Where Learning Meets Theory
Meets Technology Meets HCI Design

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Nanyang Technological University (NTU), Singapore
Greetings from Singapore!
From a Learning Scientist ...

• Consider the HCI and usability issues that afford renewed perspectives and practical implications to enhance the design and enactment of technology-enabled learning.

• Learning can be studied with different levels of analytical lenses - at the individual level, at the group level, the classroom level and at the community level.

• So different usability and design issues at each of these levels

• Learning practices needs theory, oftentimes technologies, HCI, deployment considerations

• This talk will look at the intersection of these spaces: the theories, the representations, the technologies, the usability issues

• How theory (e.g. cognitive load theory) shapes design, how technology (e.g. mobile technologies) can be designed to work around constraints and to exploit its affordances
Slide inspired by and adapted from Simon Buckingham Shum’s Keynote Address, International Conference of the Learning Sciences London Festival of Learning, June 2018, “Transitioning Education’s Knowledge Infrastructure Shaping Design or Shouting from the Touchline?”
We need also consider Human Factors:
- usability issues
- readiness of stakeholders
- participatory design cycles
- user interface design
- privacy and ethics
- end-user adoption
- organizational strategy
- staff training...

What is relevant for learning to happen in practice?

Slide adapted from Simon Buckingham Shum’s Keynote Address, International Conference of the Learning Sciences London Festival of Learning, June 2018, “Transitioning Education’s Knowledge Infrastructure Shaping Design or Shouting from the Touchline?”
Technology-enabled Learning as a Design Discipline

Learning

Ed Tech

Human Factors
1st case study: Educational Technology + Learning Sciences + HCl

> Educational technology
Screen-Level

VS

Deployment Level

Ben du Boulay in ICCE 2018 keynote
Usability in the classroom level: 
**Orchestration** issues

Takes into account design & real-time management

Orchestration is often guided by a design (e.g. in the form of a script), that may be flexibly modified during the enactment (automated or not) of the activity, in response to emergent occurrences

“Teacher centric” : User is the teacher!

Coordination of learning activities at multiple social levels

(Fischer & Dillenbourg, 2006)
Conceptual model of orchestration (Prieto, 2010)
Orchestrating learning is a complex practice

• **Awareness mechanisms**
  • that the teacher uses to assess the progress of the activity and decide on possible interventions;

• **Class management mechanisms**
  • including social and technological regulation mechanisms, e.g. to enforce that the design of the activity is followed; and

• **Adaptation or dynamic re-design of the activity**
  • in response to emergent occurrences during the activity (time and group management, tool usage and management, task/workflow modifications, etc).
From tight coercion to loose coercion

A spectrum of orchestration styles lies between from tight coercion to loose coercion.

We describe how orchestration varies by different teachers while they integrate a collaborative tool named GroupScribbles (GS) in language classes.
Rapid Collaborative Knowledge Improvement using a sharing tool called GroupScribbles
Cross-plane GS-enabled interaction pattern
Classroom environment
Technology Design
Using graphic organizer as an approach to orchestration design

A graphic organizer for new character & word learning

Graphic organizer for new character & word learning (secondary school example)
Funnel Model

1. Seek diversity of ideas
(多多益善)

2. Pool collective wisdom
(集思广益)

3. Seek greater perfection
(精益求精)

Space for inter-group interaction
Example for co-answering questions
Step 1: Seek diversity of ideas

Brainstorm answers for the guiding questions
Example for co-answering questions
Step 2: Pool collective wisdom

Re-organize and synthesize answers via FTF group discussion
Example for co-answering questions

Step 3: Inter-group visiting

Borrow good ideas and provide suggestions for other groups to realize knowledge improvement
Example for co-answering questions
Step 4: Seek greater perfection

Generate own group answers based on comments from other groups
Example for co-answering questions
Step 5: Presentation
**Example of Activity Design on collaborative writing based on Funnel Model**

<table>
<thead>
<tr>
<th>Step 1: Seek diversity of ideas</th>
<th>Step 2: Pool collective wisdom</th>
<th>Step 3: Inter-group visiting</th>
<th>Step 4: Seek greater perfection</th>
<th>Step 5: Group presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generate ideas for argumentative essay writing</td>
<td>Select and organize ideas</td>
<td>Look through other groups’ ideas; help other groups to improve their writing structure</td>
<td>Look back in own group to modify own group artifact based on comments given by other groups</td>
<td>Present the big idea and main structure of group writing</td>
</tr>
</tbody>
</table>
Class activity patterns orchestrated by the teacher
Physicality in the classroom: it varies and it matters
Physicality: Individual attention
Physicality: addressing group
Physicality: in front of class
Flexible Time Management
Awareness: Individual contributions
Awareness: via technology
Awareness: Resort also to Low-tech Feedback
Digital and Non-Digital Orchestration
But ...
Why orchestration design fails
So …

• An example of orchestration in a networked classroom for language learning
• 100 over GS lessons in science, math and language
• Some lessons did not “work well”
  • Teacher succumbed to constraints
• Different teachers have varied success
  • Linked to their beliefs and TPCK (Technological Pedagogical Content Knowledge)
Issues

• Balance (space) between too much “scripting” and empowerment of teachers
• Technology like GS leans to more “macro-scripts” and empowerment of teachers
  • Teachers need and can be real innovative
  • But they can fail to use the opportunities to orchestrate well ...
  • They need induction into productive practices/patterns
Visual representation of an activity enactment observed in a Spanish primary school classroom (Prieto et al, 2015)
HCI Research also looks at Levels of an Activity

HCI Research also looks at Levels of an Activity

Orchestration is often guided by a design (in the form of a script or not), that may be flexibly modified during the enactment (automated or not) of the activity, in response to emergent occurrences.

Surfing requires going with the flow and adapting to new situations as they emerge.

Conference theme: Surfing on the new wave
Technology-enabled Learning: User-Centred Design Discipline

- Learning
- Ed Tech
- Human Factors

Group learning and knowledge building
Technology-enabled Learning: User-Centred Design Discipline

Democratize participation
Group sharing and awareness
Technology-enabled Learning: User-Centred Design Discipline

Human Factors:
Orchestrating learning
Training teachers
Transforming teachers and students
2\textsuperscript{nd} case study: learning theory

\[ \rightarrow \]

influences/impacts on design
Human cognitive structure

Environment

Attention

Short-term memory
Working memory

Limited
Capacity: 7-9 chunks (without rehearsal)

Rehearsal ➔
Maintenance & Elaboration

Retrieve

Encode

Long-term memory

Schema Limitless

Forgotten
Cognitive Load Theory

• Basically, cognitive load theory asserts that learning is hampered when working memory capacity is exceeded during learning.
  • 2839876  V.S. 1287482176825

• New ideas, information and procedures must first be processed in the working memory before passing into the long term memory
Instructional design & Cognitive load

• Learning is “a change in long-term memory” (Kirschner, Sweller, & Clark, 2016 p. 77)

• “Novices need to use thinking skills. Experts use knowledge” (Sweller et al., 2011 p. 21)
  • The level of prior-knowledge affects the level of cognitive load (low achievements and high achievements)
  • The schema can be brought from long-term to working memory to process the learning materials
  • The element interactivity inside the learning materials need to be adjusted
Minimize Extraneous Load

Avoid the use of anything that distracts the learners and makes the learning process difficult.

Manage Intrinsic Load

Refers to the inherent complexity of the learning material. You cannot do much to reduce this load but it can be balanced.

Maximize Germane Load

It happens when the course is well designed. Proper techniques and tools are used to facilitate an effective learning process.
Ways to reduce cognitive load

• Reduce extraneous cognitive load
• Avoid redundancy unless necessary
• Use worked examples
• Use visuals if possible
• Use perspectives of maps, such as “concept map”
• Avoid split attention
• Use dual mode (hear and read/see) if possible
From Cognitive Load Theory to Collaborative Cognitive Load Theory

Collaborative Cognitive Load Principles (Kirschner, Sweller, Kirschner & Zambrano 2018)

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Task complexity</strong></td>
<td>Effective collaboration occurs when a task is complex enough to justify the extra time and effort involved in the necessary transactional activities. If a task is not complex enough, unnecessary transactional activities will cause extraneous cognitive load and will, thus be detrimental to learning.</td>
</tr>
<tr>
<td><strong>Task guidance &amp; support</strong></td>
<td>When learners face new collaborative situations and environments (e.g., in CSCL), the more guidance and support a task provides for collaborative learning, the lower the extraneous load caused by transactive activities.</td>
</tr>
<tr>
<td><strong>Domain expertise</strong></td>
<td>The greater the expertise of team members in the task domain, the lower the extraneous load caused by transactive activities.</td>
</tr>
<tr>
<td><strong>Collaboration skills</strong></td>
<td>The availability of collaboration skills of the team members will lower the extraneous load caused by transactive activities.</td>
</tr>
<tr>
<td><strong>Team size</strong></td>
<td>The more members that a team working on a learning task, the higher the number of transactive activities, and thus the extraneous load caused by transactive activities.</td>
</tr>
<tr>
<td><strong>Team roles</strong></td>
<td>Team roles make clear who has responsibility for what and as such will lower the extraneous load caused by transactive activities.</td>
</tr>
<tr>
<td><strong>Team composition</strong></td>
<td>The more heterogeneous the knowledge distribution among team members working on a learning task, the higher the extraneous load caused by transactive activities.</td>
</tr>
<tr>
<td><strong>Prior task experience</strong></td>
<td>The more experience team members have coordinating their actions on tasks in general (i.e., they know what to expect from each other in terms of task execution), the lower extraneous load caused by transactive activities.</td>
</tr>
</tbody>
</table>
When new technology becomes pervasive ...

• We want to understand its uniqueness and affordances
• and design it to be resonant with the learning theories
• Also look for opportunities for new designs and new theories
• Let’s look at the case of mobile learning
Mobile learning is distinguished from other forms of learning

- learners learn across space as they take ideas and learning resources obtained in one location and apply or develop them in another,
- learners learn across time by revisiting knowledge acquired earlier in a different context, which provides a framework for lifelong learning,
- learners move from topic by topic by managing a range of personal learning projects rather than sticking to a single curriculum, and
- learners move in and out of engagement with technology

https://techieword.com/advantages-of-mobile-learning/
Mobile learning is distinguished from other forms of learning

• how impromptu sites of learning are created out of offices, classrooms and lecture halls;

• the ubiquitous use of personal and shared technologies.

https://blog.wiziq.com/your-mobile-is-your-best-teacher/
Theorising mobile learning

- a theory of m-learning that re-conceptualizes learning by encompassing both
  - learning supported by the mobile technology and
  - learning characterized by the *mobility of people and knowledge* (Sharples, Taylor and Vavoula, 2007)

[http://learningfortress.com/three-mobile-learning-design-mistakes-that-everyones-making/](http://learningfortress.com/three-mobile-learning-design-mistakes-that-everyones-making/)
On the other hand, multiple environments and contexts may have unintended consequences on mobile learning.
Sources of cognitive load (Deegan, 2015)

Also, effects of the physical learning environment on cognitive load & theory (Choi, van Merrienboer & Paas, 2014)
Findings from mobile learning research resonant with CLT
Mobile CSCL

http://etec.ctlt.ubc.ca/510wiki/File:MCSCL_02.jpg
recurrent findings: smaller groups tend to collaborate and co-learn more effectively

• groups of 2 or 3 more optimal than groups of 4
  • a location-based mobile learning game,
  • learners' levels of engagement and immersion (Schwabe et al. 2005)

• subsequent studies (e.g., Melero, Hernández-Leo, & Manatunga, 2015; Zurita & Nussbaum, 2007) yielded similar results
recurrent findings: smaller groups tend to collaborate and co-learn more effectively

- the larger the group size, the more social or socialization overheads took place
  diluting group members' attention to the learning tasks such as their interactions with the authentic environments and the digital information provided by the device
- Consistent with: the larger the group size, the higher the extraneous load caused by transactive activities
An example of learning in groups of 3: learning mathematics
Miguel Nussbaum’s work (2008)
Susan drank blueberry juice last weekend. She drank three quarters of a liter on Saturday and half a liter on Sunday. How much did she drink in all?

Charlie says \( \frac{3}{4} + \frac{1}{2} = \frac{4}{6} \) of a liter

Susan says \( \frac{3}{4} + \frac{1}{2} = \frac{4}{4} \), or a liter

Whose answer is right? Explain your reasoning.
Susan drank blueberry juice last weekend. She drank three quarters of a liter on Saturday and half a liter on Sunday. How much did she drink in all?

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<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neither</td>
<td>neither</td>
</tr>
<tr>
<td>( \frac{3}{4} + \frac{1}{2} = \frac{6}{4} )</td>
<td>( \frac{3}{4} + \frac{1}{2} = \frac{6}{4} )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group 4</th>
<th>Group 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neither</td>
<td>neither</td>
</tr>
<tr>
<td>( \frac{5}{4} = \frac{25}{20} ) and ( \frac{4}{4} = 1 )</td>
<td>( \frac{5}{4} = \frac{25}{20} )</td>
</tr>
</tbody>
</table>

Neither Charlie nor Susan are right.

\( \frac{3}{4} + \frac{1}{2} = \frac{3}{4} + \frac{2}{4} = \frac{3 + 2}{4} = \frac{5}{4} = 1.25 \) liters

Conclusion
Distributed working memory: learning fractions or Chinese characters
Task Design: Present individual portions of an assigned learning task and students form groups

CLT Principle: Collective working memory

• Learners are each assigned fractions or parts of Chinese characters, and they need to coordinate with others to form desired fractions or characters.

• Collaboration takes the form of forming emergent groups or patterns imposed by the task requirements.

Boticki et al. (2011) and Wong, Boticki, Sun, and Looi (2011)
A fraction assigned and displayed on a student’s mobile device
Mobile learning for different purposes

• Early mobile learning design in which students learn from information presented on the mobile devices
  • Episodic
  • Cognitive learning from content presented on the devices
• There are other designs of mobile learning!
• We share one of them here – seamless learning
Where could learning happen?
What is **Seamless Learning?**

- **Learn**
- **Apply**
- **Reflect**
- **Unlearn**
- **Relearn**

**Bridging**

**Recontextualization**

**Digital Physical**

**Formal Informal**

**Individual Social**
Informal and Formal Learning

(LIFE Center: Stevens, R. Bransford, J. & Stevens, A., 2005)
Seamless Learning

- Continuity of the learning experiences across different contexts/spaces (Chan et al., 2006)
  - Formal + informal
  - Individual + social
  - Physical + digital ...

- Not just learning anytime, anywhere, but *bridging* of the learning processes and outcomes (Wong, 2012)
Type II
Planned learning out of class
E.g. Field trip to heritage site which is part of a school curriculum

Type III
Emergent learning out of class
E.g. Using mobile phones to capture pictures and video clips of animal and directed by self-interest

Type I
Planned learning in class
E.g. Searching for answers in the classroom

Emergent learning in class
E.g. Teachable moments not planned by the teachers

Planned

Emergent

(Chen, Seow, So, Toh & Looi, 2010).
Case Study 1: SEAMLESS Project ➢ WE Learn
Work in Singapore: Science lessons via mobile learning in a Primary 3 & 4 classes
Lesson Package for learning Plant Systems

Goals of Lesson

Experiment (video)

KWL

Comparison Table

Sketchy

PiCo Map

Picture Taking

Taking Sketchy PiCo Map
A trajectory of research work

Seamless science pedagogy: P3-P4
Piloted @ 1 class, Primary School in Singapore (SG)

Science + English, P3-P4
Level-wide scaling up in Primary School

Diffused to 10 more schools

PD: 4 science teachers (began)
PD: teachers of entire level (began)
PD: 10-school teachers’ PD began

Case Study 2: Move, Idioms!

MyCLOUD
### Examples of Student Artifacts

<table>
<thead>
<tr>
<th>Idioms</th>
<th>Artifact created within the school</th>
<th>Artifact created at home</th>
<th>Artifact created in other locations</th>
</tr>
</thead>
</table>
| 东倒西歪
Rickey                 | ![Photo of student manipulating a chair and ball](image1.jpg) (the student manipulated the chair and the ball to create the context for the artifact) | ![Photo of standing fan at home](image2.jpg) (the student manipulated the standing fan at home) | ![Photo of a tree in the neighborhood](image3.jpg) (a tree at the neighborhood; the twisted camera angle further highlights the meaning of the idiom) |
| 争先恐后
Striving to be the first | ![Photo of students enacting a scenario](image4.jpg) (students enacting a scenario)           | ![Photo of Singapore dollar notes on the floor](image5.jpg) (Singapore dollar notes on the floor) | ![Photo of a standee in a cinema](image6.jpg) (a standee in a cinema)                               |
| 指手画脚
Gesticulating          | ![Photo of a visiting educator from Kuwait pointing his finger at the students](image7.jpg)  | ![Photo of a student's nagging father](image8.jpg) (a student's nagging father)          | ![Photo of street performers outside a museum](image9.jpg) (street performers outside a museum)     |
### Turning home into my ‘learning playground’

(Wong, 2013b)

<table>
<thead>
<tr>
<th>Image</th>
<th>Description</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td>三五成群</td>
<td>April 7, 2010</td>
</tr>
<tr>
<td><img src="image2.png" alt="Image" /></td>
<td>人山人海</td>
<td>May 20, 2010</td>
</tr>
<tr>
<td><img src="image3.png" alt="Image" /></td>
<td>三五成群</td>
<td>May 20, 2010</td>
</tr>
<tr>
<td><img src="image4.png" alt="Image" /></td>
<td>争先恐后</td>
<td>May 20, 2010</td>
</tr>
<tr>
<td><img src="image5.png" alt="Image" /></td>
<td>一模一样的</td>
<td>May 20, 2010</td>
</tr>
<tr>
<td><img src="image6.png" alt="Image" /></td>
<td>目瞪口呆</td>
<td>May 20, 2010</td>
</tr>
<tr>
<td><img src="image7.png" alt="Image" /></td>
<td>目不转睛</td>
<td>May 20, 2010</td>
</tr>
<tr>
<td><img src="image8.png" alt="Image" /></td>
<td>争先恐后</td>
<td>October 13, 2010</td>
</tr>
<tr>
<td><img src="image9.png" alt="Image" /></td>
<td>争先恐后</td>
<td>September 10, 2010</td>
</tr>
<tr>
<td><img src="image10.png" alt="Image" /></td>
<td>三五成群</td>
<td>October 13, 2010</td>
</tr>
</tbody>
</table>
So these are 2 of several seamless learning curricular interventions in schools
Principles for Designing a Seamless Learning Curricular Innovation:

1. Design for emergent learning, and for personally and socially meaningful goals
2. Making thinking visible
3. Plan for enough time to do learning activities
4. Design for technology ready-at-hand (in and out of class)
5. Design for seamlessness (bridging across contexts)
6. Design alternative assessments (to test new competencies)
7. Design not for direct conversion from paper-based curriculum

Principles for Designing a Seamless Learning Curricular Innovation: Ways to reduce Cognitive Load

1. Design for emergent learning, and for personally and socially meaningful goals
2. Making thinking visible
3. Plan for enough time to do learning activities
4. Design for technology ready-at-hand (in and out of class)
5. Design for seamlessness (bridging across contexts)

Explaining the seams that are crossed

• Crossing individual and social learning spaces
  • Individual memory vs collective memory

• Crossing formal and informal learning spaces
  • Situated learning
  • Re-contextualizing learning
  • Schema activation and construction in different contexts

• Crossing physical and digital spaces
  • Learning with different affordances/interactive experiences
  • Schema activation and construction in different contexts
Putting more into long-term memory

• also human memory is consolidated more when students encounter a situation multiple times (the issue of repetition)

• cognitive data have shown abundant evidence that the act of retrieval induced by a recall test can be considered more potent than a passive study opportunity in facilitating long-term recall (Bjork, 1988; Landauer & Bjork, 1978)

Mobile devices capture contextual info

• Mobile devices provide knowledge augmentation

• By capturing direct info and peripheral context on a field trip or visit
  • Schema construction is made easier if knowledge is associated with context of use
  • Schema construction and automation processes reduce the load on WM (Paas & Ayres, 2014)

• The learner can re-visit that learning context at a later time, to reflect on the experience, extract new understanding, compare knowledge with other visitors and abstract share memories
Mobile devices as cognitive augmentation?

• Hypothesis: students do not have to hold everything in their heads as they can use external mobile tools, thereby reducing cognitive load
• Effects as cognitive prosthetics

Relating to Cognitive Load Theory ... some hypothesis

• Boundaries and seams in learning are removed by integrating elements from one context into the other

• Use mobile technology in different contexts to transfer experiences from one context to another

• Two distinct contexts become one enlarged, integrated context

• Hypothesis: mental schemas from different contexts become one enhanced schema
An example: learning idioms/vocabulary

• In Wong et al. (2010), with their personal smartphones, language learners share individually- or co-created social media pertaining to their real-life encounters by utilizing recently learned vocabulary.

• They then comment on their peers’ postings and review (or correct) the vocabulary usage on the social network space.
Collaborative learning with mobile devices

- Applying the borrowing and re-organizing principle (Pass & Sweller, 2012)
  - Knowledge can be borrowed from other members of the group, and reorganized, linking new knowledge with old knowledge stored in LTM

| The objects in the cupboard are rickety. | My bottle is rickety and lied down. | The books in my brother's bookcase are rickety and disorder! | My brother makes his study desk rickety. |

- Group interactions can help individuals make sense of the information and steer the re-organization of information
Broad challenge

• Challenge for research is to bring our understanding of
  • experiential and lifelong learning,
  • human memory and recall,
  • learning through inquiry and conversation, and
  • physical and social contexts

• To the design of a new generation of technologies that promote long-term seamless learning

Potential of Seamless Learning:

• Lessen limitations to human learning such as
  • Difficulties of transferring learned knowledge from one setting to another
  • Recalling a previous learning episode at a different time and space

• Support learning by accessing information in context
Challenge: find load-reducing approaches for intensive knowledge producing mechanisms

• learning from multiple representations (e.g., Ainsworth 2006; Brenner et al. 1997), self-explanations (Chi et al. 1994), inquiry learning (Linn et al. 2006), collaborative learning (Lou et al. 2001), or game-based learning (Nelson and Erlandson 2008)

• combining these approaches, which strongly stimulate germane processes, with enough structure to avoid cognitive overload will most probably be one of the leading research themes in the near future (de Jong 2006; Kirschner et al. 2006; Mayer 2004)
Summary: seamless learning

- Multiple representations
- Multiple tools
- Boundary objects
  - Objects interpreted in different settings/contexts
- Multiple interactions with multiple users
- Hypothesis: removal of seams leads to reduction in cognitive load
  - Learners draw on a range of resources to learn
Technology-enabled Learning: User-Centred Design Discipline

Learning

Ed Tech

Human Factors

Learning theories support, guide and constrain design!
Ed Technologies afford new learning possibilities, blurring the boundary between formal and informal learning.
Technology-enabled Learning: User-Centred Design Discipline

Learning
Ed Tech
Human Factors

Human Factors:
Learning with mobility
Remove the seams of learning
Technology-enabled Learning: User-Centred Design Discipline

Human Factors:
New embodied experiences (HCI) →
Internalization of Knowledge →
Knowledge Construction and Application
Ancient Chinese Philosopher Wang Yangming
Integration of Knowing and Doing

• Wang believed that only through simultaneous action could one gain knowledge and denied all other ways of gaining it.

• “Knowledge is the beginning of action and action is the completion of knowledge. Learning to be a sage involves only one effort. Knowledge and action should not be separated.”
Knowledge is the beginning of practice; doing is the completion of knowing.

Wang Yangming
Technology-enabled Learning: User-Centred Design Discipline

Human Factors:
New embodied experiences (HCI) →
Internalization of Knowledge →
Knowledge Construction and Application

Echoing “Integration of Knowing and Doing” by Wang Yangming
Take home message:

Need inter-disciplinary, 
cross-disciplinary research; 
Design thinking; User-centred and 
Learner-centred perspectives
Take home message:

In considering learning designs, “usability” takes different forms: at individual level, at group level, at classroom level, at community level, ...
Take home message:
Learning theories can inform design:
Mobile devices constrains and yet with appropriate design is liberating!

https://en.wikipedia.org/wiki/Big_wave_surfing
Team and Collaborators
Team and Collaborators
Acknowledgements

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prepared by
Carol Hui-Chun Chu
Department of Computer Science and Information Management
Soochow University
Taiwan

朱蕙君 - 台湾東吳大學 資訊管理系
감사합니다!