Personalizing and Discussing Algorithms within CS 1 Studio Experiences: An Observational Study*

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Past Algorithm Visualization Research Motivates *Active* Learning

- Active engagement à better learning outcomes (Hundhausen, Douglas & Stasko, 2002)
  - Five levels of active engagement (Naps et al., 2003)
    1. Viewing
    2. Responding
    3. Changing
    4. **Constructing**
    5. **Presenting**

Studio-Based Learning Relies On *Construction* and *Presentation*

- Studio-based instructional model imported from architecture education
  - Collaborative and problem-based
  - Students work together in a studio space
  - Focal point: "design crits"
    - » Students present their own artifacts to studio
    - » Presentations elicit constructive feedback
    - » Presentations stimulate higher-level discussions regarding general principles and methods
    - » Students' artifacts serve as *mediational resources* (Roschelle, 1990)

Studio-Based Approach Had Positive Outcomes in Prior Studies (Hundhausen, 2002)

- Students were given visualization construction and presentation assignments in junior-level algorithms courses
- Key results
  - Increased level of interest in algorithms
  - Stimulated meaningful discussions about algorithms
  - Type of AV technology matters
    - » "High Tech": Focused students in low-level details
    - » "Low Tech": Focused students on algorithms

Prior Studies Motivate Research Questions

- **General**: Might learners benefit from "low tech" AV construction and presentation activities earlier in their CS careers?
- **Specific:**
  1. Will the process of constructing personalized visual representations help CS 1 students better understand their solutions?
  2. Will the process of presenting personalized visual representations generate pedagogically beneficial conversations?
  3. What form of AV technology can best support the above two processes: simple art supplies ("low tech") or ALVIS ("high tech")?

Related Work Shares Our Interest in Empirically Investigating AV

- Study of "Visualization construction assignments" (Stasko, 1997)
- Study of student usage of AV technology (Gurka, 1996)
- Study of student-constructed AVs shared, discussed, and rated on the web (Hübscher-Younger & Narayanan, 2003)
- Development and study of specialized programming and visualization environments for CS 1 (e.g., Naps, 1990; Dann et al., 2000; Ben-Bassat Levy et al., 2000; Carlisle et al. 2005)

Study Focused on Two Offerings of CptS 121 at WSU

- CptS 121 basics
  - Caters to CS and EE majors
  - Instructional language: C
  - High drop-out rate of 30-40%
  - Typical enrollment: 80 - 160
- "Algorithms-first" unit intended to improve course retention rate
  - First five weeks of course
  - Algorithmic problem-solving in pseudocode
  - Two "Studio experience" labs provide hands-on experience, and were focal point of study
    - » Fall, 2004 Study: Two "Art Supply" sessions (*n* = 44)
    - » Spring, 2005 Study: Two "ALVIS" sessions (*n* = 44)

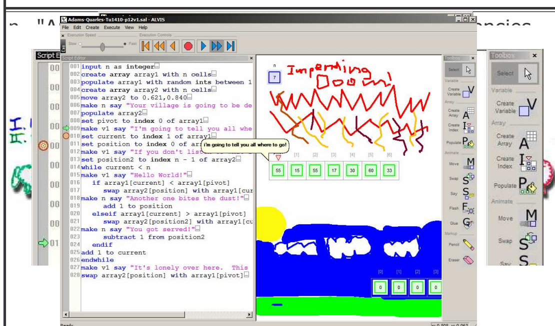
Art Supply and ALVIS Studio Experiences Were Nearly Identical…

- Took place during 2 hour and 50 minute lab period in 4th week of semester
- Students encouraged to work in self-selected pairs
- Each pair given one of 12 different algorithm design problems

SALSA Commands

Object creation: `create, set, populate`
Conditional: `if…elseif…else…endif`
Iteration: `while…endwhile`
Animation: `move, swap, say`
Input and Output: `input, print`

…Except that the AV Technology Differed



We used Five Different Field Techniques to Study Studio Sessions

- Participant observation (primary)
- Videotaping (primary)
- Artifact collection (secondary)
- Interviewing (secondary)
- Questionnaires (secondary)

"ALVIS" Students Relied on Execution; "AS" Students Relied on TAs

35% ■ Art Supplies

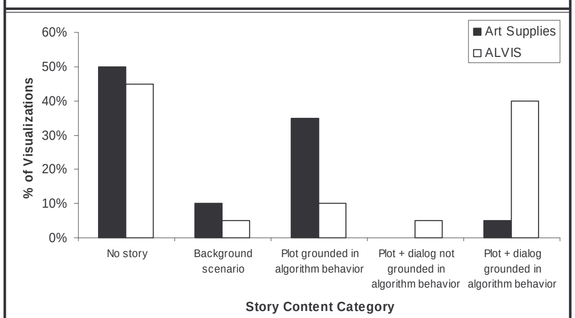
Average Number of Semantic Errors in the Algorithmic Solutions of Art Supply and ALVIS Students

Group	Lines of code per solution		Semantic errors per solution		Semantic errors per line of code	
	M	*SD*	*M*	*SD*	*M*	*SD*
Art Supply	19.07	7.77	0.77	0.95	0.04	0.01
ALVIS	21.55	6.56	0.36	0.78	0.01	0.01

Statistically significant: ($df = 1$, $H = 4.73$, $p = 0.03$)

Activity Category

"ALVIS" and "AS" Students Developed Equally Sophisticated Storylines



Audience More Involved in "ALVIS" Presentations Than in "AS" Presentations

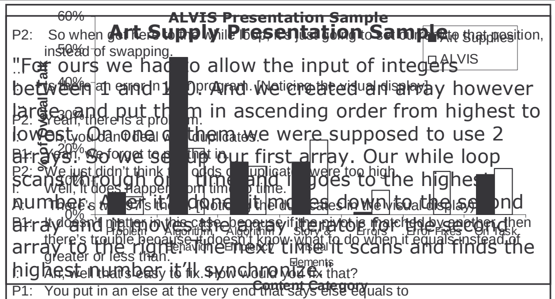
Average Number of Contributions from Student Audience and Instructor in Art Supply and ALVIS Sessions

Group	# Student audience contributions per minute		# Instructor contributions per minute		# Laughs per minute	
	M	*SD*	*M*	*SD*	*M*	*SD*
Art Supply	0.01	0.06	1.69	2.80	0.04	0.12
ALVIS	0.30	0.50	1.07	0.70	0.32	0.51

Statistically significant: (*df* = 1, *H* = 11.17, *p* = 0.001)

Statistically significant: (*df* = 11, *t* = 2.87, *p* = 0.007)

Differences in Presentation Content Stem from Degree of Grounding in Algorithm Details



Art Supply Presentation Sample

"For ours we had to allow the input of integers between 1 and 100. And we created an array however large, and put them in ascending order from highest to lowest. On one of them we were supposed to use 2 arrays. So we set up our first array. Our while loop scans through one time and it goes to the highest number. After it's done it moves down to the second array and it moves the array iterator for the second array to the right. The next time it scans and finds the highest number it'll synchronize."

P2: So when get here to the while loop, it's just going to set [...] to that position, instead of swapping.
...
I: Is there an error in your program. [Noticing the visual display]
...
P2: Yeah, there is a problem.
I: Oh, you don't deal with duplicates.
P1: Yeah, we forgot to put that in.
P2: We just didn't think the odds of duplicates were too high.
I: Well, it does happen from time to time.
A: There's two 37's there. [Noticing the duplicates in the visual display]
P1: It doesn't matter in this case, because if the pivot is matched by another, then there's trouble because it doesn't know what to do when it equals instead of greater or less than.
I: Ah, well that's easy to fix. How would you fix that?
P1: You put in an else at the very end that says else equals to
I: Or you could change the if here to less than or equal to, and just add one else.

Further Research Needed to Address Our First Two Research Questions

- **RQ 1**: *Does construction of personalized AVs aid algorithm understanding?*
  - ALVIS students had significantly fewer errors
  - But we don't know whether they actually learned!
- **RQ 2:** *Does presentation of personalized AVs lead to educationally beneficial discussions?*
  - Art Supply presentations had hand-waving, leading to less participation
  - ALVIS discussions firmly grounded in code, leading to discussions of errors and fixes and increased audience participation
  - Further research questions are raised:
    - » Did students learn from each other's algorithms in presentations?
    - » Does a student have to make a contribution in order to learn?
    - » Do storylines enhance learning?
    - » What types of facilitation strategies are most effective?

ALVIS Appears to Have Advantages over Art Supplies

- **RQ3:** What form of AV technology best supports AV construction and presentation?
  - ALVIS promoted a faster coding process, with fewer stuck periods, and less reliance on expert help
  - ALVIS promoted conversations with a sharper focus on algorithm details, leading to collaborative identification and repair of semantic errors
  - However, we have found that ALVIS is far from optimal; we are refining it in ongoing work

Implications for CS Educators Interested in the Approach

- Students need consistent access to knowledgeable experts throughout the coding process
- Students need enough time to develop their solutions prior to the presentations; otherwise, they won't participate in them
- The quality of the presentation discussions depends on skilled facilitation

Questions?

For further information, and to download the ALVIS Live! software, visit the Visualization and End User Programming Lab (VEUPL) website:

http://eecs.wsu.edu/~veupl

VEUPL

ALVIS Live!

Algorithms Studio