Expanding the reach of AIED systems: Adapting to social learning processes

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“The challenge for our education system is to leverage the learning sciences and modern technology to create engaging, relevant, and personalized learning experiences for all learners.”

-- National Education Technology Plan, 2010
Role of Technology

Create novel learning experiences → Adapt

Collect data → Adapt
Intelligent tutoring system: Cognitive Tutor Algebra
www.carnegielearning.com, Koedinger et al., 1997
Levels of Personalization

Collaborative
Motivational
Metacognitive
Cognitive

Du Boulay, Avramides, Luckin, Martinez-Miron, Mendez, & Carr, 2010
Levels of Personalization

- Collaborative
- Motivational
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- Cognitive

APTA, Online Peer Help
rTAG
MindDot, CrowdMuse
EMBRACE, Brain-Based Assessment

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Du Boulay, Avramides, Luckin, Martinez-Miron, Mendez, & Carr, 2010
MindDot: Metacognitive Level

How can we use adaptive technologies to support reading comprehension strategies?

Wang et al., 2019, Wang et al., 2017; Walker et al., 2017; Wang et al., 2015; Supported by CISE-IIS-1451431.
Concept Maps

Goal: Improve students’ understanding of an earth sciences text on biodiversity.

Theory: Students learn more when engaging in comparative strategies, where they are creating relationships between different concepts. Grabowski (1996), Ponce & Mayer (2014)

Insight: By engaging students in a concept mapping activity, we can scaffold, assess, and ultimately support their comparative strategies.
Iterative Process

Phase 1: Design concept mapping support system, collect data, extract behavior-based metrics

Phase 2: Improve system, collect data, validate metrics and efficacy

Phase 3: Design adaptive support, evaluate support
The major sources of water pollution are agriculture, industries, and mining. Agricultural activities are by far the leading cause of water pollution. Sediment eroded from agricultural lands is the largest source. Other major agricultural pollutants include fertilizers and pesticides, bacteria from livestock and food processing wastes, and excess salt from soils of irrigated cropland.

**Industrial facilities** are another source of water pollution from a variety of harmful inorganic and organic chemicals. Mining is a third source. Surface mining disturbs the earth’s surface, creating a major source of sediment and runoff of toxic chemicals.

**Climate change** from global warming can also affect water pollution. In a warmer world, some areas will get more precipitation and other areas will get less. Intense downpours can flush more harmful chemicals, plant nutrients, and microorganisms into waterways. Prolonged drought can reduce river flows that dilute wastes and spread infectious diseases more rapidly among people who lack enough water to stay clean.

**Major Water Pollutants and Their Effects (Science)**

Water is polluted by disease-causing agents, oxygen-demanding wastes, plant nutrients, organic and inorganic chemicals, sediment, and excess heat.

Two major water pollution problems are exposure to infectious disease organisms (pathogens) from having to drink contaminated water and not having enough water for effective sanitation.
Scientists have identified more than 500 types of disease-causing bacteria, viruses, and parasites that can be transferred into water from the wastes of humans and animals. Table 21-2 lists some common diseases that can be transmitted to humans through drinking water contaminated with infectious agents.

The World Health Organization (WHO) estimates that 3.2 million people most of them children younger than age 5 die prematurely every year from infectious diseases spread by contaminated water or lack of water for adequate hygiene. Each year, diarrhea alone kills about 1.9 million people—about 90% of them children under age 5 in developing countries. This means that diarrhea kills a child every 17 seconds.

The United Nations estimates that it would cost $23 billion per year over 8-10 years to bring low-cost and safe drinking water and sanitation to the 2.4 billion people who do not have it. If developed countries paid half of that cost, it would amount to an average of $19 a year for each person in developed countries.

Scientists use various methods to detect the presence of infectious agents in water. One involves measuring the number of colonies of fecal coliform bacteria (such as various strains of Escherichia coli or E. coli) present in a water sample. Various strains of these bacteria live in the colons or intestines of humans and other animals and thus are present in their fecal wastes. Although most strains of coliform bacteria do not cause disease, their presence indicates that water has been exposed to human or animal wastes that are likely to contain disease-causing agents.
Concept Mapping Behaviors

Assessments: Behavior-based metrics of student metacognitive processes

- Back navigation
- Cross links
- Context switch

Back navigations: The number of times students navigate back to a previous page.
Phase 2 Results

4 conditions examining hyperlink & template-support. 59 college students, 30 minutes of concept mapping.

Hyperlinks improved:
- Learning
- Comparative strategies

Comparative strategies were correlated with learning.
Sequence Diagram

- Alternations between compare and read
- Alternations between read and link
- Direct connections between start and end

High Learning

Low Learning

Read
Compare
Link
Cross-Link
SPECIES EXTINCTION

Three Types of Species Extinction (Science)

Species can become extinct locally, ecologically, or globally. Biologists distinguish among three levels of species extinction. Local extinction occurs when a species is no longer found in an area it once inhabited but is still found elsewhere in the world. Most local extinctions involve losses of one or more populations of species. Ecological extinction occurs when so few members of a species are left that it can no longer play its ecological roles in the biological communities where it is found. In biological extinction, a species is no longer found anywhere on the earth (Figure 11-2 and Core Case Study, p. 222). Biological extinction is forever.

Endangered and Threatened Species—Ecological Smoke Alarms

An endangered species could soon become extinct, and a threatened species is likely to become extinct.

Biologists classify species heading toward biological extinction as either endangered or threatened (Figure 11-3, p. 224). An endangered species has so few individual survivors that the species could soon become extinct over all or most of its natural range. Like the passenger pigeon (Figure 11-1), they may soon disappear from the earth. A threatened species (also known as a vulnerable species) is still abundant in its natural range but because of declining numbers it is likely to become endangered in the near future. Some species have characteristics that make them especially vulnerable to ecological and biological extinction (Figure 11-4, p. 225). As biodiversity expert Edward O. Wilson puts it, "The first animal species to go are the big, the slow, the tasty, and those with valuable parts such as tusks and skins."
Scaffolding, Assessment, Adaptivity

Technology design elicited meaningful behaviors
- Demonstrate learning experiences effective
- Demonstrate behavior-based metrics predictive

Provides solid foundation for the development of adaptive support.

Create novel learning experiences
Collect data
Adapt
Levels of Personalization

| Collaborative | Motivational | Metacognitive | Cognitive |

*Du Boulay, Avramides, Luckin, Martinez-Miron, Mendez, & Carr, 2010*
Levels of Personalization

Caring Systems
Collaborative
Motivational
Metacognitive
Cognitive

Socially & contextually-sensitive

Du Boulay, Avramides, Luckin, Martinez-Miron, Mendez, & Carr, 2010
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Du Boulay, Avramides, Luckin, Martinez-Miron, Mendez, & Carr, 2010
EMBRACE

Develop an ITS to improve the English reading comprehension of young Native Spanish speakers as they read.

Art Glenberg

Laida Restrepo

Walker et al. 2017a, Walker et al., 2017b, Glenberg et al., 2016
Supported by CISE-IIS-1736103
Context: Societal Need

Latino children are 33% of the AZ population.

The mean reading comprehension of Latino fourth graders in AZ is below Basic level.

Only 18% of Latino 4th graders in AZ are labeled proficient readers.

National Center for Education Statistics, 2015
Opportunity: Develop an ITS for reading comprehension based on embodied cognition.

Theory: Language comprehension is a cognitive simulation process. *Glenberg & Gallese (2012)*

Example: “The couple held hands while walking down the moonlit beach.”

- Picture the situation depicted by the sentence
- Perceptual, motor, and emotional systems activated
EMBRACE

Children move images associated with texts.

Given support in Spanish and English.

Sofia grabbed the bowl with red chilies and gave it to her mother to grind them. "Honey, can you go stir the champurrado, please?" her mother asked, Sofia walked over to the stove and stirred the chocolaty drink so that it would not stick to the bottom of the pot. "Oh dear, Sofia!" her mother said. "We are missing some key ingredients".
Right-Wrong Feedback

Student's manipulations are compared to encoded solutions.

Subject and object must match for manipulation to be correct.

If manipulation is incorrect, subject moves to it’s original location and error noise sounds.
Build an effective personalized learning environment for reading comprehension based on embodied cognition:

- It is an effective intervention in itself
- Collects useful behavior-based metrics
- Allows us to provide just-in-time feedback on comprehension
Does simulation improve reading comprehension of narrative texts for young English Language Learners?

4 conditions
- Simulation vs no simulation
- Spanish support vs no Spanish support

70 Latino ELL students, grades 2-5

Simulation improved reading comprehension ($p < 0.05$)

Spanish support on its own did not.
Adding Intelligent Tutoring

Cognitive simulation forms a basis for the ITS

- Knowledge tracing
- Error detection
- Targeted feedback
- Adaptive problem selection & vocabulary practice
## Error Detection

S = Source, D = Destination, K = Other objects involved in the sentence, O = All other objects involved in the sentence

<table>
<thead>
<tr>
<th>Case #</th>
<th>Situation</th>
<th>Evaluation</th>
<th>Skills increased</th>
<th>Skills decreased</th>
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<tbody>
<tr>
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<td>syntax\textsubscript{medium}</td>
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<td>Vocabulary error</td>
<td>vocab\textsubscript{S}, vocab\textsubscript{O}, vocab\textsubscript{D}</td>
<td>-</td>
</tr>
</tbody>
</table>
Caring Systems: Extensions to EMBRACE

Understand student activities during pauses in tutoring system use.

Build a system to support parent-child interactions.

Deniz Sonmez
Estimating Thinking Time

Idea: Decompose response time on a sentence into relevant subcategories.

Thinking Time = Response Time - (Reading Time + Time Spent on Help)

<table>
<thead>
<tr>
<th>Model</th>
<th>Independent Vars</th>
<th>Dependent Var</th>
<th>$R^2$</th>
<th>$p &lt;$</th>
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</thead>
<tbody>
<tr>
<td>M2 (Piecewise)</td>
<td>QRI, SELPS, Gates, # helps, # gaming, thinking time (segmented)</td>
<td>Correct answer proportion on comprehension assessment</td>
<td>0.21</td>
<td>0.001</td>
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<tr>
<td>M3 (Piecewise)</td>
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<td>Correct answer proportion on comprehension assessment</td>
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</tbody>
</table>
Relationship Between Thinking Time and Student Performance

Proportion of Correctly Answered Questions on Chapter

Mean Thinking Time on Chapter
Relationship Between Thinking Time and Student Performance

Proportion of Correctly Answered Questions on Chapter

Mean Thinking Time on Chapter
Relationship Between Thinking Time and Student Performance

![Graph showing the relationship between thinking time and student performance.](image)
Relationship Between Thinking Time and Student Performance

Proportion of Correctly Answered Questions on Chapter

Mean Thinking Time on Chapter
Relationship Between Thinking Time and Student Performance
Caring Systems: Context-Based Extensions

Understand student activities during pauses in tutoring system use.

Build a system to support parent-child interactions.

Deniz Sonmez
Caring Systems: Context-Based Extensions

Understand student activities during pauses in tutoring system use.

Build a system to support parent-child interactions.
La Familia López

La familia López vive en una casa linda. Martín es el papá y es un policía. Trabaja todos los días. En la mañana, Martín se va a trabajar. Agarra sus llaves del gancho en la cocina y se sube a su coche. Maneja hacia el frente de la casa y se despe de la familia desde el coche.
Summary

Cycled through technology design, identification of meaningful behaviors, and development of intelligent support for embodied cognition during reading comprehension.

Extending EMBRACE to take a more holistic view:
- Identify what is occurring when the child is not generating log events
- Support parents and children in reading together
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EMBRACE, Brain-Based Assessment
Develop Nico, a teachable robot that socially engages students through spoken dialogue.

Lubold et al., 2019; Lubold et al., 2018a; Lubold et al., 2018b; Lubold et al., 2016; Lubold et al., 2015. Supported by CISE-IIS-1637809.
Demo

https://stemforall2019.videohall.com/presentations/1555
## Key Results

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Self-reported Rapport</th>
<th>Linguistic Rapport</th>
<th>Learning</th>
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<tbody>
<tr>
<td><strong>Quinn</strong></td>
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<td>Non-social</td>
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<td><strong>Nico</strong></td>
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<td><strong>Emma</strong></td>
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<td>N.S.</td>
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Developing ITSs at Multiple Levels

- Create novel learning experiences
- Collect data
- Adapt
Adding Caring Systems

Recognize that students are interacting within a broader context, and that interventions might change based on that.

Explore social agents as a way of facilitating social learning.
Integration

How do we integrate social and contextual adaptations across multiple levels?
Adoption

How does social personalized learning fit into the current and future ecosystem of teaching and learning?
“The challenge for our education system is to leverage the learning sciences and modern technology to create engaging, relevant, and personalized learning experiences for all learners.”

-- National Education Technology Plan, 2010
Social personalized learning:
- Combines support and assessment
- Motivates through interaction
- Attends to the broader context of the learning