

# How Do We Design for Concreteness Fading? Survey, General Framework, and Design Dimensions

Sangho Suh, Martinet Lee, Edith Law



**WATERLOO** **HCI**

Since ...

2020



2002

## 1st IDC Conference

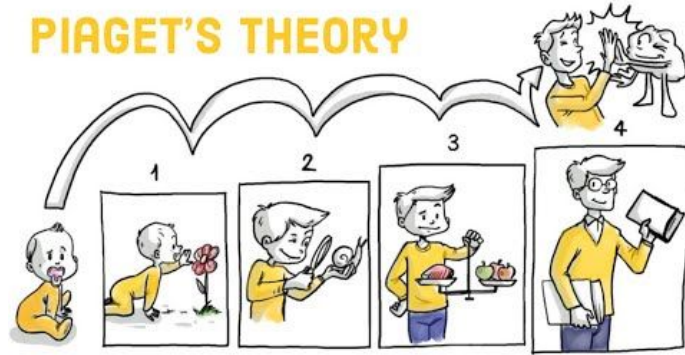


Computers and

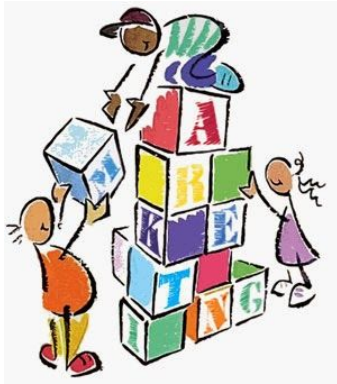
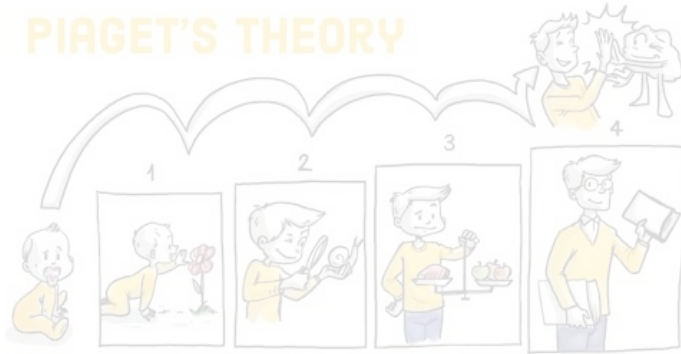
Allison Druin,  
chi-Bulletin-Kids@a

**Interaction Design and Children (IDC 2002)**

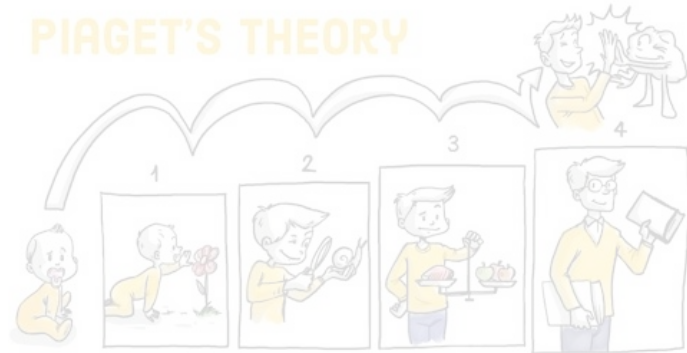
# Piaget's Theory of Cognitive Development



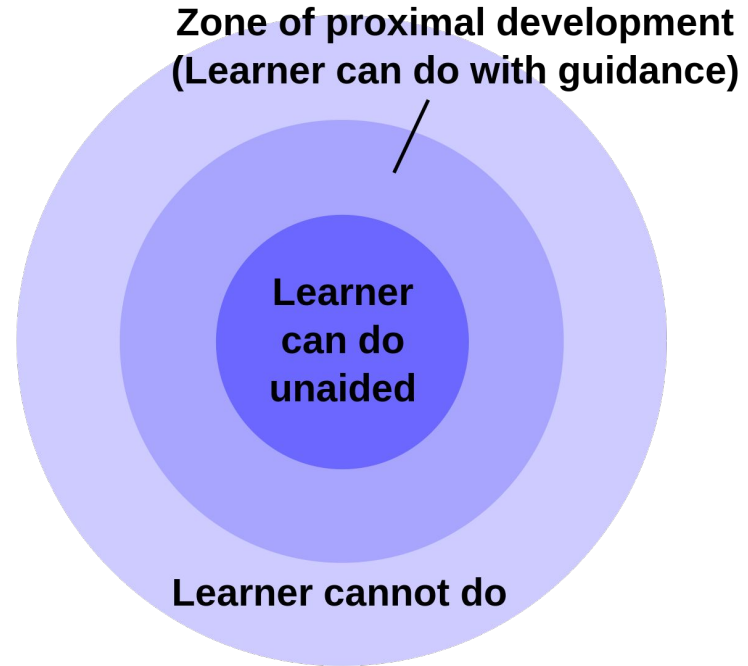
# Constructivism



# Scaffolding



# Zone of Proximal Development



# While they are different ...

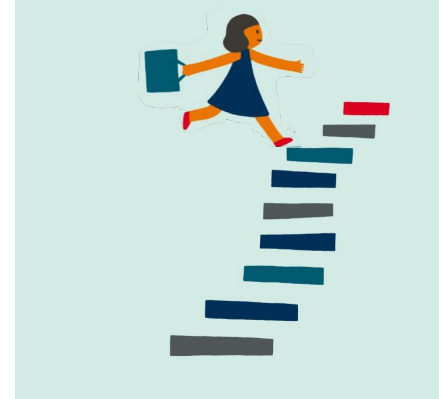
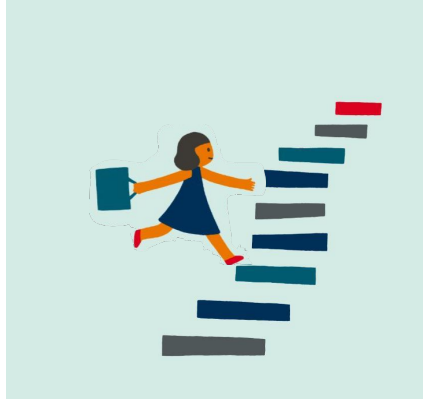
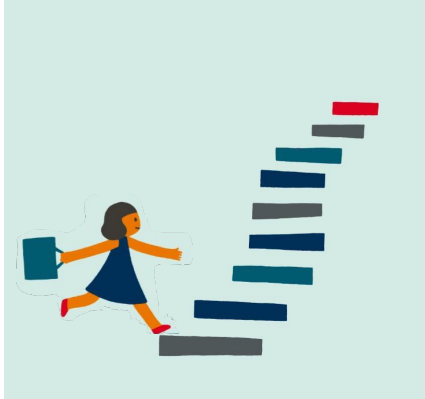


Zone of proximal development  
(Learner can do with guidance)

Learner  
can do  
unaided

Learner cannot do

At high level, they share the same idea ...



**Concrete**



**Abstract**



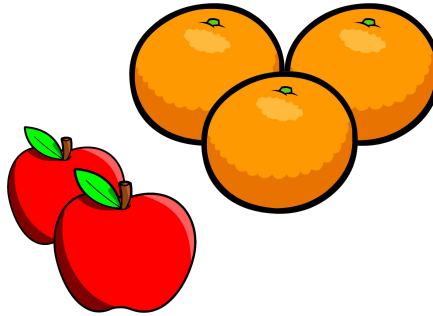
Concreteness fading uses this idea ...

... for teaching abstract concepts

Physical  
Representation



Pictorial  
Representation



Abstract  
Representation

$$2 + 3$$

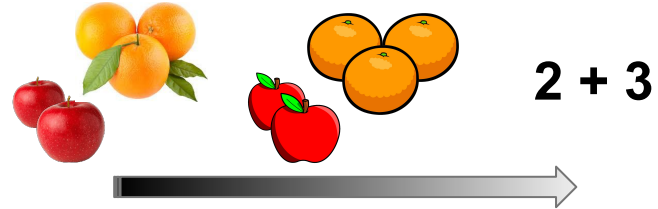
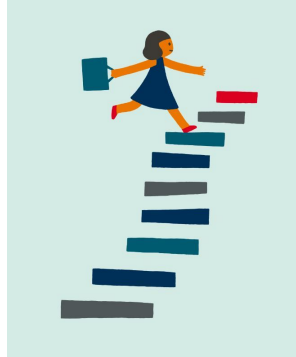
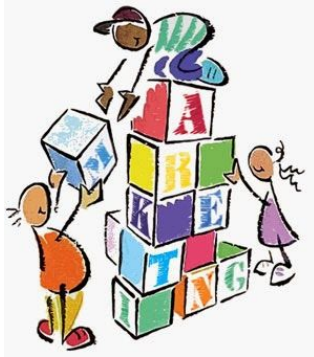
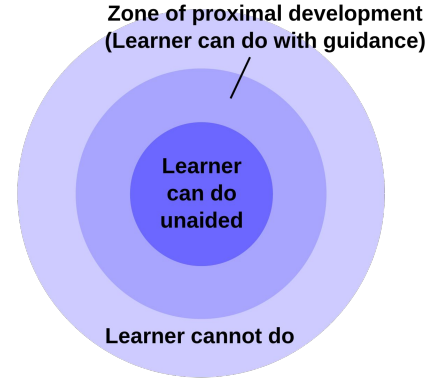
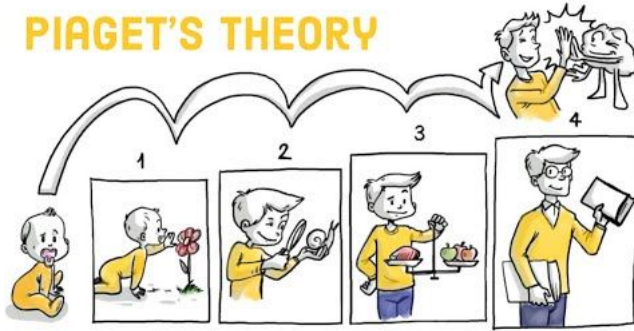
**Concrete**



Abstract

Since it is well-aligned with these theories ...

## PIAGET'S THEORY



## It has been widely used for children's education

Domain	Number of Papers
Math	177
Science	19
Computing	10
Others	13

\* Papers between 1966 and 2019

# Unfortunately

- Concreteness fading remains an underspecified technique without a clear guideline on how to design it, resulting in several problems, e.g.,
  - conflicting results due to design inconsistencies
  - lack of a shared vocabulary for reference and comparison
  - barriers to researchers interested in learning and using it

Thus we wanted to examine ...

**RQ1:** What are the **existing designs** for concreteness fading?

**RQ2:** What is the general framework we can derive from the previous designs and literature?

**RQ3:** What are the design dimensions and issues to consider when designing it?

Derive ...

RQ1: What are the existing designs for concreteness fading?

RQ2: What is the **general framework** we can derive from the previous designs and literature?

RQ3: What are the design dimensions and issues to consider when designing it?

## Identify ...

**RQ1:** What are the existing designs for concreteness fading?

**RQ2:** What is the general framework we can derive from the previous designs and literature?

**RQ3:** What are the **design dimensions** and issues to consider when designing it?



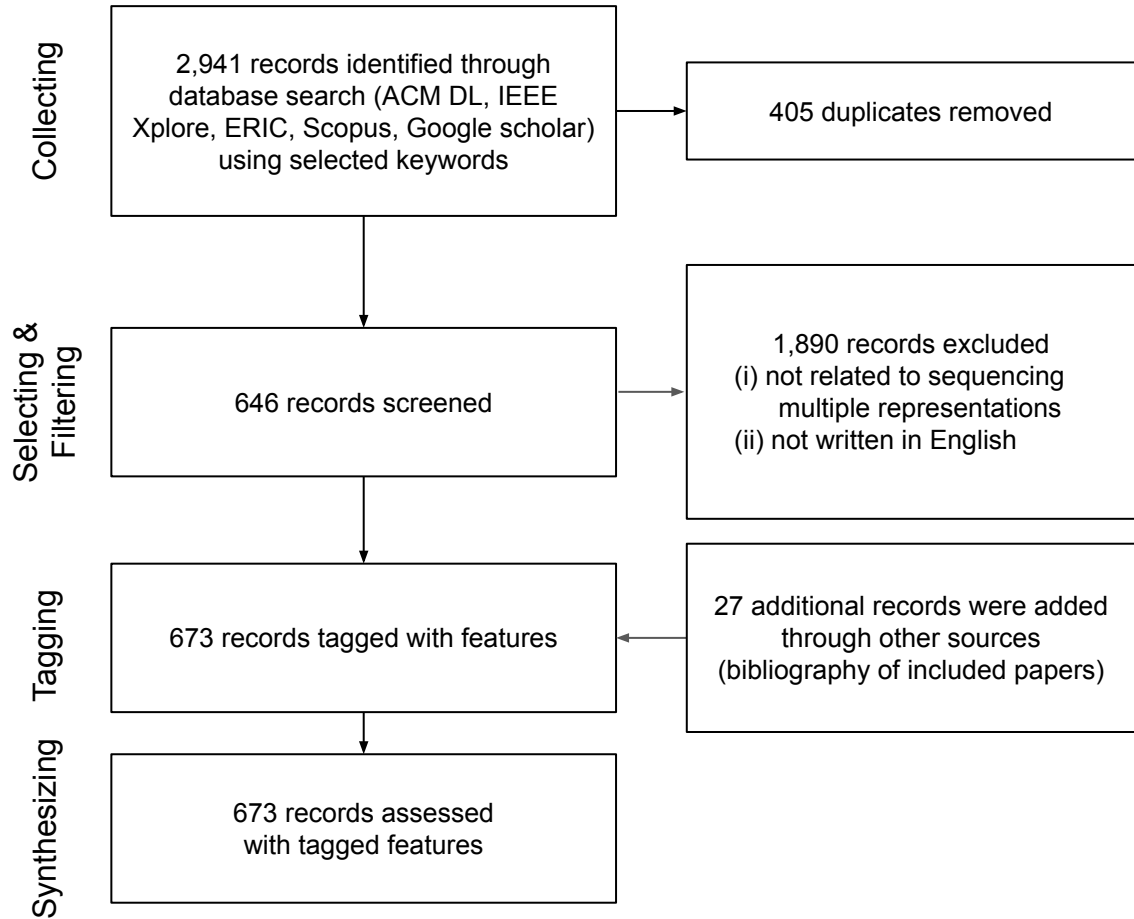
## In order to ...

- Support future researchers interested in learning and using this technique
- Formulate a shared vocabulary for reference and comparison between different forms of concreteness fading

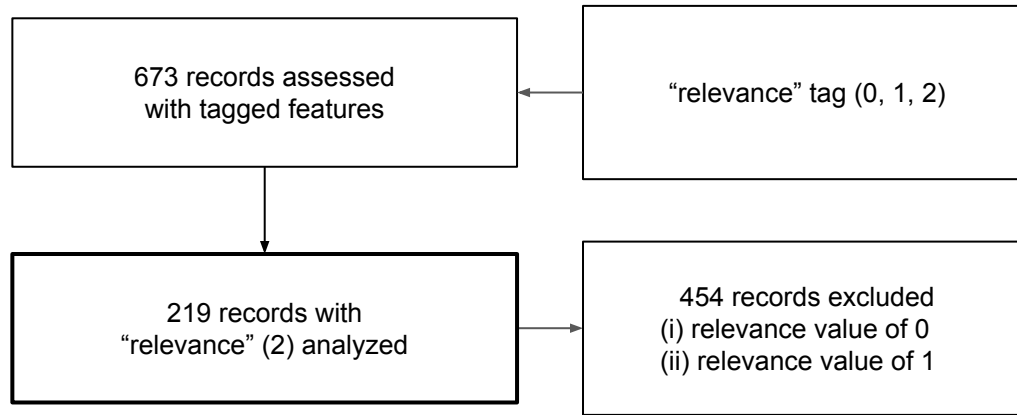
## In order to ...

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# Methodology



Synthesizing



# Results

# RQ1: What are the existing designs?

Different implementation structures & naming schemes of concreteness fading identified during our systematic literature review

	Stage 1	Stage 2	Stage 3
CRA	<b>C</b> oncrete	<b>R</b> epresentational	<b>A</b> bstract
CPA	<b>C</b> oncrete	<b>P</b> ictorial	<b>A</b> bstract
CSA	<b>C</b> oncrete	<b>S</b> emi-concrete	<b>A</b> bstract
VRA	<b>V</b> irtual	<b>R</b> epresentational	<b>A</b> bstract
CA	<b>C</b> oncrete	-	<b>A</b> bstract
VA	<b>V</b> irtual	-	<b>A</b> bstract
RA	-	<b>R</b> epresentational	<b>A</b> bstract

## RQ2: What is the general framework?

- Concreteness fading consists of a set of stages, where each stage can have a unique number of lessons.

A concreteness fading framework consists of a set of stages  $s_i$  where  $i = 1 \dots S$  and  $S \geq 2$ . Each stage  $s_i$  contains a set of lessons  $l_{i,j}$  where  $j = 1 \dots L_{si}$  and  $L_{si} \geq 1$ .



# RQ3: What are the design dimensions?

D1. Order of Progression

D2. Number of Stages

D3. Representation

D4. Presentation

D5. Connection between Representations

D6. Within-Lesson vs Across-Lesson Fading

# Summary

- Our work fills an important gap in concreteness fading research, as no prior work has proposed a design space for concreteness fading through a comprehensive literature review.
- While there have been past literature reviews focusing on specific forms of concreteness fading, this is the first to inform all of its variations and analyze them to derive a general framework and elucidate design dimensions.
- We open source our dataset through a Github repository and invite other researchers to use and contribute to this corpus, to update our understanding of the technique with new findings and materials.

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