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

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Since ...

1st IDC Conference
Piaget’s Theory of Cognitive Development

Credit: https://www.youtube.com/watch?v=lhcqYqx7aAA
Constructivism

Credit: https://venngage.com/
Scaffolding

Credit: https://eltlearningjourneys.com/
Zone of Proximal Development

Credit: https://eltlearningjourneys.com/
While they are different ...
At high level, they share the same idea ...
Concreteness fading uses this idea ...
... for teaching abstract concepts

- **Concrete**
  - Physical Representation
  - Pictorial Representation

- **Abstract**
  - Abstract Representation

2 + 3
Since it is well-aligned with these theories ...
### Domain and Number of Papers

<table>
<thead>
<tr>
<th>Domain</th>
<th>Number of Papers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math</td>
<td>177</td>
</tr>
<tr>
<td>Science</td>
<td>19</td>
</tr>
<tr>
<td>Computing</td>
<td>10</td>
</tr>
<tr>
<td>Others</td>
<td>13</td>
</tr>
</tbody>
</table>

*Papers between 1966 and 2019*

It has been widely used for children’s education

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
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- Support future researchers interested in learning and using this technique
- Formulate a shared vocabulary for reference and comparison between different forms of concreteness fading
Methodology
2,941 records identified through database search (ACM DL, IEEE Xplore, ERIC, Scopus, Google scholar) using selected keywords

405 duplicates removed

646 records screened

1,890 records excluded
(i) not related to sequencing multiple representations
(ii) not written in English

673 records tagged with features

27 additional records were added through other sources (bibliography of included papers)

673 records assessed with tagged features
673 records assessed with tagged features

“relevance” tag (0, 1, 2)

219 records with “relevance” (2) analyzed

454 records excluded
(i) relevance value of 0
(ii) relevance value of 1
Results
RQ1: What are the existing designs?

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRA</td>
<td>Concrete</td>
<td>Representational</td>
<td>Abstract</td>
</tr>
<tr>
<td>CPA</td>
<td>Concrete</td>
<td>Pictorial</td>
<td>Abstract</td>
</tr>
<tr>
<td>CSA</td>
<td>Concrete</td>
<td>Semi-concrete</td>
<td>Abstract</td>
</tr>
<tr>
<td>VRA</td>
<td>Virtual</td>
<td>Representational</td>
<td>Abstract</td>
</tr>
<tr>
<td>CA</td>
<td>Concrete</td>
<td>-</td>
<td>Abstract</td>
</tr>
<tr>
<td>VA</td>
<td>Virtual</td>
<td>-</td>
<td>Abstract</td>
</tr>
<tr>
<td>RA</td>
<td>-</td>
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<td>Abstract</td>
</tr>
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</table>
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 $i = 1 \ldots S$ and $S \geq 2$. Each stage $s_i$ contains a set of lessons $l_{i,j}$ where $j = 1 \ldots L_{si}$ 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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