Inherent Advantages of Augmented Reality for K–12 Education

A Review of Augmented Reality Learning Experiences

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Presentation has three parts.

1. Report a survey of Augmented Reality Learning Experiences (ARLEs.)
   - Objectives
   - Method
   - Results

2. Propose a participatory design model for ARLEs.

3. Illustrate the use of participatory design.
   - Developing AR x-ray interaction
   - Paper-prototyping for authoring AR content
Defining AR learning experiences imposes logical uses in education.

Augmented Reality Learning Experience (ARLE) “any form of personal experience designed to improve knowledge, facilitated by integrating virtual elements onto a real environment.”

Augmented Reality Interactions Necessary? Beneficial? Cost-effective?

Educational Interaction

Actual Classroom Use*

*Picture from http://newsinfo.inquirer.net/194569/public-schools-to-give-priority-to-early-enrollees
Conduct a review to understand AR interactions in education.

1. To find empirical proof that AR interactions can be beneficial to learning

2. To observe trends in implementation and evaluation that led to good interfaces
Approach for the survey

1. Search digital libraries
   - IEEE digital library
   - ACM digital library
   - Learning technology publications

2. Filter using criteria
   - Prototype
   - K-12 Education
   - Availability

3. Gather data
   - publication details
   - prototype description
   - use of AR
   - user study

4. Analysis and synthesis
We found 87 ARLE articles.

Type of Publication

- Journal: 15
- Conference: 72

Is it IEEE-Indexed?

- Yes: 26
- No: 61

- Computers and Education
- IEEE Wireless, Mobile and Ubiquitous Technology in Education
- IEEE Virtual Reality
- IEEE Int'l Symp. on Mixed and Augmented Reality
- IEEE Advanced Learning Technologies

Number of Articles
There are five types of evaluation methods.

1. Performance metrics
   - Performance test
   - Self-reported learning

2. Questionnaires
   - Motivation
   - Presence
   - Usability

3. Behavior observation

4. Focused-group discussion

5. Heuristic evaluation
   - Teacher evaluation
   - Expert evaluation
Reported effect sizes vary widely.

<table>
<thead>
<tr>
<th>Ref</th>
<th>Content</th>
<th>Display</th>
<th>Participants (Sample)</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>[3]</td>
<td>English</td>
<td>Handheld</td>
<td>Grade school, teachers (67)</td>
<td>Large</td>
</tr>
<tr>
<td>[5]</td>
<td>Solar system</td>
<td>HMD</td>
<td>High school (40)</td>
<td>Large</td>
</tr>
<tr>
<td>[6]</td>
<td>Kinematics graphs</td>
<td>Desktop</td>
<td>High school (80)</td>
<td>Large</td>
</tr>
<tr>
<td>[7]</td>
<td>Elastic collision</td>
<td>Handheld</td>
<td>University students (36)</td>
<td>Large</td>
</tr>
<tr>
<td>[4]</td>
<td>Spatial ability training</td>
<td>Desktop</td>
<td>University students (49)</td>
<td>Moderate to Large</td>
</tr>
<tr>
<td>[2]</td>
<td>Masterpieces of Renaissance</td>
<td>Desktop</td>
<td>High school (69)</td>
<td>Moderate to Large</td>
</tr>
<tr>
<td>[8]</td>
<td>English</td>
<td>Desktop</td>
<td>Grade school (Six classes)</td>
<td>Small to Moderate</td>
</tr>
<tr>
<td>[9]</td>
<td>Math game</td>
<td>Handheld</td>
<td>Grade school (123)</td>
<td>No effect</td>
</tr>
<tr>
<td>[10]</td>
<td>Eulerian and Hamilton Graphs</td>
<td>Projector</td>
<td>University students (20)</td>
<td>No effect</td>
</tr>
<tr>
<td>[12]</td>
<td>Library skills</td>
<td>Desktop</td>
<td>Grade school (116)</td>
<td>Small Negative</td>
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</tbody>
</table>
ARLEs (AR annotation) apply multimedia learning theory.

Multimedia Learning Theory [13]  
(Learning from words and pictures)

AR Annotation  
(Learning from virtual words and real objects)

If we substitute:
Words → virtual symbols (words, numbers, arrows)
Pictures → real objects;
Then, all of the empirically tested principles of Multimedia Learning Theory applies to AR annotation.

*Picture from http://science.howstuffworks.com/environmental/earth/geophysics/earth3.htm
ARLEs apply situated visualization.

Situated Learning Theory [14]
Learning is situated in a specific context and embedded within a particular social and physical environment.

Virtual apple + Real Fridge

✓ More cues

Virtual apple + Picture book*

ARLEs apply vision-haptic visualization.

Animate Vision Theory [15]
Vision data and haptic data are coded in the brain together.

Vision but poor haptic

Vision and better haptic [4]
World annotation, situated visualization and vision-haptic visualization improves learning in two ways.

- Easier perception, thus more allotment for processing
- More cues, better experience, thus more elaborated knowledge

![Diagram showing comparison between Non-AR and AR in terms of perception and processing with working memory.](image-url)
Given the affordances of AR, how can we design ARLEs?
We propose a participatory design model for authoring ARLEs.
We tested an implementation of AR x-ray.
We conducted two user studies on perception.

1. User Study 1: 23 Filipino students (9 male, 14 female, aged 5-15) attending 13 different schools
2. User Study 2: 47 students (21 male, 26 female, aged 11-16) from Spring Christian School
3. Questionnaire:
   - Q1. The object is inside the box.
   - Q2. The object is easy to see.
   - Q3. The object seems real.
   - Q4. The object seems flat.
   - Q5. I can see the different parts of the object clearly.
   - Q6. My classmates will say the object is real.
User study set up

Demonstration

Control: without occlusion

Experiment: with occlusion

Set up for User Study 1 (involving younger kids)
There are no significant differences in perception.

### User Study 1

<table>
<thead>
<tr>
<th>Question (Construct)</th>
<th>Without Occlusion</th>
<th>With Occlusion (x-ray)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (95% Conf.)</td>
<td>STDV</td>
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<tr>
<td>Q1 (Depth)</td>
<td>3.7 (3.1 – 4.2)</td>
<td>1.2</td>
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<tr>
<td>Q2 (Visibility)</td>
<td>4.0 (3.5 – 4.4)</td>
<td>1.0</td>
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<tr>
<td>Q3 (Realism)</td>
<td>3.4 (2.8 – 3.9)</td>
<td>1.4</td>
</tr>
<tr>
<td>Q4 (Depth)</td>
<td>4.1 (3.7 – 4.6)</td>
<td>0.9</td>
</tr>
<tr>
<td>Q5 (Visibility)</td>
<td>4.0 (3.6 – 4.5)</td>
<td>0.9</td>
</tr>
<tr>
<td>Q6 (Realism)</td>
<td>3.3 (2.8 – 3.8)</td>
<td>1.2</td>
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### User Study 2

<table>
<thead>
<tr>
<th>Question (Construct)</th>
<th>Without Occlusion</th>
<th>With Occlusion (x-ray)</th>
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<tr>
<td></td>
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<tr>
<td>Q1 (Depth)</td>
<td>3.4 (2.9 – 3.9)</td>
<td>1.2</td>
</tr>
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<td>Q2 (Visibility)</td>
<td>3.8 (3.3 – 4.3)</td>
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Schools find ARLEs beneficial and would like to use it for specific content.

Perceived advantages in practice
1. “Learning by experience”
2. Improved attention
3. Increased motivation

Perceived issues in practice
1. Cost and availability of technology
2. Accuracy of virtual information
3. Time constraint

Focused group discussions with Teachers, Parents, School Administrators
On-going paper-prototyping for ARLEs.

Target Object

Drop-down Menu

• Can test knowledge in navigation
• Limited interactions and experience

Authoring on target object

Annotated frog
Summary of contributions

We showed that:

• ARLEs have variable effect to learning.
• ARLEs have inherent advantages that improve perception and knowledge construction.

We recommend that:

• We can design better ARLEs using participatory design. Using participatory design, we...
• Tested perception in AR x-ray interactions
• Gathered preliminary user requirements for ARLEs
Future Work

Main Goal

Simple Authoring Tool for Teachers

- Continue using Participatory Design
  Model that considers teachers and students in the authoring process

- Continue implementing state-of-the-art AR interactions
  Example: AR x-ray, AR Annotation

- Implement Augmented Reality Learning Objects (ARLOs)
  Standard ARLE file that packages AR content (real object, virtual objects, interactions)
References