Intro to Learning Sciences

Lectures 22 and 23, October 30 and Nov 4, 2025
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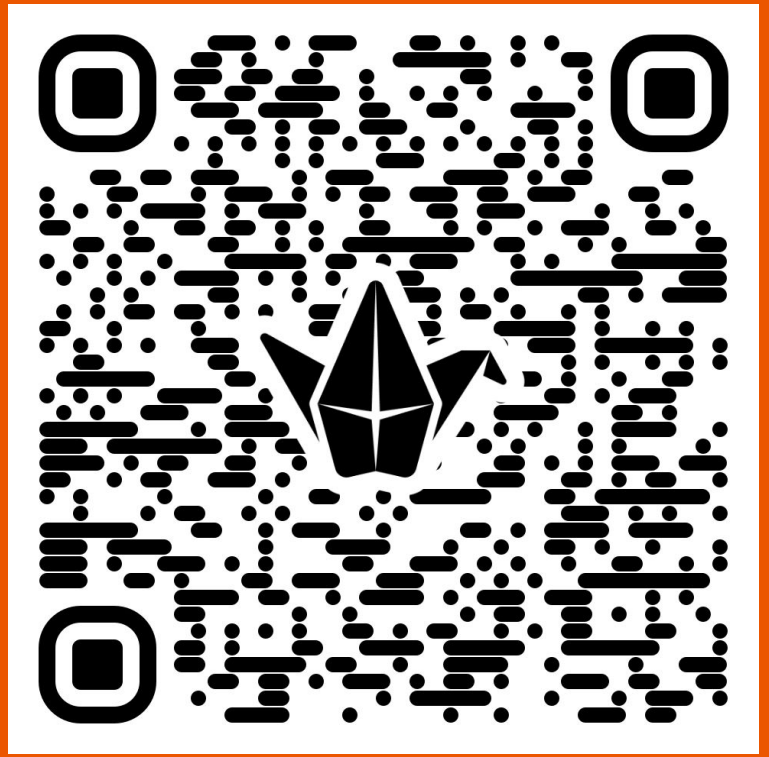
Reflection - the course so far

- Theories of how people learn based on different assumptions regarding
  - The nature of the learner
  - Their motivations for learning
  - What do they learn
  - What does it mean to learn
- But our goal is to design learning environments
- So, what do we need next?
  - **Design principles!**

Share (each one say two): Design principles from all the theories read so far



Design Principles

- Generate cognitive conflict
- Provide opportunities for exploration by creating useful problem situations
  - Give students a “construction kit” so they have agency to choose their problem
- Have multiple activities or kits in a classroom aligned with developmental stages and interests of different students
- Desirable features in the activity:
  - Make the activity intuitive, engaging and with an appealing and relatable context
  - Engage students in inventing or designing something in open-ended problems
  - Have multiple solutions and representations
  - Use contrasting cases - cases across which some features are constant and some vary - to bring about specific kinds of failure
- Give students agency to approach in any way, but probe solution process
  - Bricolage or planned
- Provide desirable difficulties
  - Allow learners to be in a state of “flow” where challenge and ability is balanced

Design Principles

- Stay in learner's ZPD
- Design scaffolds - ie, tools, signs and social interactions
  - modify the environment by creating tools, and thinking by creating signs
    - give hints to guide understanding about how to do activities
    - use labels to classify objects and events
    - frame or model language and behavior
    - help the child connect a new situation to a more familiar one
    - reduce the number of steps required to solve a problem
    - demonstrate an idealized version of the act to be performed
  - maintain pursuit of a goal by directing activity and motivational feedback
  - control frustration and risk
  - interest the child in the task
  - structure interactions with peers

Design Principles

- Facilitate reflection on conflict to assimilate or accommodate experience to existing scheme
  - Lead student from concrete, close to object thinking to formal, abstract thinking
- Build on students activities by:
  - Compare and contrast students solutions to distill critical features
  - Direct student attention to notice these critical features
  - Assemble the critical features into the “correct” form of the concept
  - Unpack moments of “failure”
- Provide direct instruction about the concept
  - Build on prior knowledge

Design Principles

- Let the newcomer experience the practice, the space, tools and discourse practices in its most authentic form
  - Flatten the hierarchy so the newcomer feels included and that they have a voice
  - Reinforce their identity from the start to increase motivation
- Provide opportunities for legitimate peripheral participation
  - Design tasks that an oldtimer/experienced practitioner would do and let the newcomer do a small part of it - provide agency
  - Gradually increase the complexity of the tasks the newcomer does
- Create the concentric circle of expertise.
  - Help the newcomer learn from the “circle of experts” centripetally nearest to them through observing, questioning and reflecting
  - Facilitate the nearest experts to monitor their nearest newcomers and help them reflect

What is common across these principles?

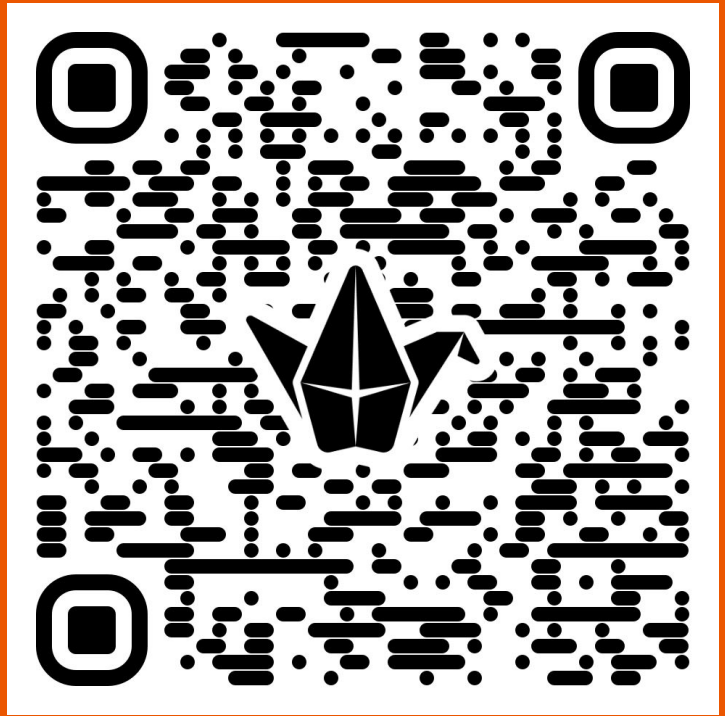
- Experience or activity
- Reflection

Group activity (10 mins):

Consider one of the following topics:

1) Newton's first law of motion
2) Photosynthesis
3) Seasons

Use the design principles we just identified to create a learning activity on one of the above topics, with appropriate justification.



Debrief: what kind of activities

1. Discussion to build a connect to real-life - making a 3d model regarding seasons
2. Activity kit + guided questions
3.

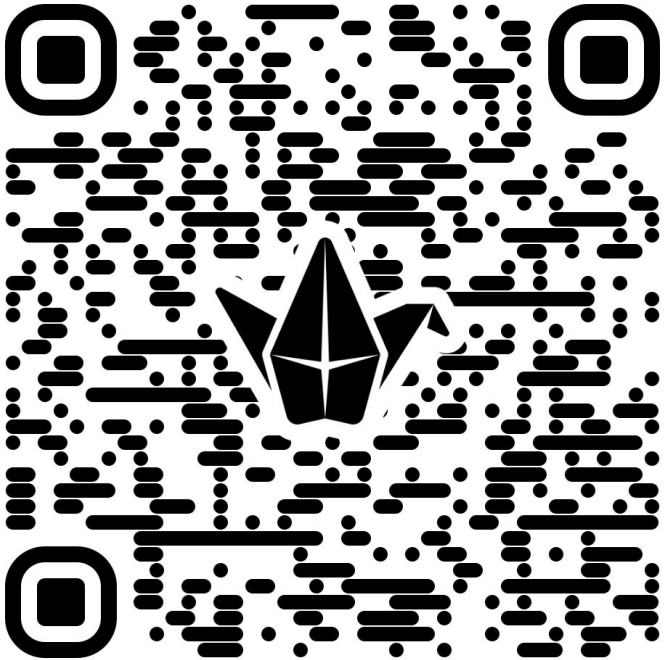
The complementarity and tension between exploration and guidance

Kirschner, Sweller, Clark

- Human cognitive architecture is incompatible with minimally guided instruction
- There is evidence that strongly guided instruction leads to more effective and efficient learning
- More structured instruction benefit more novice learners and less structured instruction benefit learners with more expertise => Discovery learning after some instruction
- Practicing a discipline not the same as *learning to practice* a discipline
- Problem-based learning needs explicit teaching of PS strategies and problem-specific basic content

Hmelo-Silver, Duncan, Chinn

- PBL and IL are not minimally guided - heavily scaffolded - structured, including direct, JIT instruction and problematized to stop “mindless progress”.
- Teachers scaffold mindful and productive engagement with task, tools and peers.
- Scaffolding:
  - makes disciplinary ways of thinking and doing explicit
  - provides expert guidance directly
  - structures complex tasks and supports process management.
  - can automate certain tasks that are irrelevant to the learning goals and help learners focus on what is relevant.
- PBL and IL participants perform as well on declarative knowledge while performing better on reasoning strategies/knowledge application, even “weaker” students and especially socially disadvantaged groups.



REFLECT: Which approach did you choose?

Designing Scaffolding

The more important questions to ask are ***under what circumstances do these guided inquiry approaches work****, what are the kinds of outcomes for which they are effective, what kinds of valued practices do they promote, and* ***what kinds of support and scaffolding are needed for different populations and learning goals****.*

Understanding the mechanisms of scaffolding

- Learners need to accomplish a task, but also *learn from the efforts*
- The need for maintaining a delicate balance between providing support and ensuring productive work on the complex task.
- How does a (software) tool act as a scaffold? The mechanisms need to be characterized for better design.
- Consider tool and person as a distributed system
- Needs of learners:
    - Sense-making - conceptual knowledge
    - Process management - domain-specific strategies and process skills
    - Articulation and reflection - metacognitive processes

Challenges of learners

- Tacit knowledge and unfamiliar domain-specific explanations, strategies and heuristics
- More than products (nonreflective work) - reflection and articulation to abstract from products (solutions/ arguments/explanations) to general disciplinary frameworks
- See the underlying structure - map intuitive understanding to scientific constructs and formal representations, overconfident in self-assessment
- Keeping track of social interactions - weigh opinions, keep track of alternatives, offer and learn from critiques
- Using discourse appropriately - use of appropriate language and connect language with the practices

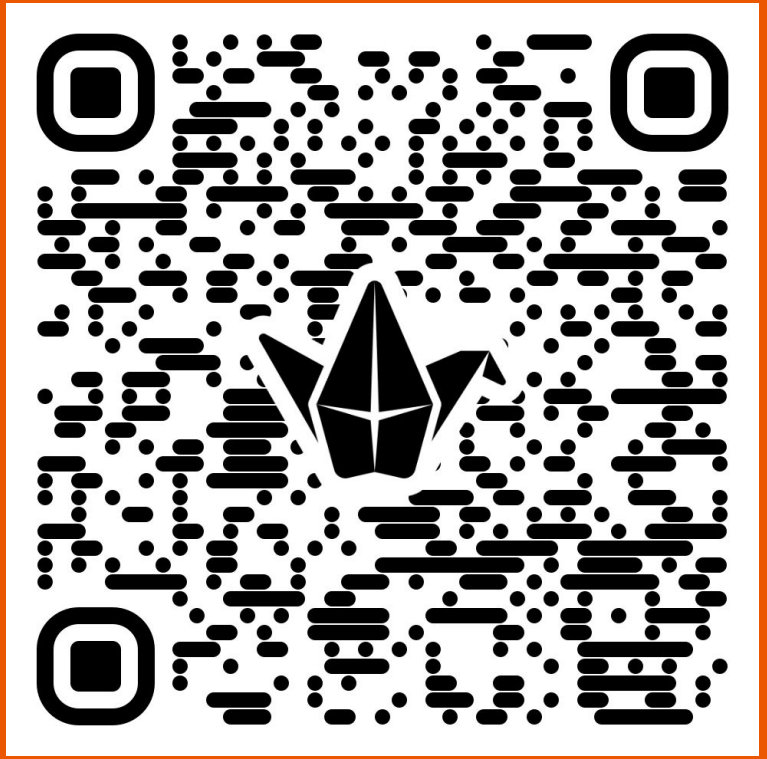
Roles of tools

- As a way to offload parts of the task that are not crucial for learning, allow learners to focus on tasks that are productive for learning
- Tools create new representations that are more usable, transform the task - make it more tractable, extend the range of what the users can do
- Tools can change the nature of interactions between collaborators
- Tools create representations that map to the world - this mapping must be clear for learners
    - These representations can be designed in certain ways to change the way learners think about tasks

Examples of Scaffolding strategies

1. Leverage prior knowledge - conceptual “hooks”
2. Graphic organizers
3. Modeling
4. Chunking
5. Differentiation
6. Cooperative learning
7. Visual aids - videos, animations, simulations

PAIR ACTIVITY: Three different lesson designs



Debrief: Strengths and weaknesses of each design

1. Strengths: Easy to follow and do

   Weaknesses: Non reflective work

2. Strengths: It does not limit the kinds of problem to be identified, better for higher ed students, teaches how to plan and execute the research, how and where to start

Weaknesses: Cognitive load

3. Strengths: Layered problems, different factors introduced, overall understanding of the problem, metacognition, Directed learning + subset discovery with prompts, can't see the broader picture
   a. Initial questions are very directed, but the reflection prompts are general and make you think broader - prompts pre-empt the missing links that students are likely to miss
   b. Weakenesses: Too many scaffolds - simple to complex - which grade decides

Structuring

1) Adding constraints or decreasing degrees of freedom to reduce the complexity of the task.
2) Decomposing complex tasks:
    a) Overcome challenge of unfamiliar strategies by indicating important goals
    b) Help with non reflective work
    c) Help groups organize work for themselves
3) Focusing Effort: Restricting the problem space by narrowing options or offloading routine parts of the work
    a) Overcome challenge of unfamiliar strategies
    b) Help working together more effectively
4) Monitoring: Keep track of plans and monitor progress (criteria)
    a) Helps with the tendency for nonreflective work
    b) Tie in relevant disciplinary ideas during sense-making and communication

Example of structuring