



## RESEARCH QUESTION

How do subgoal-labeled worked examples affect learning through an entire introductory programming course?

## PROJECT ACTIVITIES

1. Conduct a cognitive task analysis to identify the subgoals of core concepts evaluating and writing **expression** and **selection** statements, evaluating and writing **loops**, evaluating and writing **arrays**, using **objects** and writing **classes**, and calling and writing **methods**
2. Develop subgoal labeled worked examples to use as instructional materials in Java-based CS1
3. Pilot test the materials in Morrison's CS1 course, collecting qual and quant data from quizzes and exams
4. (Future) – test the Java materials in ~10 sites nationally [Fall 2019]
5. (Future – develop Python-based materials and test at ~5 sites

## REFERENCES

Margulieux, L. E., Morrison, B. B., & Decker, A. (2019). Design and pilot testing of subgoal labeled worked examples for five core concepts in CS1. In *ITICSE '19: Innovation and Technology in Computer Science Education Proceedings*. New York, NY: ACM. doi: 10.1145/3304221.3319756

Decker, A., Margulieux, L. E., & Morrison, B. B. (2019). Using the SOLO Taxonomy to Understand Subgoal Labels Effect in CS1. In *Proceedings of the 15<sup>th</sup> annual Conference on International Computing Education Research (ICER '19)*. New York, NY: ACM. (August 2019)

## SUBGOAL LABELS

### Subgoals for evaluating and writing expression (assignment) statements

#### A. Evaluate expression statement

1. Determine whether data type of expression is compatible with data type of variable
2. Update variable for pre based on side effect
3. Solve arithmetic equation
4. Check data type of copied value against data type of variable
5. Update variable for post based on side effect

#### B. Write expression statement

1. Determine expression that will yield variable
2. Determine data type and name of variable and data type of expression
3. Determine arithmetic equation with operators
4. Determine expression components
5. Operators and operands must be compatible

### Subgoals for evaluating and writing selection statements

#### A. Evaluate selection statement

1. Diagram which statements go together
2. For if statement, determine whether expression is true or false
3. If true – follow true branch, if false –follow else branch or do nothing if no else branch

#### B. Write selection statement

1. Define how many mutually exclusive paths are needed
2. Order from most restrictive/selective group to least restrictive
3. Write if statement with Boolean expression
4. Follow with true bracket including action
5. Follow with else bracket
6. Repeat until all groups and actions are accounted for

### Subgoals for evaluating and writing loops

#### A. Evaluate loops

1. Identify loop parts
  - a. Determine start condition
  - b. Determine update condition
  - c. Determine termination condition
  - d. Determine body that is repeated
2. Trace the loop
  - a. For every iteration of loop, write down values

#### B. Write loops

1. Determine purpose of loop
  - a. Pick a loop structure (while, for, do\_while)
2. Define and initialize variables
3. Determine termination condition
  - a. Invert termination condition to continuation condition
4. Write loop body
  - a. Update loop control variable to reach termination

### Subgoals for calling and writing methods

#### A. Call or trace method calls

1. Classify method as static method or instance method
  - a. If static, use the class name
  - b. If instance, must have or create an instance
2. Write (instance / class) dot method name and ( )
3. Determine whether parameter(s) are appropriate
  - a. Number of parameters passed must match method declaration
  - b. Data types of parameters passed must match method declaration (or be assignable)
4. Determine what the method will return (if anything: data type, void, print, change state of object) and where it will be stored (nowhere, somewhere)
5. Evaluate right hand side of assignment (if there is one). Value is dependent on method's purpose

#### B. Write methods

1. Define method header based on problem
2. Define return statement at the end
3. Define method body/logic
  - a. Determine types of logic (expression, selection, loop, etc.)
  - b. Define internal variables
  - c. Write statements

## METHOD

Java-based CS1 at UNOmaha

5 sections of one course (shared everything)

- 2 sections used subgoal labeled materials,  $n = 120$
- 3 sections used original materials,  $n = 145$

Collected data with

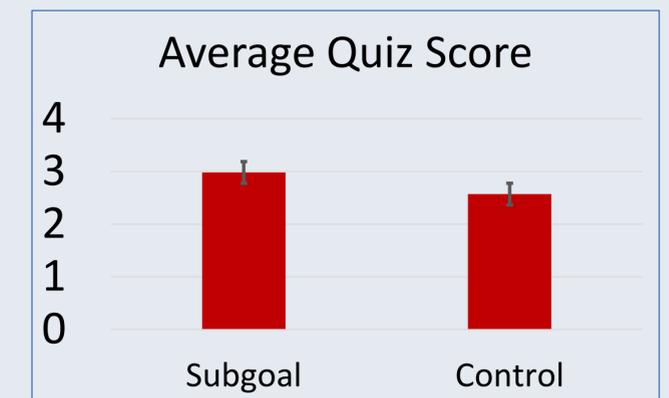
- Demographic survey
- Weekly timed quizzes (multiple choice, short answer, and Explain in Plain English questions)
- Four timed exams (multiple choice, short answers, and long answer question)

Analyzed data with

- Inferential analysis of assessment performance
- SOLO analysis of Explain in Plain English responses

## RESULTS

Quiz performance (only for weeks with subgoal materials)



Explain in Plain English on Quiz 1 (analyzed with SOLO taxonomy)

	1	2	3	4	5
<b>Subgoal</b>	1	8	18	43	14
<b>Mode = 4</b>	(1%)	(10%)	(21%)	(51%)	(17%)
<b>Control</b>	6	14	27	25	3
<b>Mode = 3</b>	(8%)	(19%)	(36%)	(33%)	(4%)

