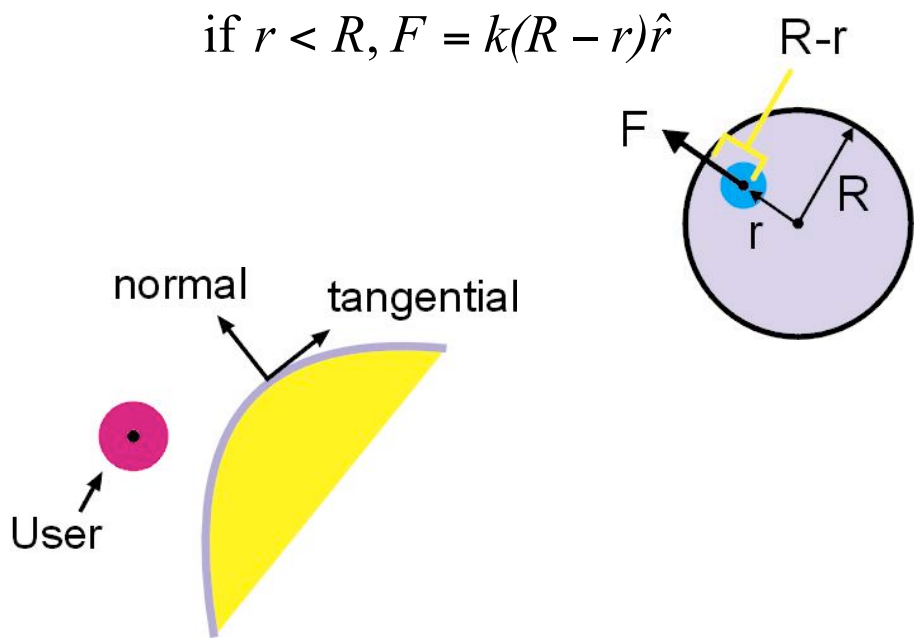
Part 2: Haptic Devices

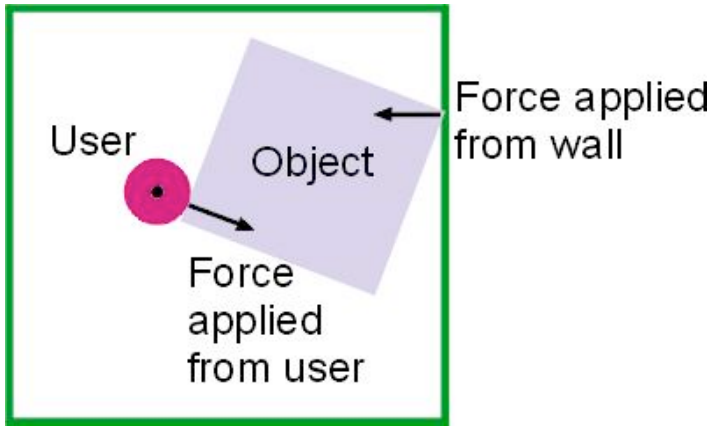
- Kinematics
- Dynamics
- Sensors and actuators
- Device simulation
- Design principles
- Control basics
- Admittance vs. impedance control
- Ungrounded devices
- Tactile/vibrotactile displays
- Device dissection



Part 3: Haptic Rendering

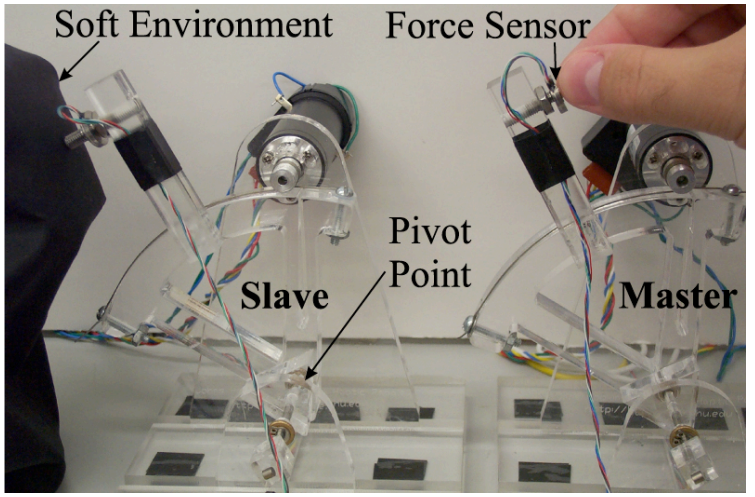
- The virtual wall
- Proxy objects
- Implicit surfaces
- Dynamic simulation
- Surface properties
- Graphics
- Deformable surfaces
- Tricks of the trade
- Implementation on Phantom Omnis

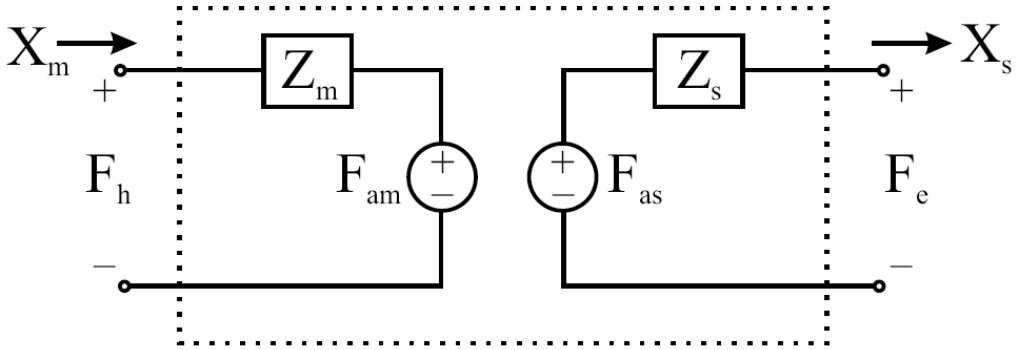




Part 4: Teleoperation

- Bilateral teleoperation models
- Force and motion scaling
- Stability and passivity
- Time delay
- Implementation on a pair of Phantom Omnis





Part 5: Student paper reviews

- Each student selects a paper from the literature (must be approved by the instructor)
- The paper is presented to the class in 12 minutes + 5 minutes Q&A
- Review includes student's assessment of the paper

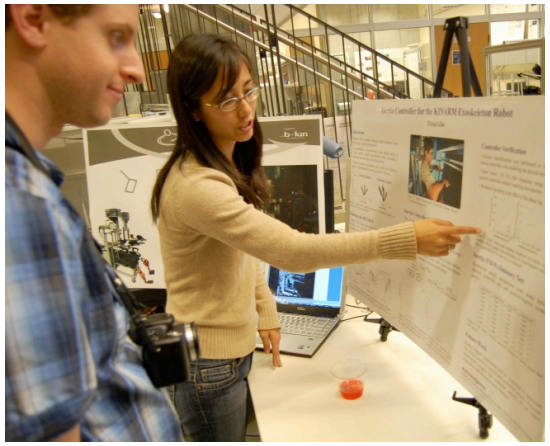
Peer evaluation form

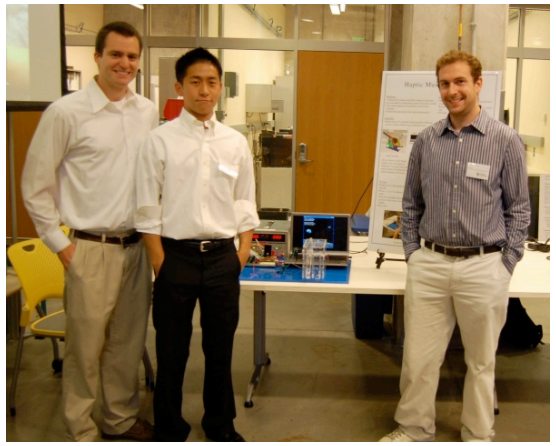
	0	3	7	10	Rating (0-10)
Organization	Audience cannot understand the presentation because there is no order to the sequence in which information is presented.	Audience has difficulty following the presentation because the student jumps around without connecting different topics very well.	Student presents information in a reasonable sequence that the audience can mostly follow, perhaps with some effort.	Student presents information in a logical, interesting order that the audience can easily follow.	
Subject Knowledge	Student does not grasp the information in the presented paper and cannot answer questions on the subject.	Student is uncomfortable with the information and is able to answer only rudimentary questions.	Student is at ease with the presented topics but cannot elaborate on all issues and does not handle challenging questions smoothly.	Student demonstrates full comprehension of the subject of the paper and handles questions adeptly.	
Slides	Student uses superfluous graphics or no graphics; the slides have many errors in spelling, grammar, and/or legibility; or they are otherwise unprofessional in appearance.	Student occasionally uses graphics that support the text and presentation, and/or the slides have some problems with spelling, grammar, and/or legibility.	Student's graphics relate to text and presentation, but there is room for improvement. Slides have few misspellings, grammar errors, and illegible areas.	Student's graphics explain and reinforce the text on the slides and the spoken narrative. The slides have no misspellings or grammatical errors and look very professional.	
Presentation Skills	Student mumbles, pronounces terms incorrectly, and/or speaks too quietly or too loudly for the audience to hear well. Alternatively, student may read most of the report and not make eye contact.	Audience members have difficulty understanding the presentation. For example, student's voice may be low, and he or she may make eye contact with the audience only occasionally.	Student's voice is clear, and most words are pronounced correctly. Most audience members can hear the presentation, but the student turns to notes or slides for prompting several times.	Student uses a clear voice and correct, precise pronunciation of terms so that all audience members can hear the presentation. Student maintains eye contact and does not use notes.	
Timing	Student begins late, poorly allocates time between topics during talk, and/or continues speaking long past the time limit.	Student does not cover all of the material planned and has to rush, or student fails to present enough information to fill the time.	Timing is a little off, in that parts of the talk feel rushed or slow, and/or student does not leave adequate time for questions, discussion, and/or activity.	Timing is perfect: the student starts and ends on time, leaving sufficient opportunity for questions and discussion.	
				Total	

Challenge: Balancing focus on research with class size (~20 people) and time constraints

Project

- Plan and execute a haptics research project that provides a specific new contribution to haptics/engineering science
- Functionality is graded
- Demonstrated at a "Haptics Open House"
- Final report is a conference paper in the appropriate format





Content Delivery

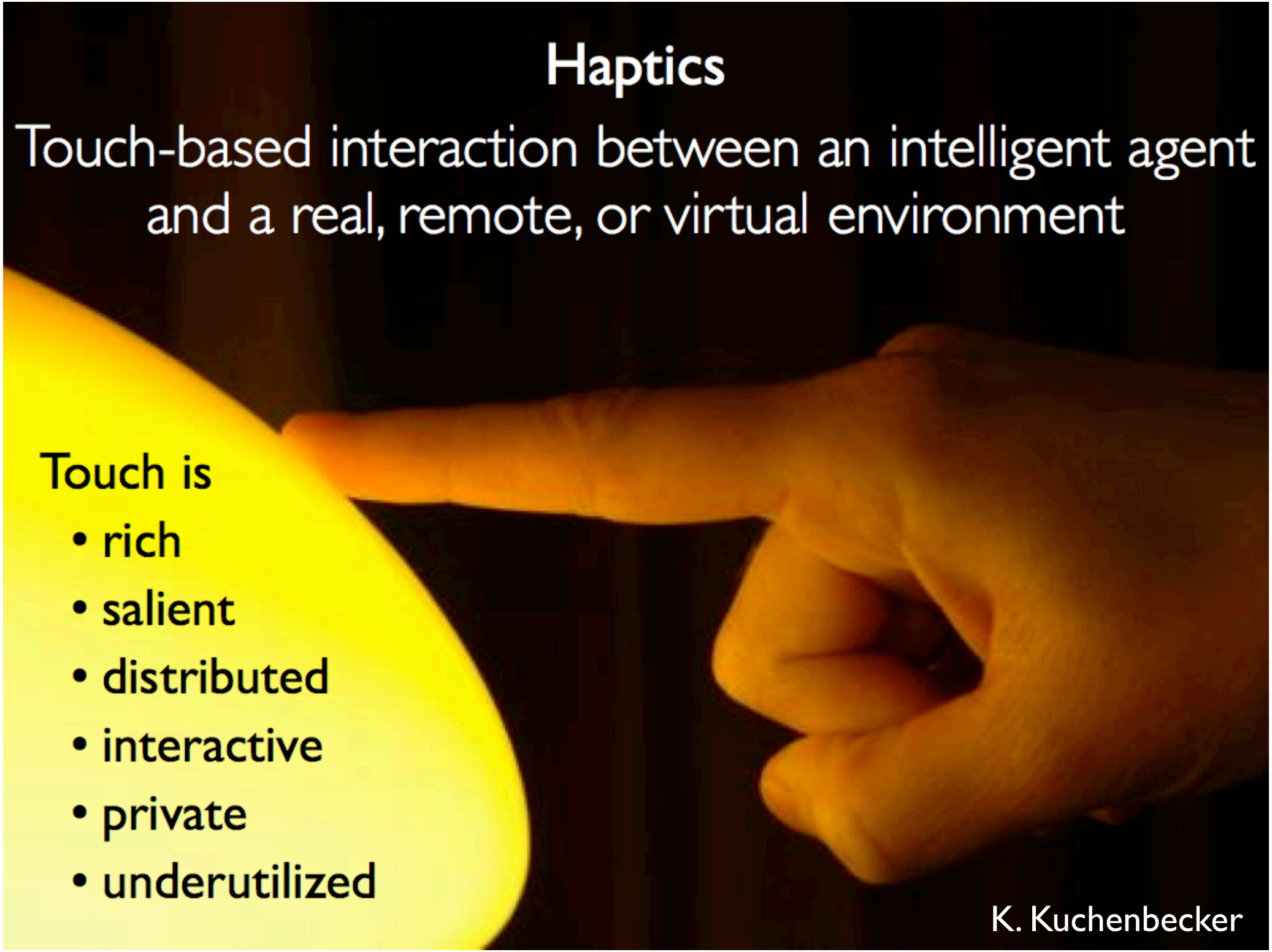
Learning Method	**Retention**
What one reads	10%
What one hears	26%
What one sees	30%
What one sees and hears	50%
What one speaks	70%

What one does? What one feels?

J. E. Stice. Using Kolb's Learning Cycle to Improve Student Learning. Engineering Education, 77(5):291-296, 1987.

Introducing Haptics to Students

Definition
Importance
Relevance


Haptics
Touch-based interaction between an intelligent agent and a real, remote, or virtual environment
Touch is
• rich
• salient
• distributed
• interactive
• private
• underutilized
K. Kuchenbecker

Hearing

Sight

Smell

Taste

Touch

Which sense is most valuable to you?

Which would you relinquish last?

K. Kuchenbecker

Sight

Centralized
Broad
Passive
Cognitive

Distributed
Narrow
Interactive
Fundamental

Touch

K. Kuchenbecker

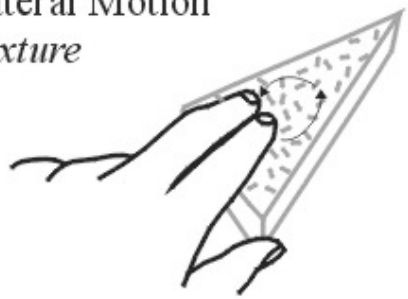
Haptic Box

Pass it around. Feel inside. Try to identify three objects.

[Students must perform haptic exploration (no looking). I fill the box with interesting objects, like a battery, pad of post-it notes, screw driver, and plastic objects that are not easily identifiable. I ask the students what they recognized and how.]

Exploratory Procedures

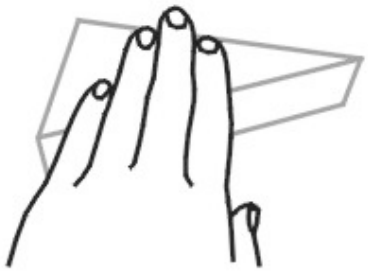
Lateral Motion
Texture



Pressure
Hardness

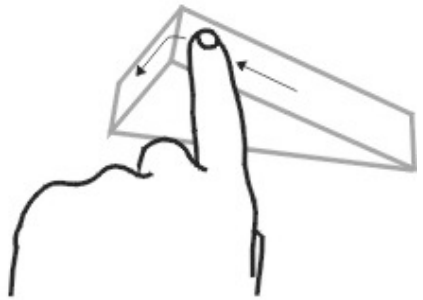
Enclosure
Global shape/Volume

Static Contact
Temperature



Unsupported Holding
Weight

Contour Following
Shape



Adapted from R.L. Klatzky, *et al.*, "Procedures for haptic object exploration vs. manipulation," Vision and action: The control of grasping, ed. M. Goodale, New Jersey: Ablex, 1990, pp. 110-127.

Haptic Metaphors

Emotion

Touching, tactful, stroke one's ego

Exploration

Get a feel for, poke around, scratch the surface

Contact

At one's fingertips, touch base, keep in touch, on/at hand

Constraint/Manipulation

Get a grip, massage an ego, pushy, magic touch

Surface Properties

Sticky situation, hot idea, abrasive personality, smooth operator

Haptics Education Resources

Online Resources

http://eduhaptics.org/

provides pointers to educational materials
and information for teaching
and learning about haptics

(maintained by Will Provancher)

Examples

http://www.cim.mcgill.ca/~hayward/Teach/HapticsCourseOutline.html
McGill University

http://www.cs.ubc.ca/~cs543/current-term/index.html
University of British Columbia

https://engineering.purdue.edu/~ece511/ (psychophysics)
Purdue University

http://www.postech.ac.kr/~choism/courses/introduction%20to%20haptics/
POSTECH

http://www.lmt.ei.tum.de/courses/chlab/index.php
Technische Universität München

Examples

http://albion.ee.washington.edu/EE589/index.html
University of Washington

https://www.lcsr.jhu.edu/Education/Courses/530_651
Johns Hopkins University

http://www.mech.utah.edu/haptics/index.php/Main/HomePage
University of Utah

http://www.mech.northwestern.edu/colgate/Haptics_Course/
Northwestern University

http://www.stanford.edu/class/cs277/
Stanford University

Pedagogically-focused Books

Force and Touch Feedback for Virtual Reality
by Grigore C. Burdea

Engineering Haptic Devices: A Beginner's Guide for Engineers
by Thorsten A. Kern

Haptic Rendering: Foundations, Algorithms and Applications
by Ming C. Lin and Miguel Otaduy

Human Haptic Perception: Basics and Applications
by Martin Grunwald

Human Hand Function
by Lynette A. Jones and Susan J. Lederman

Research on Educational Haptics

Many researchers and educators have explored the role of haptics in teaching, a topic beyond the scope of this tutorial.

A good (but not very recent) review of developments in educational haptics is:

J. Minogue and M. G. Jones. Haptics in Education: Exploring an Untapped Sensory Modality. Review of Educational Research, 76: 317-348, 2006.
DOI: 10.3102/00346543076003317

Small Group Discussion

Split into 5 groups of 5 people each:

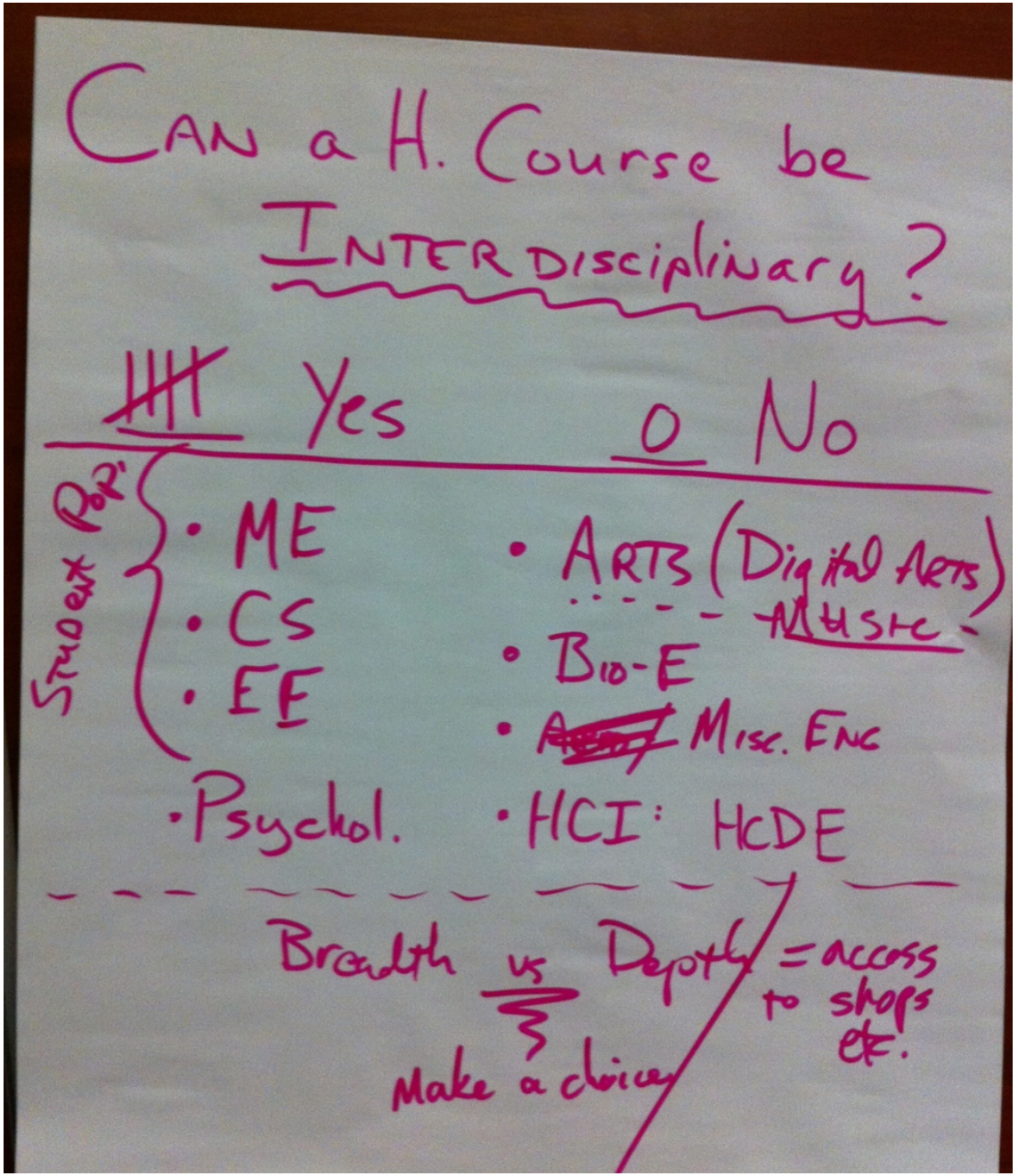
Group 1: Can a haptics course be widely interdisciplinary?	Blake
Group 2: What is the proper scope/depth for a haptics course?	Sonny
Group 3: What are the goals/audience of a haptics course?	Will
Group 4: What support/resources are available/required?	Allison
Group 5: What do students get out of group/individual activities?	Karon

For 15 minutes, discuss this topic with your group:

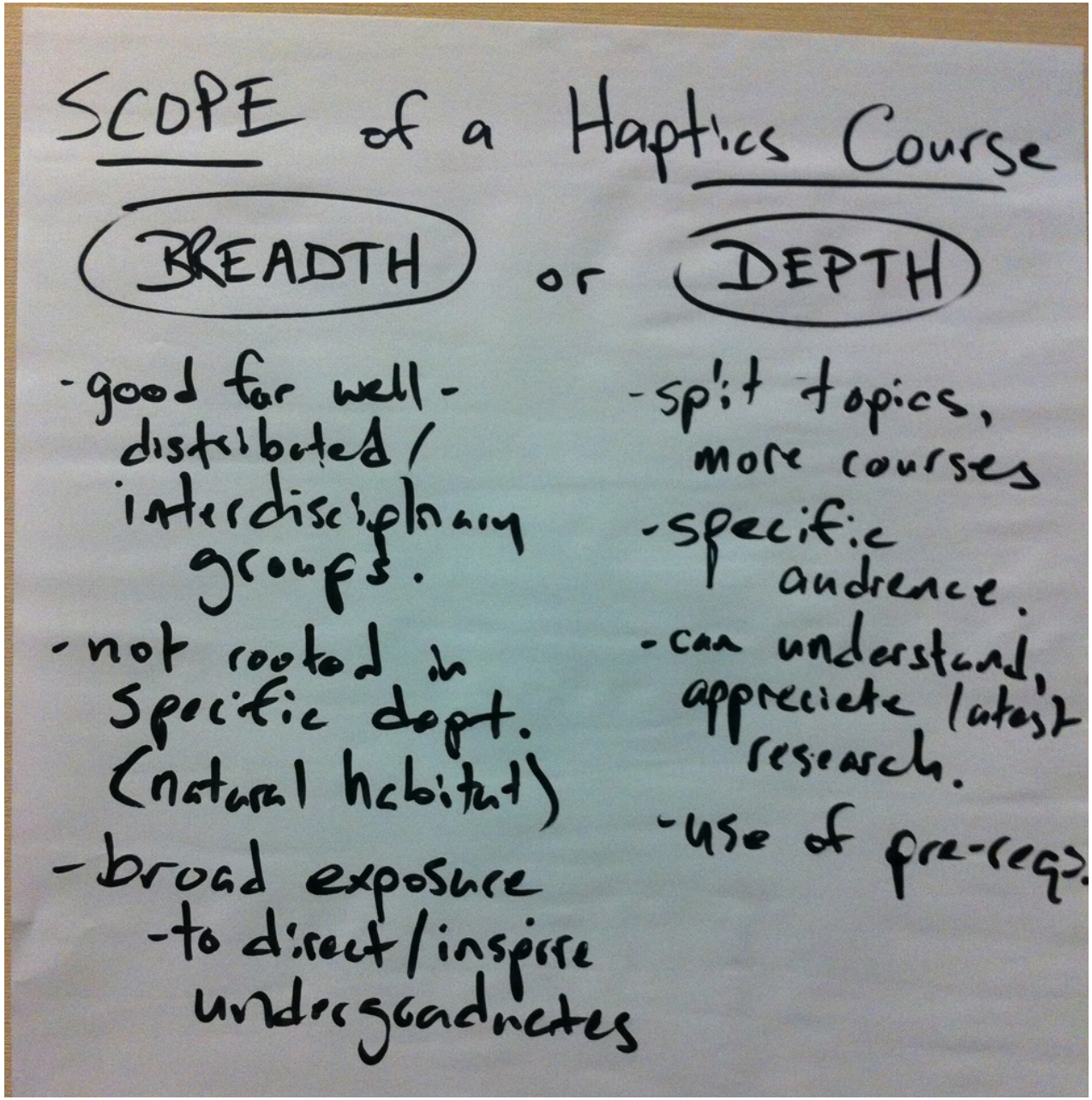
What has been your experience?
What are the opportunities?
What are the challenges?

Then you will briefly present your findings to everyone.

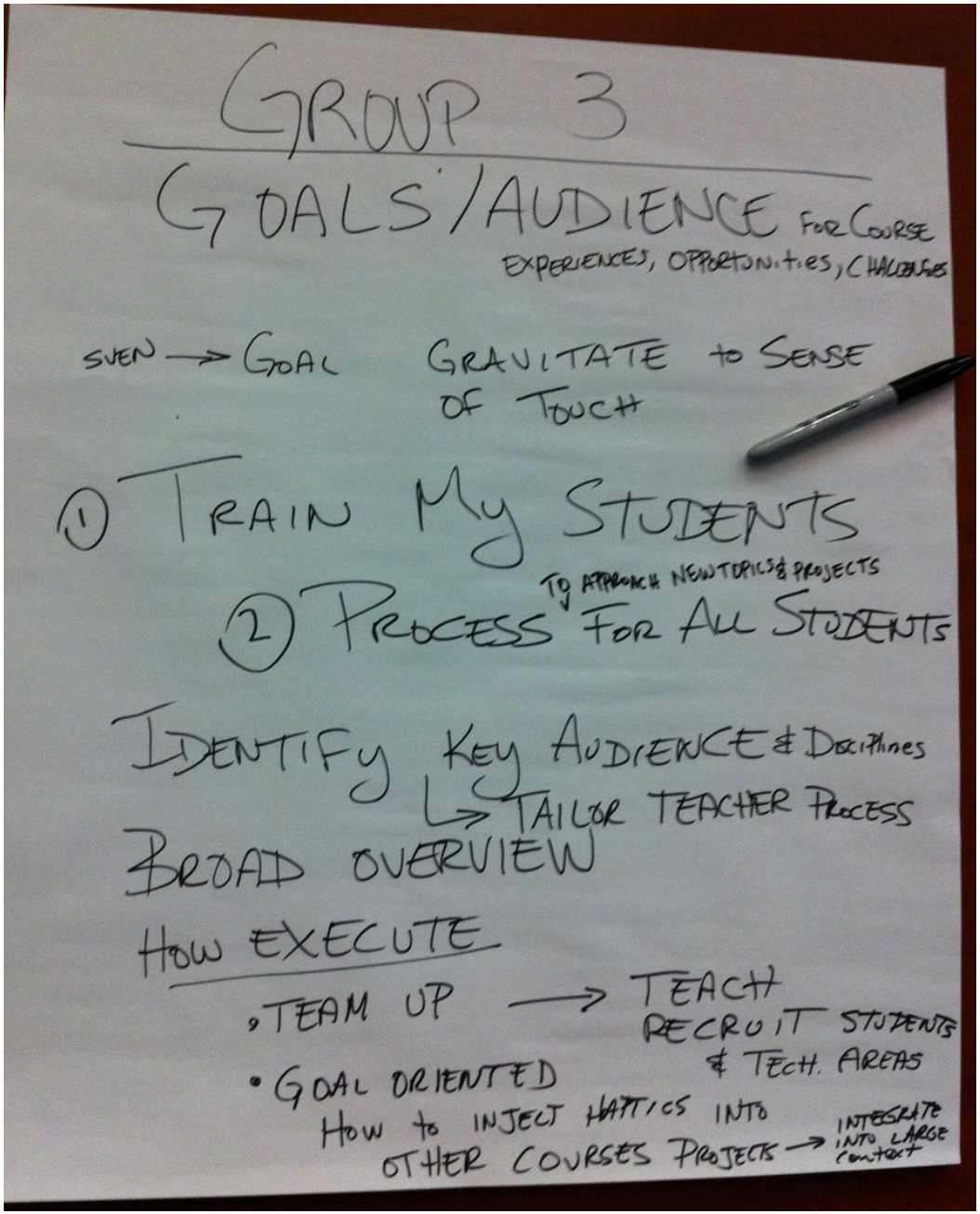
Group 1: Can a haptics course be widely interdisciplinary?



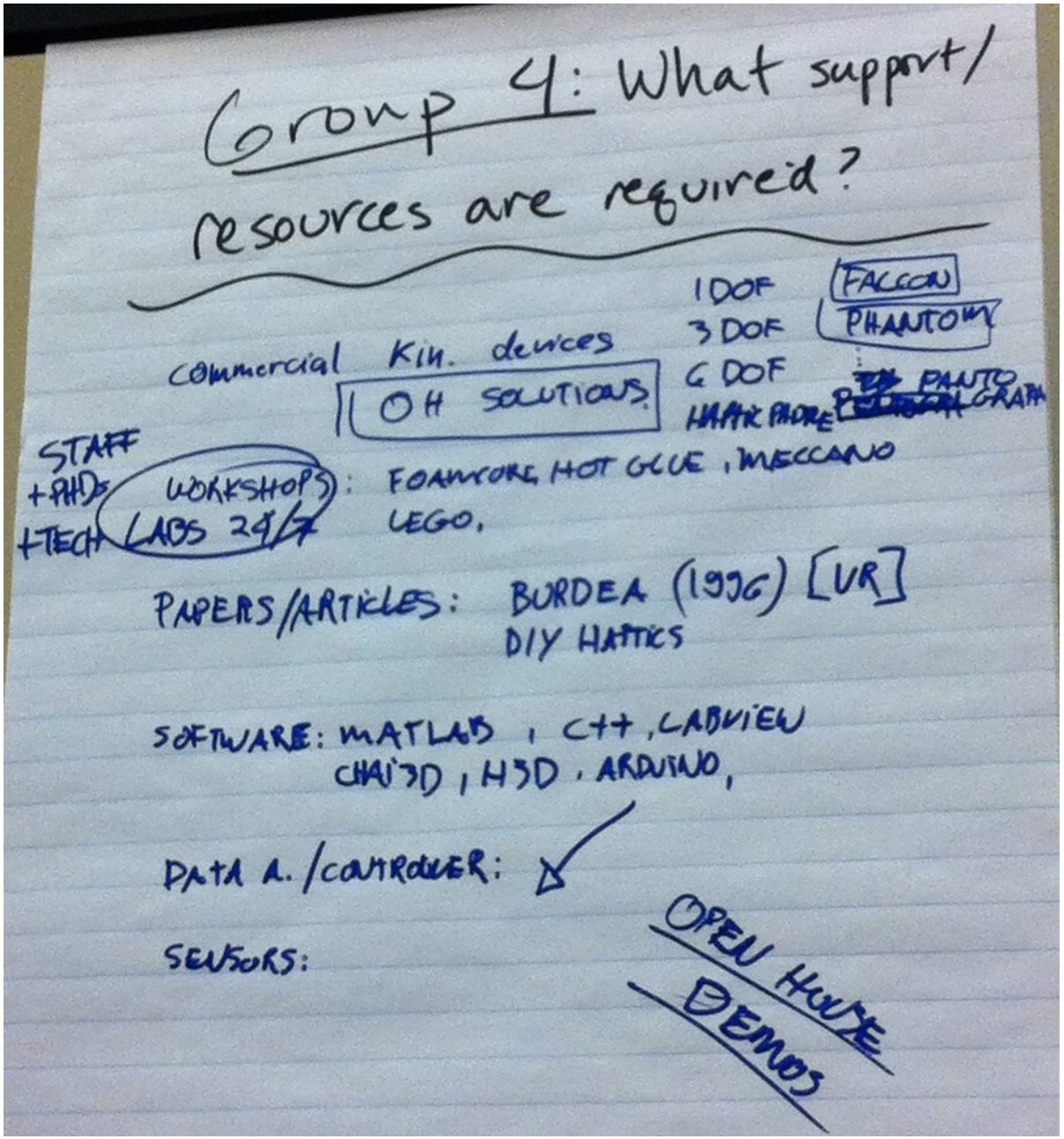
Group 2: What is the proper scope/depth for a haptics course?



Group 3: What are the goals/audience of a haptics course?



Group 4: What support/resources are available/required?



Group 5: What do students get out of group/individual activities?