software design & why it matters

Daniel Jackson · MIT CSAIL
Milan, Paris, Frankfurt · May 16-20, 2016
introduction
my background
my background

MA in Physics,
Oxford University
my background

MA in Physics, Oxford University

PhD in Computer Science, MIT
my background

MA in Physics,
Oxford University

PhD in Computer Science, MIT

Assistant Prof, CMU
my background

MA in Physics, Oxford University

PhD in Computer Science, MIT

Assistant Prof, CMU

Prof, MIT
other projects

new programming paradigms

cyberphysical security
changes in how we live & work
growth of online activity
growth of online activity

72% of millennials research & shop online before going to a store
growth of online activity

72% of millennials research & shop online before going to a store
growth of online activity

72% of millennials research & shop online before going to a store

27 metro areas in US
connectivity
connectivity

browser, 1986
connectivity

browser, 1986

browser, 2016
deprofessionalization
<table>
<thead>
<tr>
<th>Property Information</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>FITN</td>
<td>Y</td>
</tr>
<tr>
<td>CSNO</td>
<td>N</td>
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<tr>
<td>GOLF</td>
<td>N</td>
</tr>
<tr>
<td>POOL</td>
<td>Y</td>
</tr>
<tr>
<td>WCHR</td>
<td>Y</td>
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<tr>
<td>TENS</td>
<td>N</td>
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<tr>
<td>BCTR</td>
<td>Y</td>
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<td>DINE</td>
<td>Y</td>
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<td>MEET</td>
<td>Y</td>
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<tr>
<td>KIDS</td>
<td>N</td>
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<tr>
<td>CONV</td>
<td>Y</td>
</tr>
<tr>
<td>PETS</td>
<td>Y</td>
</tr>
<tr>
<td>DATA</td>
<td>Y</td>
</tr>
<tr>
<td>NSMK</td>
<td>Y</td>
</tr>
<tr>
<td>DCLN</td>
<td>Y</td>
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<tr>
<td>JACZ</td>
<td>N</td>
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<tr>
<td>BKST</td>
<td>N</td>
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<tr>
<td>INPL</td>
<td>N</td>
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<tr>
<td>OUPL</td>
<td>Y</td>
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<tr>
<td>KTCN</td>
<td>N</td>
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<tr>
<td>INTR</td>
<td>Y</td>
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<td>RMSV</td>
<td>Y</td>
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<tr>
<td>HSPD</td>
<td>Y</td>
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<tr>
<td>SHTL</td>
<td>N</td>
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<tr>
<td>LCAL</td>
<td>Y</td>
</tr>
<tr>
<td>EXEC</td>
<td>Y</td>
</tr>
<tr>
<td>BECH</td>
<td>N</td>
</tr>
<tr>
<td>PARK</td>
<td>N</td>
</tr>
</tbody>
</table>

Sabre reservation system
example: book publishing

- design layout: Adobe Indesign
- printing: Blurb
- marketing: Facebook, Twitter, etc
- distribution: Amazon
complexity
Braun SK4 by Dieter Rams (1957)
complexity

Braun SK4 by Dieter Rams (1957)

Apple iTunes (2016)
changes in how things are made
expectations of usability
expectations of usability
expectations of usability
expectations of usability
an exciting launch

AVON plans to use mobile technology to connect better with customers

SAP Sapphire Event (2011)
an exciting launch

"Avon wanted to have the Avon lady enabled on the iPad so she could digitize the experience with the consumer... This was innovating a 100-year-old company and making it brand new again."

AVON plans to use mobile technology to connect better with customers

SAP Sapphire Event (2011)
what happened
“While the new system based on software supplied by SAP AG worked as planned, it was so burdensome and disruptive to the representatives’ daily routine that they left in meaningful numbers.”

Avon spokesperson
“While the new system based on software supplied by SAP AG worked as planned, it was so burdensome and disruptive to the representatives’ daily routine that they left in meaningful numbers.”

Avon spokesperson

Avon is pulling the plug on a $125 million software system...

Wall Street Journal (2013)
“While the new system based on software supplied by SAP AG worked as planned, it was so burdensome and disruptive to the representatives’ daily routine that they left in meaningful numbers.”

Avon spokesperson

Avon is pulling the plug on a $125 million software system...

The failure is the latest – and perhaps most dramatic – example of how usability has become a critical issue in the workplace. People who are accustomed to using simple, well-designed applications in their personal lives have no patience for disappointing technology at work...

Wall Street Journal (2013)
Designed by Apple in California  Assembled in China
Model No.: A1241  FCC ID: BCGA1241  IC ID: 579C-A1241
Apple vs Foxconn profit margins
iPhone 5: where the money goes
iPhone 5: where the money goes

parts
$322
iPhone 5: where the money goes

- Apple: $319
- Parts: $322
iPhone 5: where the money goes

apple $319

parts $322

foxconn $8
the emergence of design
progression from craft

The first scheme represents the unselfconscious situation described in Chapter 4. Here the process which shapes the form is a complex two-directional interaction between the context C1 and the form F1, in the world itself. The human being is only present as an agent in this process. He reacts to misfits by changing them; but is unlikely to impose any “designed” conception on the form.

The second scheme represents the selfconscious situation described in Chapter 5. Here the design process is remote from the ensemble itself; form is shaped not by interaction between the actual context’s demands and the actual inadequacies of the form, but by a conceptual interaction between the conceptual picture of the context which the designer has learned and invented, on the one hand, and ideas and diagrams and drawings which stand for forms, on the other. This interaction contains both the probing in which the designer searches the problem for its major “issues,” and the development of forms which satisfy them; but its exact nature is unclear. In present design practice, this critical step, during which the problem is prepared and translated into design, always depends on some kind of intuition. Though design is by nature imaginative and intuitive, and we could easily trust it if the designer’s intuition were reliable, as it is it inspires very little confidence.

In the unselfconscious process there is no possibility of misconstruing the situation: nobody makes a picture of the context, so the picture cannot be wrong. But the selfconscious designer works entirely from the picture in his mind, and this picture is almost always wrong.

The way to improve this is to make a further abstract picture of our first picture of the problem, which eradicates
context
c1
\downarrow
C2
\downarrow
C3

form
F1
\uparrow
F2
\uparrow
F3

\rightarrow

\leftrightarrow
context  form

C1  F1

C2  F2

C3  F3
IBM, 1981
Personal computer
Alfonso Bialetti, 1933
La Moka coffee maker

IBM, 1981
Personal computer
Alfonso Bialetti, 1933
La Moka coffee maker

Leica, 1953
M3 rangefinder camera

IBM, 1981
Personal computer
Alfonso Bialetti, 1933
La Moka coffee maker

Leica, 1953
M3 rangefinder camera

IBM, 1981
Personal computer

Dieter Rams, 1958
Pocket transistor radio T3
Alfonso Bialetti, 1933
La Moka coffee maker

Leica, 1953
M3 rangefinder camera

Dieter Rams, 1958
Pocket transistor radio T3

IBM, 1981
Personal computer

Jony Ive, 2002
Apple iPod
Alfonso Bialetti, 1933
La Moka coffee maker

Leica, 1953
M3 rangefinder camera

Dieter Rams, 1958
Pocket transistor radio T3

IBM, 1981
Personal computer

Jony Ive, 2002
Apple iPod

Fred Bould (2011)
Nest thermostat
from digital to physical
from digital to physical

Fred Bould (2011)
Nest thermostat
from digital to physical

Fred Bould (2011)
Nest thermostat

Henry Dreyfuss (1953)
Honeywell T68 thermostat
from digital to physical

Fred Bould (2011)
Nest thermostat

Henry Dreyfuss (1953)
Honeywell T68 thermostat

Fuji (2013?)
Instax 90 film camera
from digital to physical

Fred Bould (2011)
Nest thermostat

Henry Dreyfuss (1953)
Honeywell T68 thermostat

Fuji (2013?)
Instax 90 film camera

iOS6 clock app
from digital to physical

Fred Bould (2011)
Nest thermostat

Henry Dreyfuss (1953)
Honeywell T68 thermostat

Fuji (2013?)
Instax 90 film camera

iOS6 clock app

Swiss Federal Railways
SBB clock
inclusive design
inclusive design

Bradley watch from Eone
design goes mass market
design goes mass market

Michael Graves
(1934-2015)
design goes mass market

Michael Graves
(1934-2015)

Michael Graves (1985)
Alessi 9093 tea kettle
design goes mass market

Michael Graves (1934-2015)

Michael Graves (1985)
Alessi 9093 tea kettle

Michael Graves (1999)
Target spinner whistle tea kettle
design consultancies
design consultancies

IDEO

Frog
acquired by Flextronics
(2004)

Fjord
acquired by Accenture
(2013)
design consultancies

- **IDEO**
- **Frog** acquired by Flextronics (2004)
- **Fjord** acquired by Accenture (2013)

**Timeline**

2011: GlobalLogic buys Method
2012: Google buys Mike and Maaike
2013: Facebook buys HotStudio
design schools & programs

Stanford D School founded 2004 by David Kelley and George Kembel
design thinking for business
coworking + maker spaces
a startup whose founders met at RISD
IBM (re)embraces design
IBM (re)embraces design

Eliot Noyes (1961)
IBM Selectric Typewriter
IBM (re)embraces design

Eliot Noyes (1961)
IBM Selectric Typewriter

IBM’s design studio in Austin, Texas
what is design thinking?
theories of design
what is design?

Nigel Cross (1982)
Designerly Ways of Knowing
excerpted from RCA report
The central concern of Design is the conception and realisation of new things. It encompasses the appreciation of material culture and the application of the arts of planning, inventing, making and doing. At its core is the language of modelling... equivalent to aptitudes in the language of the sciences (numeracy) and the language of humanities (literacy).

Design has its own distinct things to know, ways of knowing them, and ways of finding out about them.

Nigel Cross (1982)
Designerly Ways of Knowing
excerpted from RCA report
user centeredness
user centeredness
user centeredness

translation:
“please load letter-sized paper into paper cassette”
user centeredness

translation:
“please load letter-sized paper into paper cassette”
user centeredness

translation:
“please load letter-sized paper into paper cassette”
diversity of contributors
diversity of contributors
diversity of contributors

anthropology

psychology
diversity of contributors

anthropology

psychology

economics
diversity of contributors

anthropology

psychology

art

economics
attention to detail

That’s quite obsessive, isn’t it?
Jonathan Ive in “Objectified”

The details are not the details. These make the design.
attributed to Charles Eames by Garrett
example: signatures in Apple Preview

You can add your handwritten signature to PDF documents. To start, use your Mac's camera to capture an image of your signature.

Create Signature...
example: signatures in Apple Preview

Sign your name in black ink on a small piece of white paper.

Hold the paper up to your Mac's camera so your signature rests on the blue line.

Save this signature for use after Preview quits
The need itself is a perceived lack, something that is missing. Needfinding is thus a paradoxical activity—what is sought is a circumstance where something is missing. In order to find and articulate a need, this missing thing must be seen and recognized by someone.

users don’t know what they want
users don’t know what they want

new recipe won blind taste tests
users don’t know what they want

new recipe won blind taste tests

Aeron office chair low ratings in early tests
brainstorming

diagram from Tim Brown, IDEO
prototypes & user studies
prototypes & user studies
paper prototypes

Summer Weekdays

Create Program
Change Program
Set Time/Date

Jan 01, 2005

Temp.

15°

Program

Summer on Vacation

Morning

From 7:00 to 9:00

Temperature

Day

8:00

Evening

5:00 to 12:00

Night

12:00 to 7:00

Date

Time

Temperature

Today

Time:

12:00

Program

Time/Date

Change Temp.
where did requirements & design go?
where did requirements & design go?

client developer

client developer

client developer

client developer
so what is software design?
designers & engineers
<table>
<thead>
<tr>
<th>elements</th>
<th>designer</th>
<th>engineer</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>door, window, wall</td>
<td>column, beam, truss</td>
</tr>
<tr>
<td>goals</td>
<td>comfortable, convenient, attractive</td>
<td>structural integrity, durable, sustainable</td>
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</table>
software design & engineering
# software design & engineering

<table>
<thead>
<tr>
<th>elements</th>
<th>designer</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>function, object, type</td>
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<tr>
<td>goals</td>
<td></td>
<td>maintainable, correct, fast</td>
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## software design & engineering

<table>
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<th>designer</th>
<th>engineer</th>
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<tbody>
<tr>
<td>elements</td>
<td>function, object, type</td>
<td>decoupling &amp; localization</td>
</tr>
<tr>
<td>criteria</td>
<td>decoupling &amp; localization</td>
<td>maintainable, correct, fast</td>
</tr>
<tr>
<td>goals</td>
<td>maintainable, correct, fast</td>
<td>maintainable, correct, fast</td>
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### Software Design & Engineering

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<tr>
<td>Elements</td>
<td></td>
<td>function, object, type</td>
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<tr>
<td>Criteria</td>
<td></td>
<td>decoupling &amp; localization</td>
</tr>
<tr>
<td>Goals</td>
<td>learnable, effective, tolerant</td>
<td>maintainable, correct, fast</td>
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# Software Design & Engineering

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<th>Engineer</th>
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<td>Decoupling &amp; Localization</td>
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<th>Goals</th>
<th>Designer</th>
<th>Engineer</th>
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<tbody>
<tr>
<td>Learnable, effective, tolerant</td>
<td>Maintainable, correct, fast</td>
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</table>
# Software Design & Engineering

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<th>designer</th>
<th>engineer</th>
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<tr>
<td>concepts</td>
<td>function, object, type</td>
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<table>
<thead>
<tr>
<th>criteria</th>
<th>concept/purpose correspondence</th>
<th>decoupling &amp; localization</th>
</tr>
</thead>
</table>

| goals     | learnable, effective, tolerant | maintainable, correct, fast |
software
design tools
concepts
structuring functionality
concepts
structuring functionality

modeling concepts
focused data models
concepts
structuring functionality
modeling concepts
focused data models
usability heuristics
well known principles
concepts
a common view of software design

UI design
soft & human
about presentation

programming
hard & technical
about content
a better view of software design

conceptual design:
- essential concepts & behavior

representation design:
- organization & performance
what characterizes an app?

Apple Mail

Microsoft Word

Twitter

Photoshop
what characterizes an app?

concepts!

Apple Mail

Microsoft Word

Twitter

Photoshop
what characterizes an app?

concepts!

Apple Mail
Microsoft Word
Twitter
Photoshop

EmailAddress
Message
Folder or Label
what characterizes an app?

concepts!

Apple Mail
- EmailAddress
- Message
- Folder or Label

Microsoft Word
- Paragraph
- Format
- Style

Twitter

Photoshop
what characterizes an app?

concepts!

Apple Mail
- Email Address
- Message
- Folder or Label

Microsoft Word
- Paragraph
- Format
- Style

Twitter
- Tweet
- Hashtag
- Following

Photoshop
what characterizes an app?

concepts!

Apple Mail
- EmailAddress
- Message
- Folder or Label

Microsoft Word
- Paragraph
- Format
- Style

Twitter
- Tweet
- Hashtag
- Following

Photoshop
- PixelMap
- Layer/Mask
- Adjustment
the fundamental principle
the fundamental principle

in a well-designed system
the fundamental principle

in a well-designed system
each concept is motivated by one purpose
concept, purpose, principle, misfit
concept, purpose, principle, misfit

**concept**: trash
concept, purpose, principle, misfit

**concept**: trash

**purpose**: allow undo of deletions
concept: trash

**purpose**: allow undo of deletions

**operational principle**: if you delete a file, it moves to a special folder; you can restore from there, but emptying it removes contents for good (and makes space on disk)
**concept, purpose, principle, misfit**

**concept**: trash

**purpose**: allow undo of deletions

**operational principle**: if you delete a file, it moves to a special folder; you can restore from there, but emptying it removes contents for good (and makes space on disk)

**misfit**: if you delete a file on an external drive, you cannot reclaim the space until you empty the trash, but then you’ll lose the ability to restore files deleted from the main drive
organizing concepts
organizing concepts

stylesheet

style

format

paragraph

text
organizing concepts

stylesheet

style

format

paragraph

text

eemacs
organizing concepts

stylesheet

style

Stickies

format

paragraph

text
organizing concepts

stylesheet

style

format
paragraph

TextEdit
text
organizing concepts

stylesheets
text
paragraph
format
style

OpenOffice
organizing concepts

Word

stylesheet

style

format

paragraph

text
Who Is in These Photos?

To tag your friends, review the suggested names and click Save Tags at the bottom of this page. If a name is missing or incorrect, list a new name and press Enter.
Remember: If someone doesn't like a photo, they can untag themselves or ask you to take it down.

Who is this?  Who is this?

Skip Tagging Friends  Save Tags
facebook concepts

reply

comment

friend

post

tag

user
tag concept
tag concept

**purpose**: share photo with people who appear in it
**tag concept**

**purpose:** share photo with people who appear in it

**operational principle:** if you tag a photo, then it becomes visible to the person tagged, and to their friends (in addition to your friends)
**tag concept**

**purpose**: share photo with people who appear in it

**operational principle**: if you tag a photo, then it becomes visible to the person tagged, and to their friends (in addition to your friends)

**misfit**: suppose I get drunk at a party with strangers and one of them tags me. If my boss is my friend, she will now see the photo.
Tag concept

Real purpose: increase connectivity of friend graph?

Purpose: share photo with people who appear in it

Operational principle: if you tag a photo, then it becomes visible to the person tagged, and to their friends (in addition to your friends)

Misfit: suppose I get drunk at a party with strangers and one of them tags me. If my boss is my friend, she will now see the photo.
skype concepts
skype concepts
hold concept
purpose: make it possible to multiplex calls
**hold concept**

**purpose**: make it possible to multiplex calls

**operational principle**: if you put a call on hold, you can answer another call, and then switch back to the first one by putting that on hold (or ending it) and resuming the first.
**hold concept**

**why not just allow concurrent calls?**

**purpose**: make it possible to multiplex calls

**operational principle**: if you put a call on hold, you can answer another call, and then switch back to the first one by putting that on hold (or ending it) and resuming the first.
modeling
the core of design

Nigel Cross (1982)
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excerpted from RCA report
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Design has its own distinct things to know, ways of knowing them, and ways of finding out about them.

Nigel Cross (1982)
*Designerly Ways of Knowing*
excerpted from RCA report
facebook tags
facebook tags

Bob

friends

Carol

Dave

Alice
facebook tags

Bob

Carol

tags

Dave

Alice

Image
facebook tags

Bob → Carol → Dave
Alice → Image

who can see the image?
who can see the image?

Bob, Carol, and Dave can see the image.
facebook tags

who can see the image?

User → friends

User → posts

Image → sees

tags

Alice → Image

Bob → Image

Carol → Image

Dave → Image

Bob 

Carol 

Dave 

Alice

Image
facebook tags

who can see the image?

all $i: \text{Image} \mid \text{sees}.i = (\text{posts}.i).\text{friends} + (i.\text{tags}).\text{friends}$

textual constraint in Alloy
modeling data (i.e., state)
modeling data (ie, state)

Set_1 \rightarrow \text{relation} \rightarrow \text{Set_2}
modeling data (ie, state)

the state includes two sets Set1 and Set2 and a relation that associates elements of Set1 with elements of Set2
constraint that explains conversation labels:

\[
\text{all } c: \text{Conversation} \mid c.clabels = cmsgs.mlabels
\]
strange consequences
strange consequences

search for unlabelled messages
in conversation view, shows conversations
any conversation that contains an unlabelled message
but this conversation may appear to be labelled
strange consequences

search for unlabelled messages
in conversation view, shows conversations
any conversation that contains an unlabelled message
but this conversation may appear to be labelled

no ops?
deleting then adding a label
adding then deleting a label
both can modify a conversation
strange consequences

search for unlabelled messages
in conversation view, shows conversations
any conversation that contains an unlabelled message
but this conversation may appear to be labelled

no ops?
deleting then adding a label
adding then deleting a label
both can modify a conversation

a puzzle
can a conversation have a Sent label?
skype data
skype data

- User
  - participants
  - number
- Phone Number
- Call
skype data

- how many users/number
- how many numbers/user?
skype data

User

participants

Call

? number +

Phone Number
skype data

- User
- Phone Number
- participants
  - no special participants?
- Call

? number +
skype data

User

Phone Number

participants

initiator

Call

? number +
skype data

User -> Phone Number

? number +

participants

initiator

Call

(can initiator change?)
skype data

Diagram:

- User
- Call
- Phone Number

Connections:
- User to Phone Number: ? number +
- User to Call: participants
- Call to Phone Number: initiator
skype data

- User
  - ? number + Phone Number
  - ! initiator
  - participants, pending
  - !

- Call

- OnHold
skype data

User -> Call -> OnHold

? number +

initiator

participants, pending

is OnHold a set of calls?
skype data

User

? number +

Phone Number

participants, pending, on_hold

! initiator

Call
skype data

- User
- Call
- Phone Number

participants, pending, on_hold

initiator

? number +

no, it’s a relation!
heuristics
sources of heuristics

Jakob Nielsen
10 Usability Heuristics

Ben Shneiderman
8 Golden Rules

Don Norman
Design of Everyday Things

Bruce Tognazzinni
First Principles of Interaction Design
consensus heuristics

visibility
  of functions, state, feedback

consistency
  within app, platform, domain, culture

constraints
  prevent errors
platform consistency

icons shown in Google Drive
platform consistency

icons shown in Google Drive

Grid view
platform consistency

icons shown in Google Drive
platform consistency

icons shown in Google Drive

design lesson: make sure same name or symbol used for a function or feature throughout
cultural consistency

why is ‘History’ greyed out?
heuristic: information scent

Amazon.com

ToysRUs.com
heuristic: information scent

design lesson: give good scent to aid information ‘foraging’
conclusions

to learn more, see references at http://tinyurl.com/acn-refs
conclusions

design thinking
will change software development

to learn more, see references at http://tinyurl.com/acn-refs
conclusions

design thinking
will change software development

brings good ideas
user-centeredness
incrementality
prototypes

to learn more, see references at http://tinyurl.com/acn-refs
conclusions

design thinking
will change software development

brings good ideas
user-centeredness
incrementality
prototypes

applied to software
focused data models
usability heuristics
concepts & purposes

to learn more, see references at http://tinyurl.com/acn-refs