Outline and feedback of reviewer's comment

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Title: Impact of Augmented Reality (AR) Types in Science Education: Focusing on Student-Centered Learning

Revised Paper

Impact on AR Types in Science Education Promoting Student-Centered Learning

General Introduction
- Background
- Constructivism and Student-Centered Learning
- Rationale for selecting the key papers
- Guiding research questions

Key concepts
- The definition of Augmented Reality
- Augmented Reality Platform
- Types of Augmented Reality
    - 1.Image-based AR
    - 2.Location-based AR

Influence of AR types in science education
1. Overview of AR types in science education
    - 1.1. Subjects in AR Types
    - 1.2. Educational level
    - 1.3. AR platform
    - 1.4. Educational context

2. Impact on AR types to Student-centered learning
    - **2.1. Improving students' conceptual understanding**
      (visualization, spatial cognition in AR types will improve conceptual understanding)

    - **2.2. Changing to positive attitude**
      (satisfaction, enjoyment and motivation on AR technology will be the factor to influence attitude)

    - **2.3. Promoting students' engagement**
      (collaboration and inquiry learning in AR types will promote students' engagement)

3. Challenges of AR types in science education
    - 3.1. Technical issues
        - 3.1.1. Unstable system
        - 3.1.2. Difficult to use of AR
        - 3.1.3. High cost of AR devices
    - 3.2. Learner issues
        - 3.2.1. Being overwhelmed by the task
        - 3.2.2. Cognitive issue

Discussion
(helpful/not helpful/future question)

List of analyzed AR journal papers

Table 1. *Background information on reviewed articles related to AR in science education*

Primary author (year of publications)	Article title	AR feature
Akçayır et al. (2016)	Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories	Image-based
Bursztyn et al. (2017)	Increasing Undergraduate Interest to Learn Geoscience with GPS-based Augmented Reality Field Trips on Students’ Own Smartphones	Location-based
Cai et al. (2017)	Applications of augmented reality-based natural interactive learning in magnetic field instruction	Image-based
Chen and Wang (2015)	Employing Augmented-Reality-Embedded Instruction to Disperse the Imparities of Individual Differences in Earth Science Learning	Image-based
Chen et al. (2016)	An Augmented-Reality-Based Concept Map to Support Mobile Learning for Science	Image-based
Chiang et al. (2014)	Students' online interactive patterns in augmented reality-based inquiry activities	Location-based
Dünser et al. (2012)	Creating interactive physics education books with augmented reality	Image-based
Enyedy et al. (2015)	Constructing liminal blends in a collaborative augmented-reality learning environment	Image-based
Frank and Kapila (2017)	Mixed-reality learning environments: Integrating mobile interfaces with laboratory test-beds	Image-based
Huang et al. (2016)	Animating eco-education: To see, feel, and discover in an augmented reality-based experiential learning environment	Location-based
Ibáñez et al. (2014)	Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness	Image-based
Ibáñez et al. (2016)	Support for Augmented Reality Simulation Systems: The Effects of Scaffolding on Learning Outcomes and Behavior Patterns	Image-based
Kamarainen et al. (2013)	EcoMOBILE: Integrating augmented reality and probeware with environmental education field trips	Location-based

Liou et al. (2016)	Beyond the Flipped Classroom: A Highly Interactive Cloud-Classroom (HIC) Embedded into Basic Materials Science Courses	Image-based
Tarng et al. (2015)	Development of a virtual butterfly ecological system based on augmented reality and mobile learning technologies	Location-based
Tarng et al. (2016)	Development of a Lunar-Phase Observation System Based on Augmented Reality and Mobile Learning Technologies	Location-based
Wang et al. (2014)	An Investigation of University Students' Collaborative Inquiry Learning Behaviors in an Augmented Reality Simulation and a Traditional Simulation	Image-based
Yoon et al. (2017)	How augmented reality enables conceptual understanding of challenging science content	Image-based
Zimmerman et al. (2016)	Using Augmented Reality to Support Children's Situational Interest and Science Learning During Context-Sensitive Informal Mobile Learning	location-based

1. General comparison of AR types

1.1. Subjects in AR types

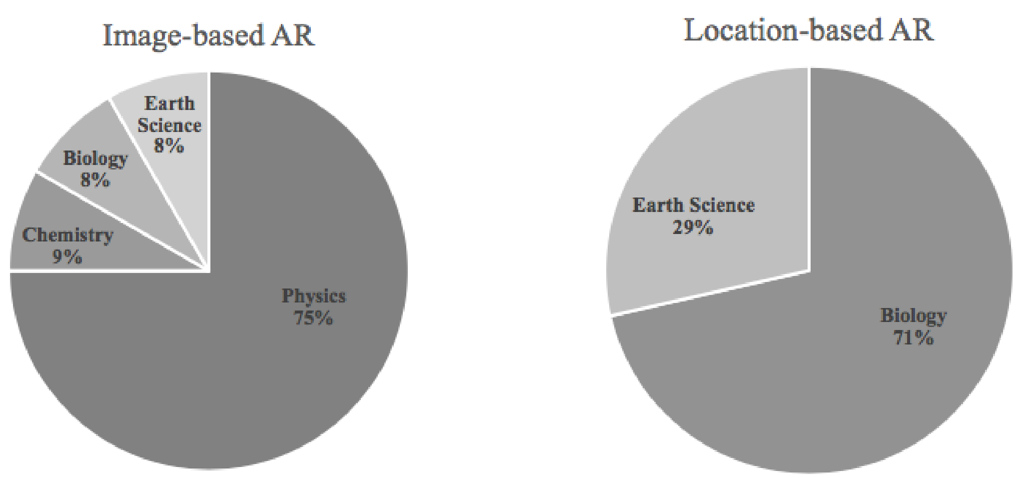

Figure 1. comparison of use of AR types in different subjects

1.2 Education level

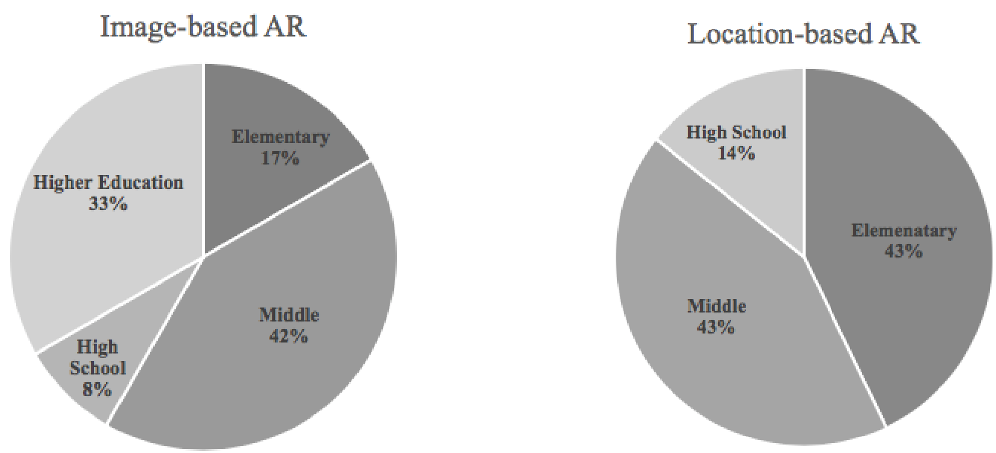

Figure 2. comparison of use of AR types in different educational level

1.3. AR Platform

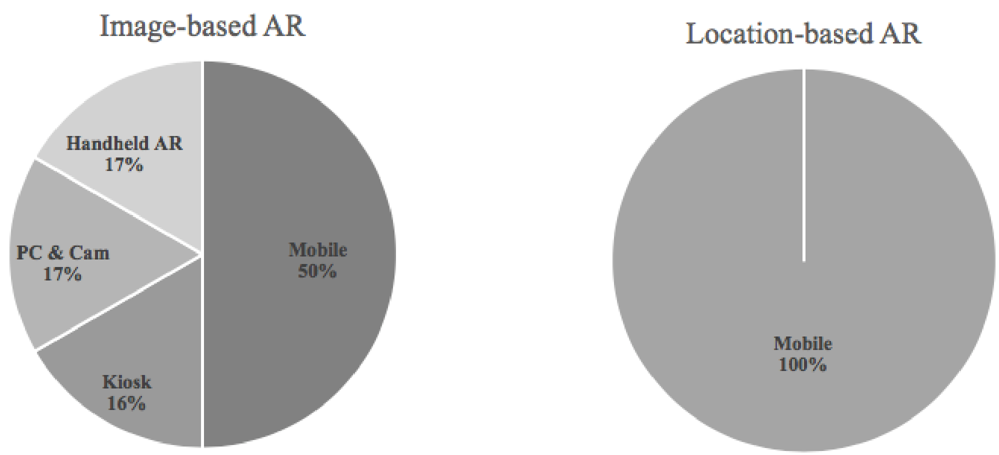

Figure 3. Different AR platforms in AR types

1.4. Educational Context

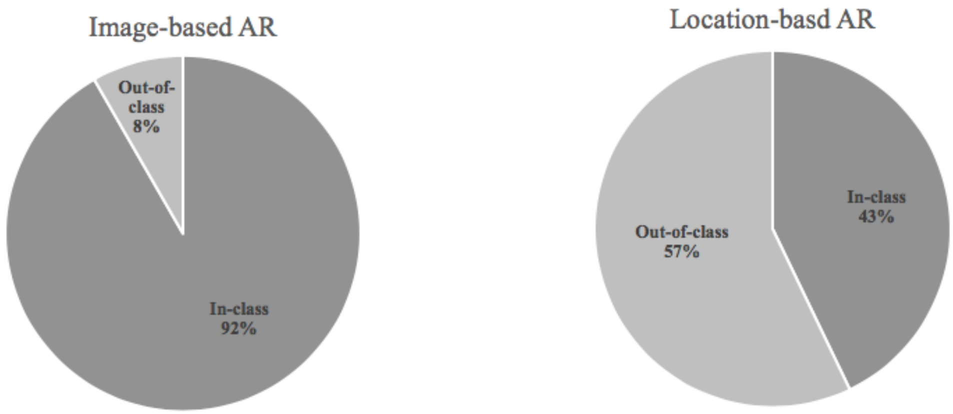

Figure 4. AR types in educational context

2. How AR types Affects to Science Education

Table 2. *Analysis of how AR types impact science education*

AR types	Primary author	Effects of AR	Learning outcomes
Image-based	Akçayır et al. (2016)	･Simulation ･visualization of invisible objects ･Inquiry learning	･Enhanced science learning capabilities ･Positive attitude ･Improved students' laboratory skills ･Higher motivation, enjoyment, and satisfaction
	Cai et al. (2017)	･Simulation ･Visualization of invisible ･Natural interaction technology ･Inquiry learning process	･Higher magnetic knowledge quiz score in AR group (including an understanding of magnetic fields) ･Active learning
	Chen and Wang (2015)	･Simulation ･Spatial cognition ･Cooperative/collaborative ･Blended learning	･Enhanced instruction adaptiveness ･Enjoyment ･Self-evaluation progress
	Chen et al. (2016)	･Visualization of invisible ･Scaffolding	･Increased motivation ･Improved students' attitudes ･Easier to understand on concept-mapped AR
	Dünser et al. (2012)	･Visualization of invisible ･Spatial cognition ･Constructivist learning theory ･Exploration	･Effective in teaching complex ･Remembering information

AR	Enyedy et al. (2015)	· Simulation · Visualization of invisible · liminal blends · Learning Physics through play	· Engagement · Creating knowledge
	Frank and Kapila (2017)	· Exploration · Inquiry-based learning	· Improved conceptual understanding · positive student perceptions
	Ibáñez et al. (2014)	· Simulation · Visualization of invisible · Spatial cognition	· Higher flow experience · More Effective than web-based application in promoting knowledge
	Ibáñez et al. (2016)	· Scaffolding · Simulation-based learning · Visualization of invisible objects	· Positive inquiry learning behavior · Decreasing cognitive load
	Liou et al. (2016)	· Spatial cognition · Observation · Exploration	· Spatial knowledge · Enhancing knowledge, comprehension and application skills · Active learning (engagement)
	Wang et al. (2014)	· Simulation · Collaborative inquiry learning	· AR is more supportive · Authentic environment
	Yoon et al. (2017)	· Simulation · Spatial cognition · Scaffolding	· Improved understanding of the concept (Bernoulli's principle)
Location-based AR	Bursztyn et al. (2017)	· visualization the invisible · Game-based learning · Lab vs. AR field trip	· Higher motivation and engagement
	Chiang et al. (2014)	· Collaboration (Inquiry-based learning) · Immediacy · Immersion	· Engagement · High immersion level · High phases of knowledge construction · High-level thinking and cognition
	Huang et al. (2016)	· visualizing the invisible · Experimental learning theory · Immediacy · Immersion	· Engagement · More pleasure from learning · Positive emotion and ecological experimental experience
	Kamarainen et al. (2013)	· Visualization the invisible · Situated learning theory · Collaboration · Immersion	· Self-efficacy · High engagement and deeper understanding (collaboration) · Positive attitude · Student-centered learning
	Tarng et al. (2015)	· Visualization the invisible · Situated learning · Interaction	· Increasing motivation and interest · Improving learning effectively · Helping to understand · Suitable assistant tool

Tarng et al. (2016)	▪ Visualization the invisible ▪ Situated learning ▪ Interaction	▪ Retaining knowledge in long-term memory ▪ Easy to use ▪ Like to use
Zimmerman et al. (2016)	▪ Collaboration ▪ Context-Sensitive Learning ▪ Place-based education	▪ Engagement ▪ hands-on experiences ▪ Highly enjoyable activity