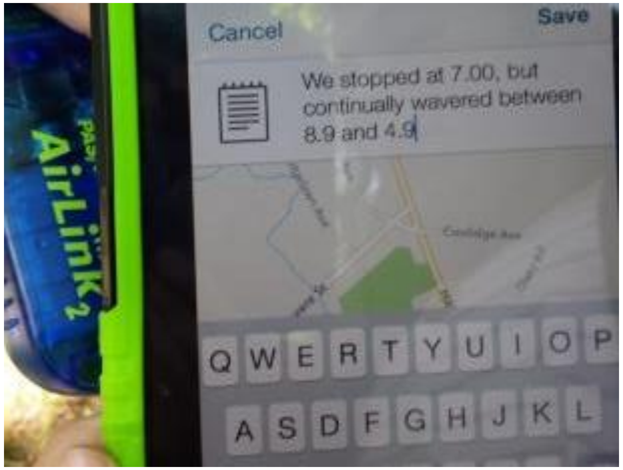
The Importance of Time and Sequence on Learning in Mobile Augmented Reality



HARVARD
GRADUATE SCHOOL OF EDUCATION

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Context

- Place-based education in environmental science
  - focus on contextualized, relevant knowledge that does not rely on the teacher as the sole source of knowledge (Smith, 2007)
  - Eases transfer of classroom knowledge to real-world contexts, turns it “inside out” (Grotzer et al., 2015)
  - Can be expensive, logistically challenging, and overwhelming for students placed in a novel, stimulus-rich environment (Falk, Martin, & Balling, 1978)

Context (cont.)

- Mobile Augmented Reality (AR)
  - can enhance learning experiences by situating learning in authentic contexts and providing appropriate scaffolding for complex tasks while facilitating communication and social construction of knowledge (Dunleavy & Dede, 2014; Reilly & Dede, 2018)
- Affordances for designers as well
  - Rich log files of user locations and movements as well as records of what content was seen when

Prior Work

EcoMUVE
Virtual Simulation
Classroom
Consistent Data

EcoMOBILE
Augmented Reality
Field Trip
Highly Variable Data

Current Study

- Augmented reality (AR) shown to scaffold collection and aggregation of empirical data
- Students spend variable amounts of time exploring content
- Students view different content in different orders
- Log file data thus far underutilized in mobile AR design for education

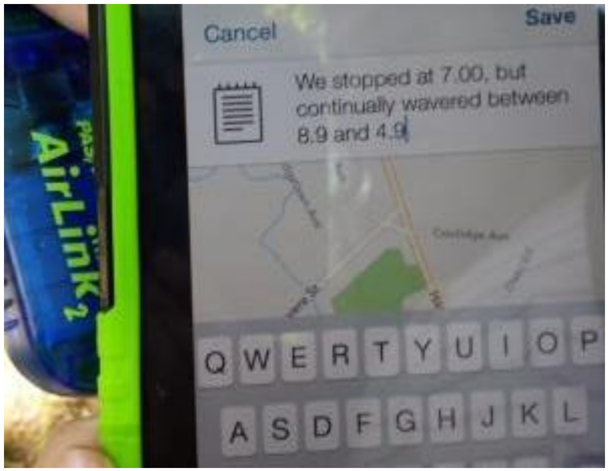
Research Questions

1. How much does the time spent in the open exploration part of EcoMOBILE vary between groups, and how does this correlate with learning gains?
2. Which learning quests are associated with the largest learning gains?
3. Does the order of content viewed impact student success?

Intervention

- Design-based research
  - one teacher, four classes of seventh graders, suburban district in the northeastern United States
- Two week EcoMUVE curriculum, then one week intervention with EcoMOBILE field trip

Intervention (Cont.)



- Mobile broadband devices running AR software and data gathering applications connected to probeware
- Groups of 2-3 (n = 20) complete two portions:
  - Challenge 1: Collect water quality measurements at different locations to see if they are the same or different.
  - Challenge 2: Investigate multiple stations to determine why measurements differ between and within groups

Survey

- Four constructs:

Understanding Variability	**Describing Data**
Construct Explanations	**Ecological Mechanisms**

Pre —EcoMUVE→ Mid —EcoMOBILE→ Post

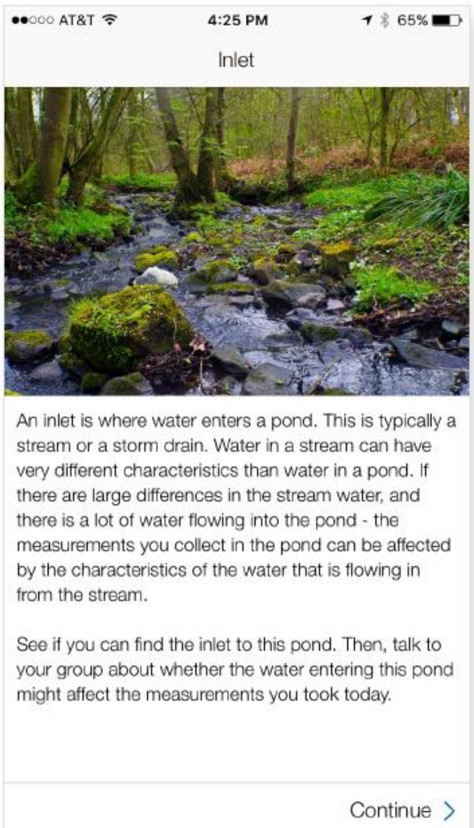
Results: Time Spent Exploring

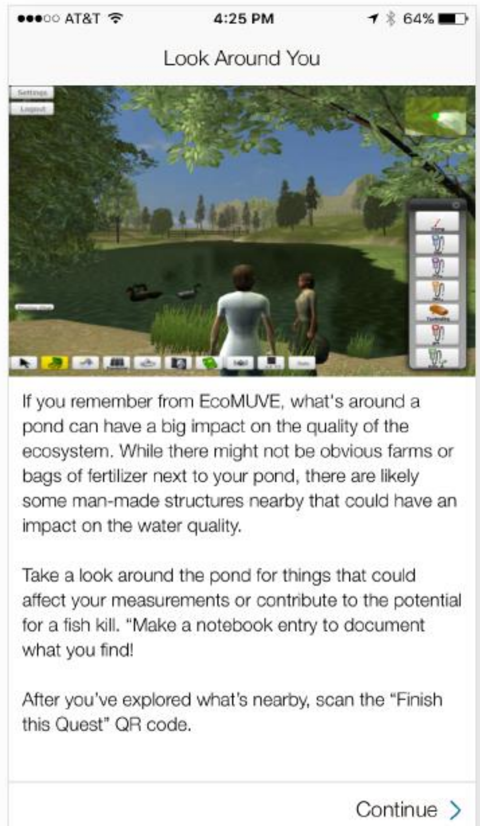
- Two groups unable to progress past Challenge #1 in 45 minute field trip
  - Technical issues and difficulty with probeware
- Groups who finished Challenge #2:
  - spent a mean of 22 minutes exploring versus the 9:35 mean of groups who were unable to finish ($t = -4.62$, $p < 0.001$)
  - gained 7.7 percentage points on the “explaining reasoning” construct while groups who were unable to finish averaged a 5 percentage point decrease in scores ($t = -2.76$, $p < 0.05$)

Results: Learning Quests

- Linear mixed-effects model (with students grouped by teams) built for all constructs to determine what learning quests are associated with the largest learning gains
- Understanding Variability:
  - Completing "What's Nearby?" quest associated with a 26.1 percentage point gain on the post survey when controlling for reading level, gender, performance on the mid-survey, and completion of other quests ($t = 2.43$, $p < 0.05$)
  - Not intentional for one quest to have such large impact
- Ecological Mechanisms:
  - Students below grade reading level gained 30 fewer points than their above grade reading level peers ($t = -3.03$, $p < 0.05$),
  - Students on grade reading level gained 23 fewer points than their above grade reading level peers ($t = -3.25$, $p < 0.05$)

"What's Nearby" quest





- Draws student attention to other parts of the pond
- Explicitly links EcoMUVE content to EcoMOBILE
- Prompts students to reflect on these connections

Results: Order of Content

- Sequential pattern mining revealed four distinct paths of quest activity students undertook in Challenge #2
  - one sequence of quests (“Path A”) correlated strongly with gains on “explaining reasoning” ($r = 0.64$, $p = 0.006$), “describing data” ($r = 0.57$, $p = 0.02$), and overall score ($r = 0.67$, $p = 0.003$)
- The only other path that completed four optional quests (“Path B”) did not see similar associations with gains
  - Groups in Path B completed a quest that repeated data collection instead of seeing more new content
  - This option later dropped due to being too time intensive and risking more issues with probeware

Results: Order of Content

- Path A:

Same or Different → Under the Water → Let’s Compare → Why?

- Path B:

Same or Different → What’s Nearby? → Collect Other Measurements → Why?

Discussion

- Quests should all link explicitly to prior learning as part of a multi-stage curriculum or else certain parts will result in higher learning gains and transfer
- Rely on AR's ability to "show not tell" by avoiding text in favor of multimedia content
- Carefully consider the possible paths students might take when given options of what content to view, as some may result in a subpar experience

Contact / Acknowledgements

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Results of Multilevel Models

	Dependent variable:	
	Variation Gain	Mechanisms Gain
	(1)	(2)
Variation mid score	-0.383*	
	(0.213)	
Mechanisms mid score		-1.226***
		(0.173)
Completed What's Nearby Quest	26.061**	0.733
	(10.708)	(9.328)
Below grade reading level	-0.187	-30.357***
	(11.401)	(10.028)
On grade reading level	-2.091	-23.208***
	(7.822)	(7.149)
User Completed "Collect Data" Quest	-19.640	45.811*
	(27.316)	(26.285)
User Completed "Collect Other Measurements" Quest	-25.378*	-0.061
	(13.781)	(14.406)
User Completed "Let's Compare" Quest	-0.034	-0.122
	(8.810)	(8.173)
User Completed "Map and Graph It" Quest	7.018	-29.942
	(21.173)	(19.314)
Number of notes created	0.589	-0.804
	(2.263)	(2.266)
Male	-6.176	2.611
	(7.001)	(6.386)
Constant	38.790**	83.769***
	(18.129)	(15.118)
Observations	36	36
Log Likelihood	-120.882	-118.655
Akaike Inf. Crit.	267.764	263.310
Bayesian Inf. Crit.	288.350	283.896
Note:		*p**p***p<0.01