Science versus Engineering:
Invention as the Basis of Technical HCI Work

Now, back to Hudson and Mankoff
Science versus Engineering: Differences in How the Fields Move Forward

“Activities of discovery can have a variety of aims, including generating rich, empirically based descriptions, and creating new theoretical understandings. Once articulated, theories typically form framing truths that establish a context for the work. The work of discovery often proceeds by elaborating and refining these framing truths to progress towards improved understandings.

For example, both Newtonian and Einsteinian notions of gravity explain everyday objects falling to earth, and even the motion of planets, quite well. Only when we consider finer and more difficult-to-observe phenomena does one clearly improve on the other.

As another [HCI] example, the speed and accuracy of directed reaching movements are well described in one dimension by Fitts’ law (Fitts, 1954). However this theory has various limits (for example, when applied to 2D targets of arbitrary shape).”
Science versus Engineering: Differences in How the Fields Move Forward

“In contrast, activities of invention almost always progress towards the creation of new or better things but not necessarily through refinement. Normally we invent by combining a set of things we already understand how to create into larger, more complex, or more capable things that did not previously exist.

In an HCI context the first graphical interfaces (Sutherland, 1963) were created using existing input and display devices (a light pen, buttons, rotary input knobs, and a random dot CRT) along with new concepts expressed in software to create (among other pioneering advances) the ability of users to manipulate objects displayed graphically by pointing at them.”
Science versus Engineering: Differences in What Makes a Result Valuable and Trustworthy

“In discovery work, the properties of valuable and trustworthy results are intertwined. Core values in discovery work include increasing understanding (e.g., of new phenomena) or understanding in more powerful ways (e.g., more profoundly or in some cases predictively). But the desire to know and have confidence in results makes the details and reliability of the methods used to reach a result of central importance.

The need for high confidence in results drives the familiar tactic of isolating and testing a small number of variables—often just one or two—in an attempt to separate their effects from other confounds. This tactic achieves increased trustworthiness at the cost of focusing on less complex circumstances.

This can make it hard to generalize to more complex, real-world settings without replicating the study in many different but similar settings to be sure that the underlying theory is robust across changing circumstances.”
"The contributions that can be made by inventive HCI research can come in a number of forms. Many of them might be summed up at the highest level as supporting the invention of things that meet human needs.

This can in turn be separated into at least two overall categories: (1) **Direct creation of things meeting human needs** and (2) **development of things that enable further invention**.

*Direct creation* is most straightforward. This might involve creation of something that improves some aspect of a long-standing goal such as supporting collaborative work at a distance, etc., etc., etc., etc.

*Enabling research* on the other hand is more indirect. It has as a goal not directly addressing an end-user need, but rather to enable others to address a need by making it possible, easier, or less expensive for future inventive work to do so (e.g. the development of better tools)."
The Work of Invention in Technical HCI
Types of Contributions

“Tools generally seek to make it much easier to create a certain class of things. Tools normally do not directly meet end-user needs. Instead, they act indirectly by enabling developers to quickly and easily meet end-user needs or to construct complex and functional artifacts.

Systems bring together a set of capabilities into a single working whole—often providing abstractions that make these capabilities more useful, more manageable, and/or easier to deploy or reuse.

Systems also sometimes bring together a disparate set of capabilities that had not been combined before or combine capabilities in new ways that make them more useful. As an example, every major operating system today includes a subsystem specifically for handling overlapping windows, which provides basic input and output capability on a single set of devices that can be shared by many programs.”
The Work of Invention in Technical HCI
Approaches to Concept Creation

“One of the most frequent outcomes of inventive work in HCI is to devise a new way to bridge between technical capabilities and human needs. A researcher can start from an observed human need and seek to find a technical approach that can make a positive impact on the need.

A researcher may do discovery-based work [e.g., in aging, decision making, disabilities, memory, vision, hearing, perception, etc. etc.] to better understand these needs (and human properties that impact them) and then seek (mostly existing) technological capabilities that might be used to meet these needs.

Within this general framework, one can also work from the technology side: a researcher may specialize in one or more areas of useful or promising technology— and then seek to find existing human needs that the technology might have a positive impact on.”
Validation Through Building of Proof-of-Concept Implementations

“When we consider validation of an invented concept there are many criteria with which we might judge it. However, most fundamental is the question of “does it work?”

Experience with invented concepts shows that many ideas that seem excellent at the early point we might call on paper fail in the details that they must confront during implementation.

This difficulty leads to the most fundamental of validation approaches for inventive work: proof-of-concept implementation. Because of the difficulty of uncovering critical details, experienced inventors do not put much credence in an idea until it has been at least partly implemented; in short: you do not believe it until it has been built.”
Validation Through Building of Proof-of-Concept Implementations

Types of Proof-of-Concept Implementations

Many proof-of-concept implementations take a form that can best be described as a *demonstration*. To succeed, that demonstration must illustrate the worth of the invention and in many cases motivate why it should be considered a success. Demonstrations fall along a rough scale of completeness or robustness. As used in the HCI research community, the presentation form of a demonstration is an indirect measure of its robustness, ordered below from the least to the most robust:

- Description in prose
- Presentation through photos (or screen dumps) showing the invention working
- Video showing the invention in use
- Live demonstration by the inventors
- Testing of properties with users
- Deployment to others to use independently
“For inventions that are providing a direct contribution, we value creating an artifact that meets a stated human need. These needs are often met by creating a new capability or by speeding or otherwise improving a current capability.

Perhaps the most common evaluation methods we see employed to demonstrate this are usability tests, human and machine performance tests, and what we will call expert judgment and the prima facie case.

Although these are not universally appropriate, they are the most common in the literature.”
“Because of the current and historical importance of usability and related properties as a central factor in the practice of HCI, usability tests of various sorts have been very widely used in HCI work and are the most recognizable of evaluation methods across the field. In fact the authors have frequently heard the assertion among students and other beginning HCI researchers that “you can’t get a paper into CHI without a user test!”

This assertion is demonstrably false. An invention must be validated, but validation can take many forms. Even if a usability test shows that an invention is easy to use, it may not be very impactful. Its ability to be modified, extended, or applied to a different purpose may be much more important than its usability.”
Secondary Forms of Validation
Human Performance Tests

“Another very widely used class of evaluation methods involves measuring the performance of typical users on some set of tasks. These tests are most applicable when goals for results revolve around a small set of well-defined tasks.

Work in interaction techniques is one of the few areas where this type of validation is consistently appropriate.”

**NOTE:** To close approximation, “human performance tests” or “experimentation” is largely the focus of our “ExpHCI” textbook.
Secondary Forms of Validation
Machine Performance Tests

“Tests can also be done to measure the performance of an artifact or an algorithm rather than the person who uses it. These can be very practical in providing information about the technical performance of a result such as expected speed, storage usage, and power consumption. These measures resemble the validation measures commonly used in other domains such as systems research in computer science.”

Take Away Message: A good HCI researcher should also get their computer science right. If it is too much to expect that both skill sets should reside within one’s personal domains of expertise, then it will be useful to perform research in collaborative teams that include at least member with each required skill set.
“Properties such as innovation and inspiration are of substantial value for many research results. Opening new areas others had not considered before and providing a motivated basis for others to build within them are central to progress within the community.

However, these factors are extremely hard if not impossible to measure in any standardized way. For these important but more nebulous properties we most typically must rely on what amounts to expert opinion—whether the result impresses other researchers experienced in the area.”

**Take Away Message:** As you move forward pay attention to actively cultivating an *aesthetic skill* or *sense of taste* in evaluating research and its products, much in the way that your skills or tastes in appreciating many other creative endeavors (music, visual arts, cookery, wine) have matured.
Richard Feynman on Aesthetics and Science