Challenges & Opportunities:

Creating AR/VR content to teach complex problem solving

Computing Community Consortium Workshop, Atlanta, GA

March 14, 2019

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The workforce content creation opportunity…

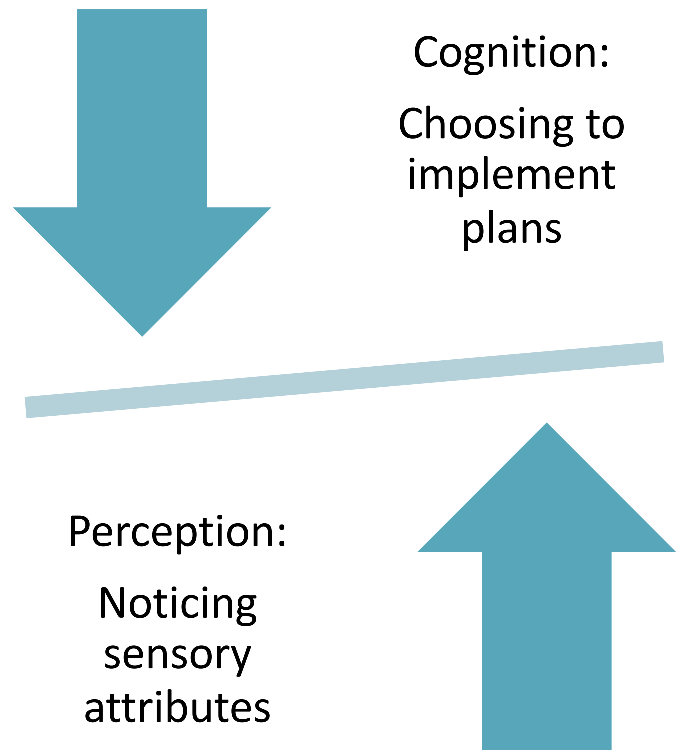
Employers seek:

- Problem solvers
- Critical thinkers
- Troubleshooters
- Particularly in technical maintenance fields…

How complex skills are learned...

Learning science indicates:

- Novices rely on bottom up processing:
  - Look for similarities to simple models
  - Favor color
- Experts rely on top-down processing:
  - Use rules
  - Build on pattern-learning
- Quality problem solving relies on both



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The challenge in AR/VR content generation…

Basic procedural learning[1]
- "Show one, do one"
- Step-by-step

Complex problem solving[1]
- Iterative, dynamic application
- Multiple concepts and procedures
- Multiple cases over time

Visual overlays

Activities Diagrams Imagery

Dialogue scripts

[1]Jonassen, 1999

The challenge in AR/VR knowledge extraction...

Basic procedural learning

- Can rely on technical manuals
- Routinized knowledge

Complex problem solving[2]

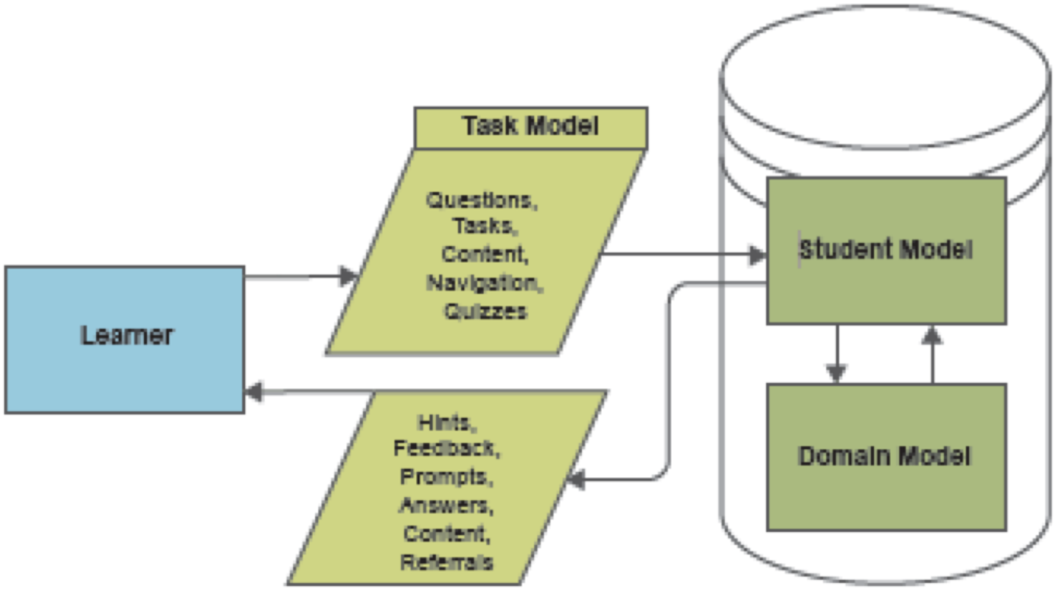
- Requires engagement with experts
- Requires methods to deal with "expert blind spot"

[2]Harteis, Koch, & Morgenthaler, 2008

Tools that instructional designers use…

Developers of intelligent instruction[3] create:

- Domain model
- Student model
- Task model



[3]Based on Park & Lee, 2003

Specialized tools needed for to create these models

Requirements

- Anticipates learner needs
- Documents range of problem situations, activities
- Elicits and documents experts' tacit knowledge

Evidence-centered design approach[4]

[4]Mislevy & Haertel, 2006

AR Mentor Example

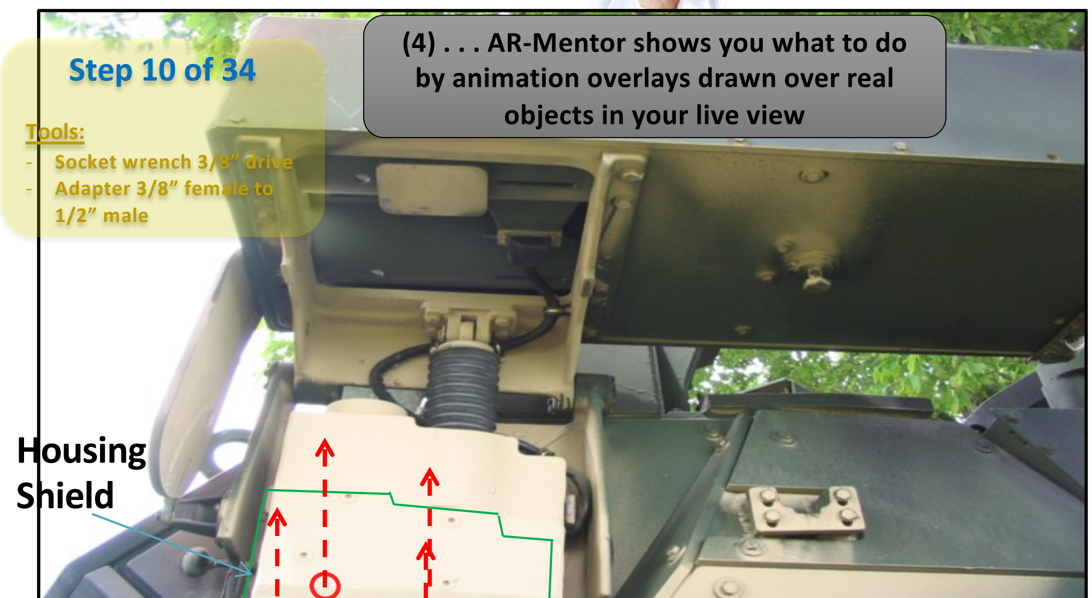
(1) Head-up Hands-Free
- Glasses with See-through Display for seeing directions
- Head-phone for giving direction
- Mic for listening to user
- Sensors for observing user

(2) User can talk to AR-Mentor

I want to Adjust TOW Lift upper position switch on an M3A3 Bradley CFV

(3) AR-Mentor Talks back to soldier . And…

(4) . . . AR-Mentor shows you what to do by animation overlays drawn over real objects in your live view



Remove the 4 screws highlighted in red from the housing shield (highlighted in green)

Remove shield from the housing (highlighted in green)

Warning: Missile Launcher, in the up position, can fall rapidly and injure personnel. Stay clear of the launcher path when launcher is up. Stand in front of gunner's sight when manually raising or lowering launcher

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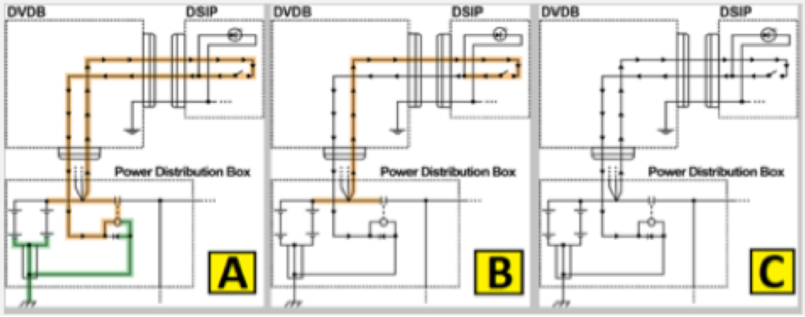
AR Mentor Models for Troubleshooting Created with ECD

- Domain Model: Troubleshooting procedures to be learned
  - Top-down cognition: Decision making based on rules
  - Bottom-up perceptions: “Seeing” electrical problems in vehicle

- Student Model: Novices will vary in knowing useful starting strategies
  - Top-down cognition: Split-half heuristic strategy
  - Bottom-up perception: Fluency in using electrical schematics that focus attention on specific parts of the electrical circuit and components

Task Model

- 3 knowledge checks embedded in step-by-step procedure to develop dynamic skill of making decisions during troubleshooting

Audio	To figure out where to start checking the circuit, you need to start closest to the component where you have power. Remember when you flipped the master power switch and heard the click? Think about what component is getting power based on that click. Select the correct schematic representing the status of the circuit.
Graphics	Schematic A? Schematic B? Schematic C? 

Results

Novice mechanics’ overall scores on the 3 knowledge checks were:

- KC1: 80% of time they chose to “keep checking” – higher than desired
- KC2: Only 44% correct on identifying nonfunctioning circuits
- KC3: Only 33% correct on identifying functioning circuits

Implications and Next Steps

Prototype illustrates feasibility of:

- Using ECD to analyze domain and student model and develop task model for AR application to complex troubleshooting
- Using AR embedded quizzes to:
  - Determine whether novices are using expert strategies, both top-down and perceptual
  - Prompting novices when to use those strategies in a complex troubleshooting process
  - Giving novices repeated practice in these expert strategies over the course of a complex task

Implications and Next Steps

Questions for further exploration:

- When is the best point in AR-based learning to “phase in” such embedded AR quizzes for novices (e.g., not too much cognitive load)?
- What pre-requisite knowledge or procedural skill automaticity needs to be in place in the learners?
- Can the model of embedded AR quizzes be used to measure those pre-requisite forms of knowledge and skill?

Current Work, Reference Article, and Contact

- SRI's Artificial Intelligence Center and SRI Education are using the ECD approach now with a new AR technician technology:
  - We are modeling both basic and expert knowledge of metalworking manufacturing troubleshooting procedures for a major automotive parts manufacturer
  - This will form the foundation of a knowledge management system that will build libraries of intelligent learning content by creating ontologies and using knowledge extraction techniques from machine learning and vision technologies

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- Articles on request:

- **Yarnall, L., Snow, E., Snow, E., & Katz, I. R. (2017).** Leveraging domain models for personalizing problem solving and learning. In R. A. Sottilare, A. C. Graesser, X. Hu, and G. A. Goodwin (*Eds.*) *Design Recommendations for Intelligent Tutoring Systems* (Vol. 5: Assessment Methods). Orlando, FL: Army Research Laboratory.
- **Yarnall, L., Vasquez, S., Werner, A., Kumar, R., Samarasekera, S., Acharya, G., Murray, G., Wolverton, M., Zhu, Z., Branzoi, V., Vitovitch, N., & Carpenter, J.** (2015, December). *Human performance in content design for interactive augmented reality systems.* Paper published in the proceedings of the annual meeting of the Interservice/Industry Training, Simulation and Education Conference (I/ITSEC). Orlando, FL.