

# Instructional Design + Knowledge Components:

## A Systematic Method for Refining Instruction

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**Computer Science**: *Luke Gusukuma, Austin Cory Bart, Dennis Kafura*

**Education**: *Jeremy Ernst, Katherine Cennamo*



# Cliff Notes

Concrete



# Instructional Design

Theoretical

Knowledge  
Component



# Prior Work

## Modularization: a Key for the Dynamic Selection of Relevant Knowledge Components

Mathieu d'Aquin, Marta Sabou, and Enrico Motta

## The Knowledge Warehouse: Reusing Knowledge Components

Michael Yacci

## Discovering Prerequisite Relationships among Knowledge Components

Richard Scheines

Elizabeth Silver

Ilya Goldin

## Specifications of Knowledge Components for Reuse

Enrico Motta<sup>1</sup>, Dieter Fensel<sup>2</sup>, Mauro Gaspari<sup>1</sup>, and Richard Benjamins<sup>3</sup>

## The Knowledge-Learning-Instruction Framework: Bridging the Science-Practice Chasm to Enhance Robust Student Learning

Kenneth R. Koedinger,<sup>a</sup> Albert T. Corbett,<sup>b</sup> Charles Perfetti<sup>c</sup>

## Components of instruction toward a theoretical tool for instructional design

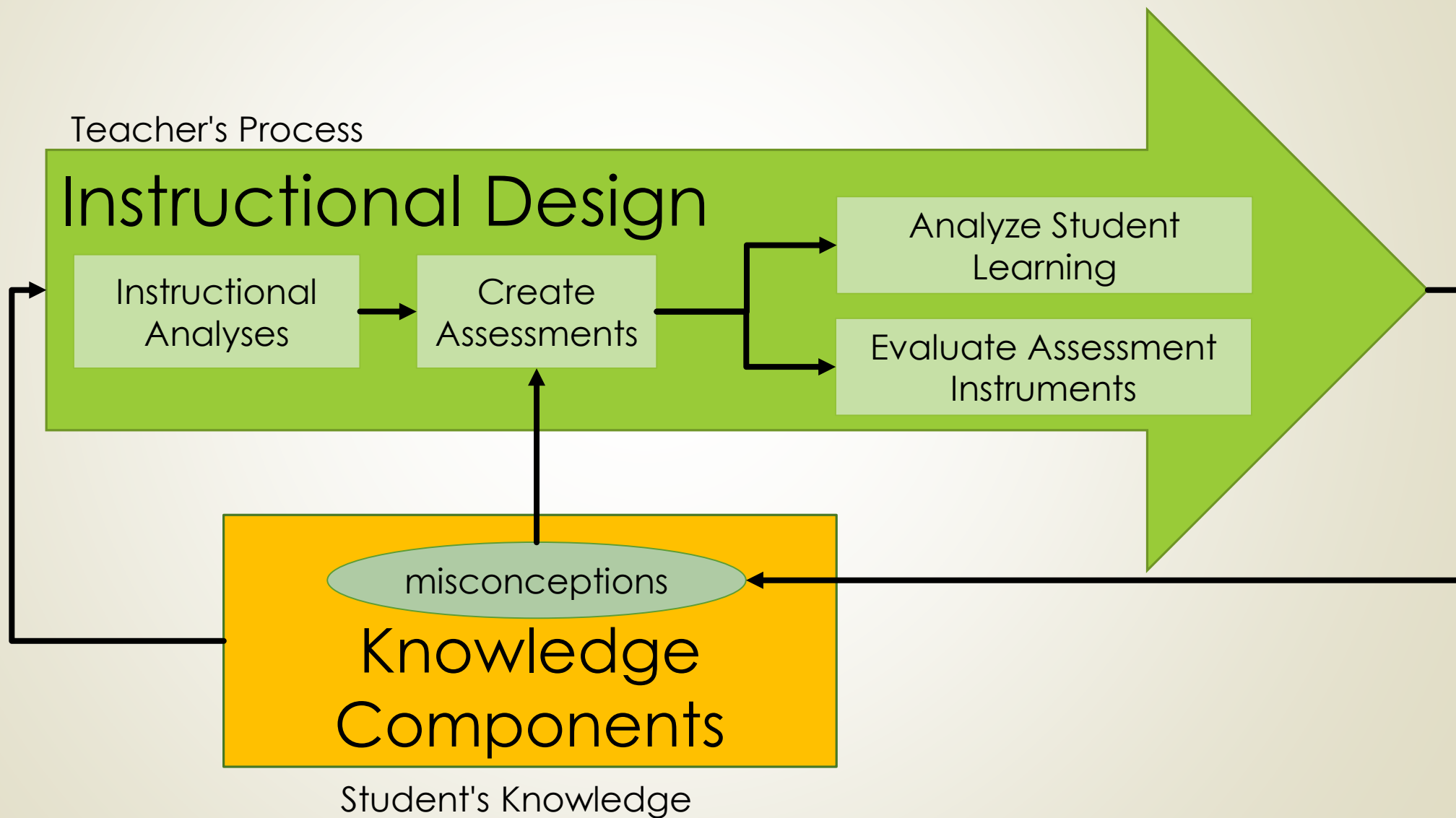
M. DAVID MERRILL

# Systematically Improving Instruction

- Instruction revision is crucial to course design
- Instruction needs to evolve with time
- Don't typically need to revise an entire course
- Don't have a formalized process



# What is ID + KC



# Knowledge Component

“...an acquired unit of **cognitive function** or structure that can be **inferred** [observed] from performance...”

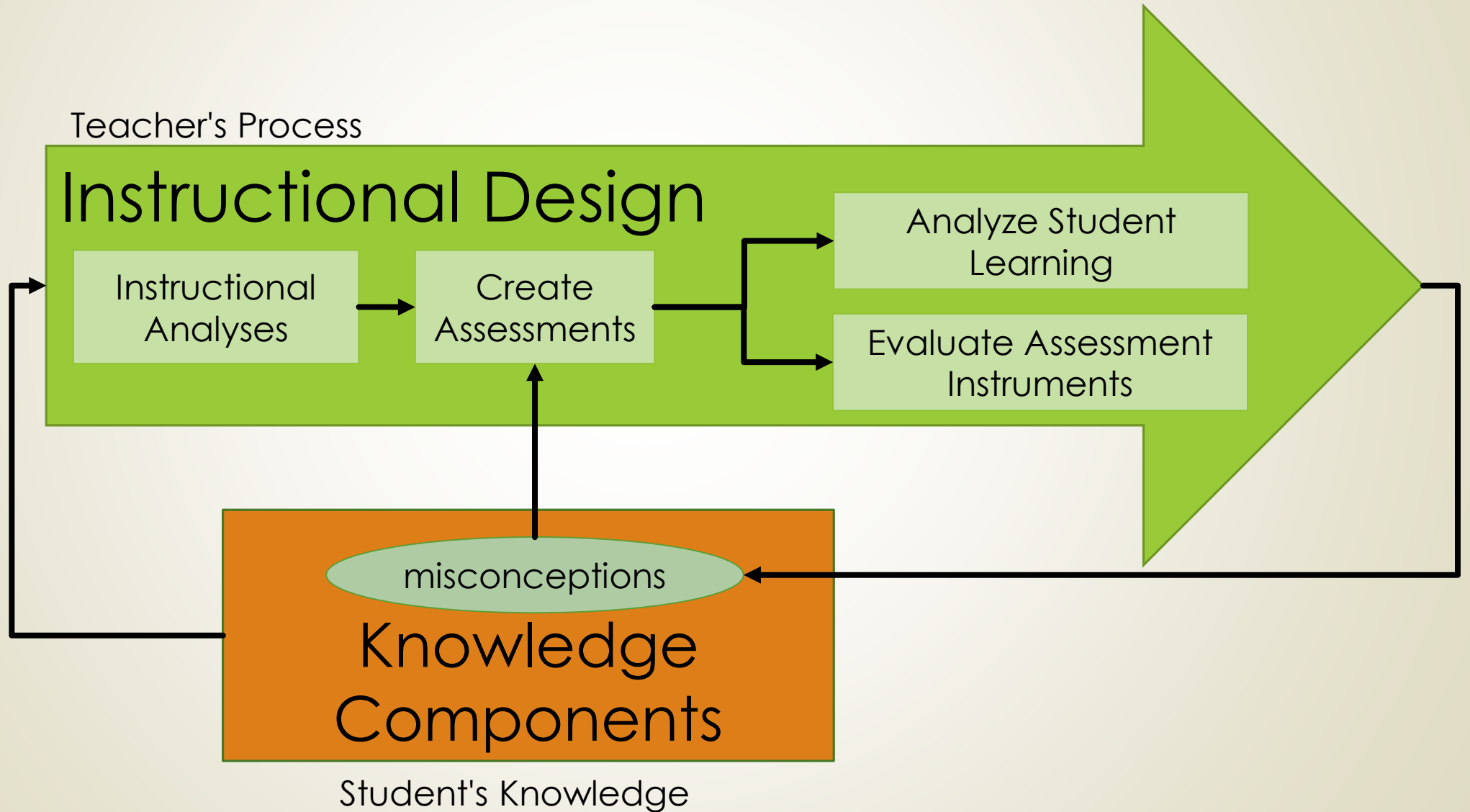
## Knowledge Component - Example

You can add together a number and a list



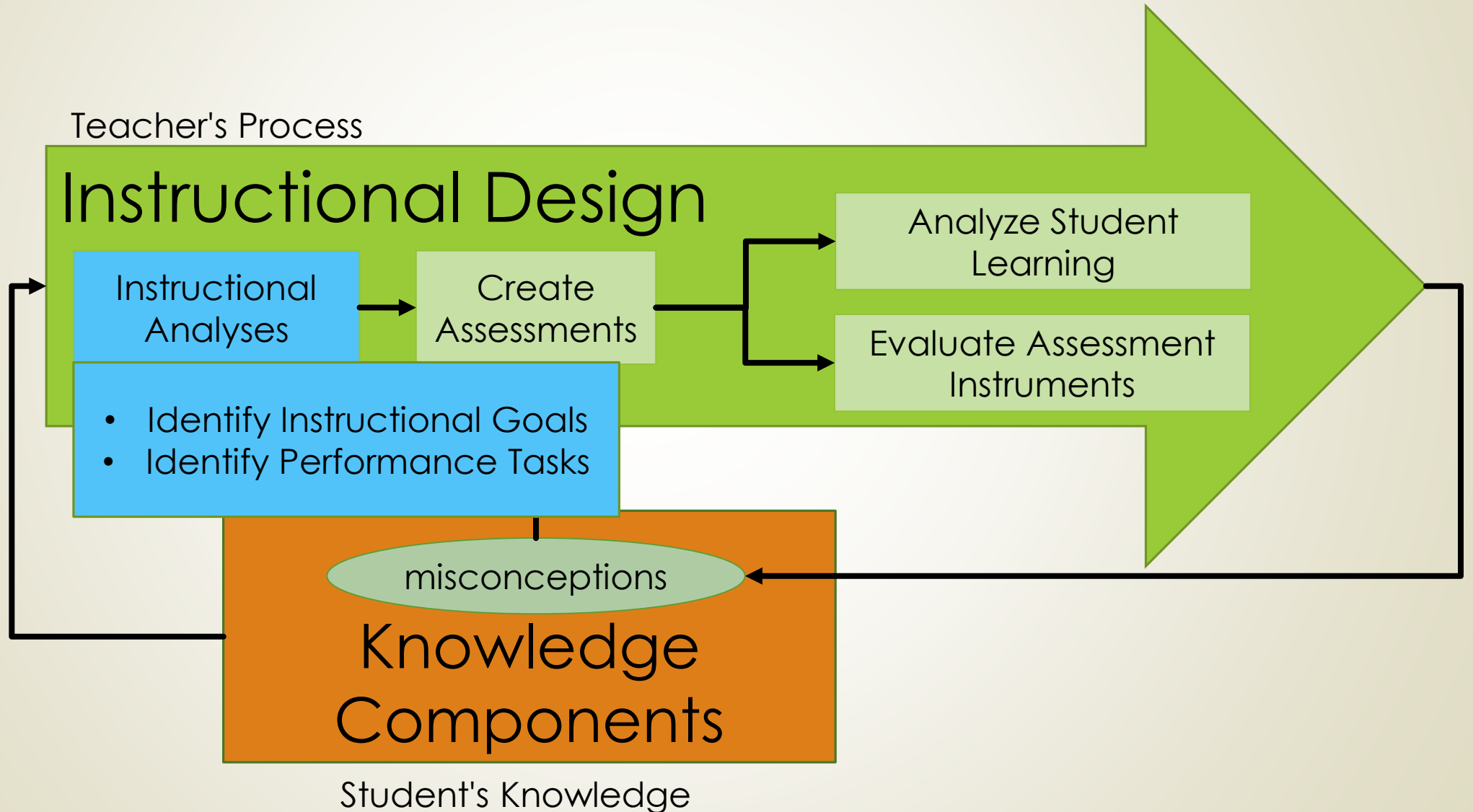
You can't add together a number and a list

# ID + KC: The steps

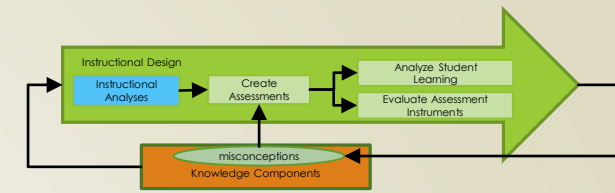




# ID + KC: The steps



# Identify Instructional Goals

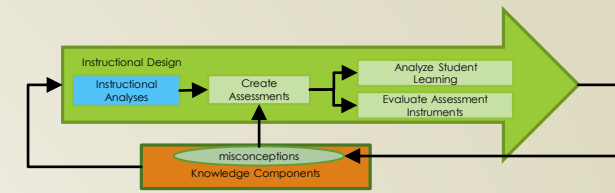


Construct an algorithm that outputs a quantitative measure of the values in a given list

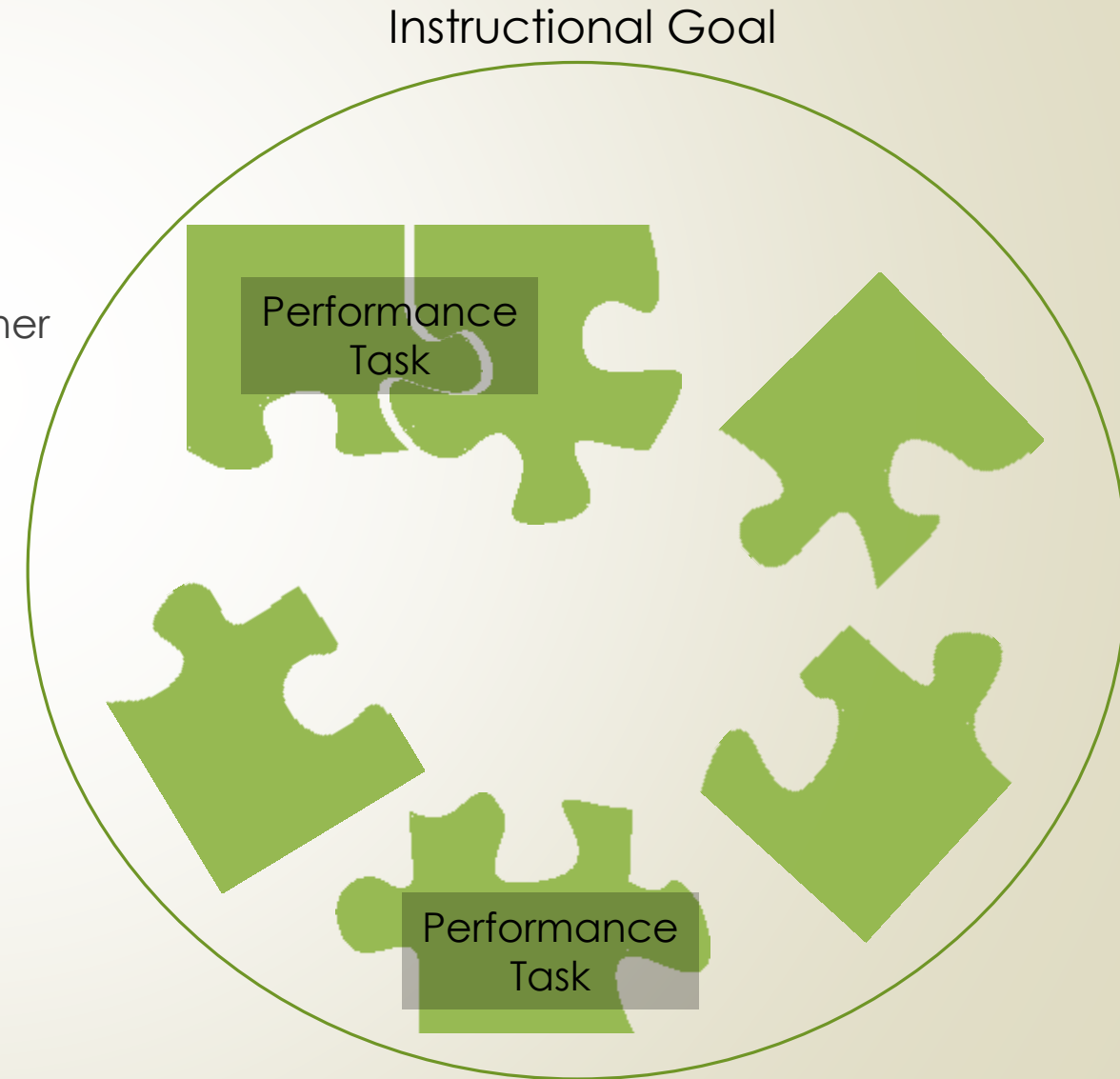
Instructional Goal



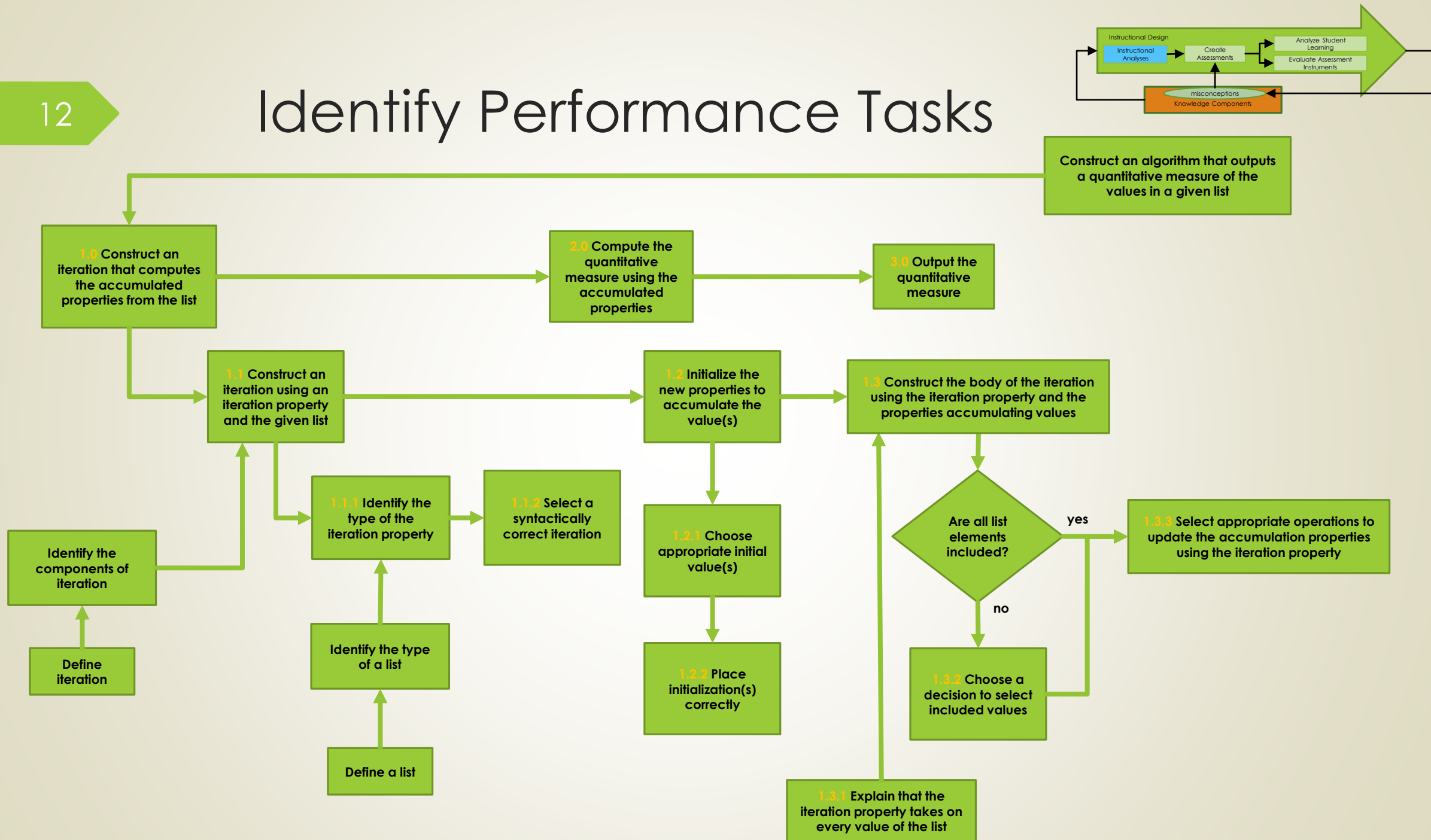
# Identify Performance Tasks



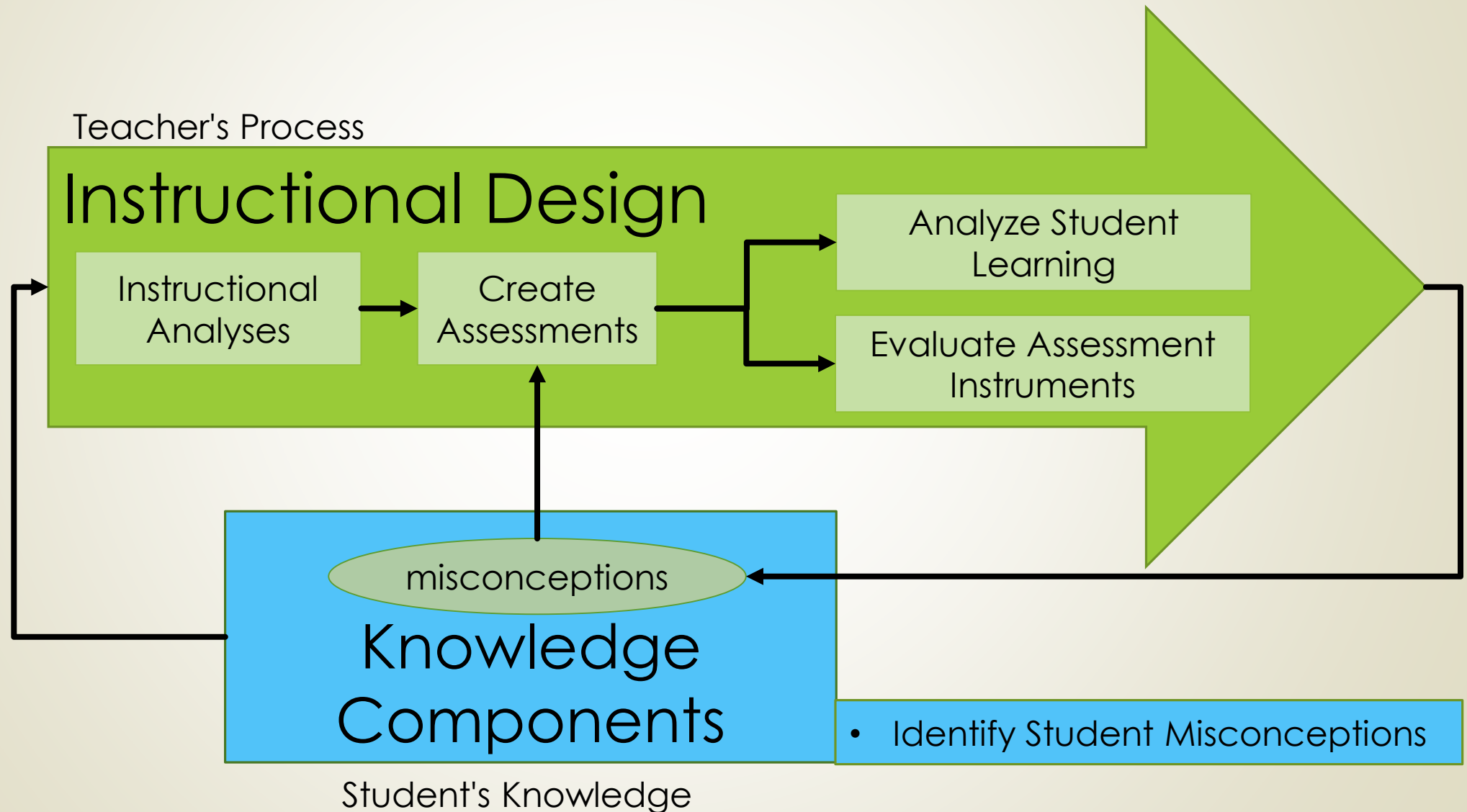
- Why?
  - Helps create assessments
  - Groups misconceptions together



# Identify Performance Tasks



# ID + KC: The steps

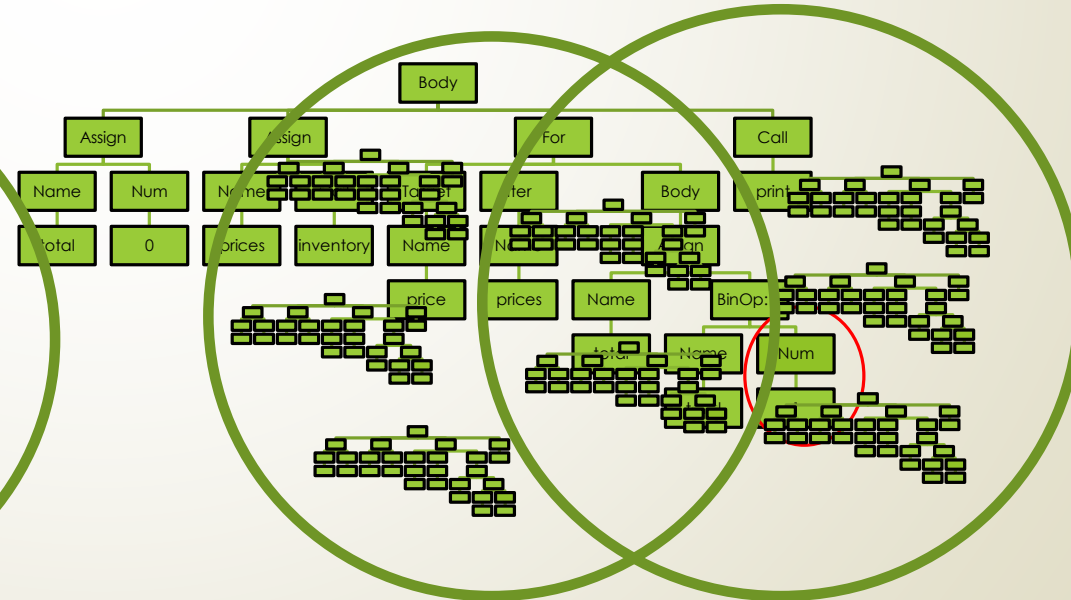
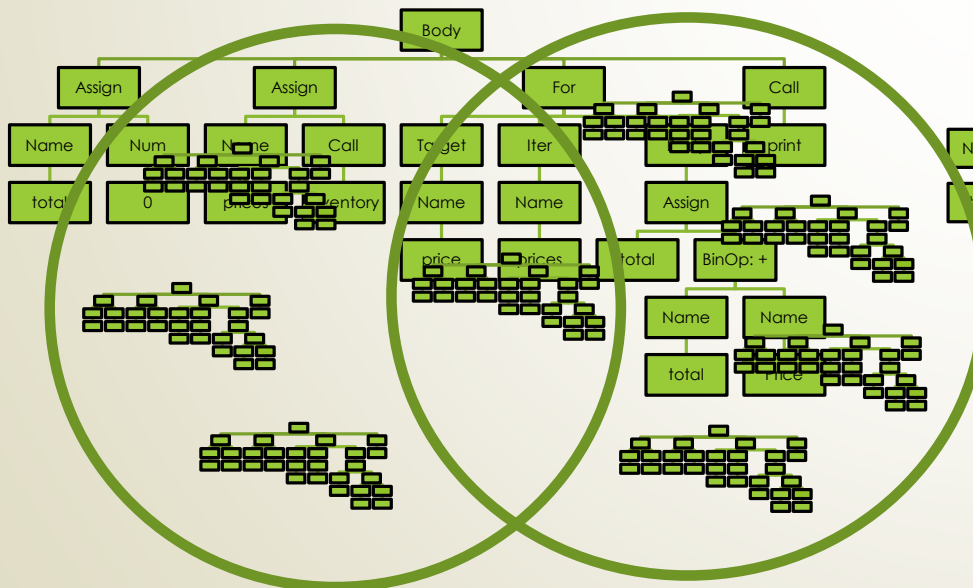
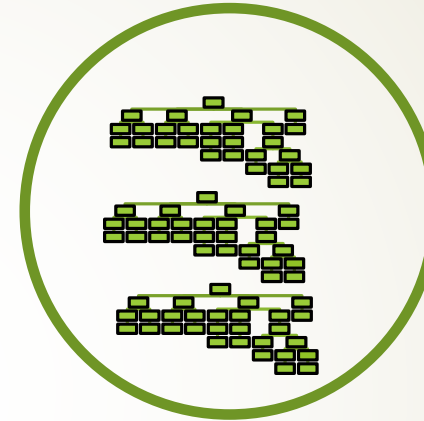
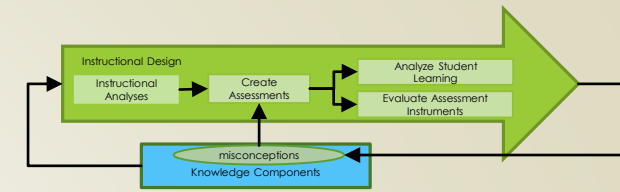




# Identify Student Misconceptions

## Identifying Misconceptions

- Classroom Observations
- Personal Experience
- Manual Inspection student work
- Automated Code Analysis



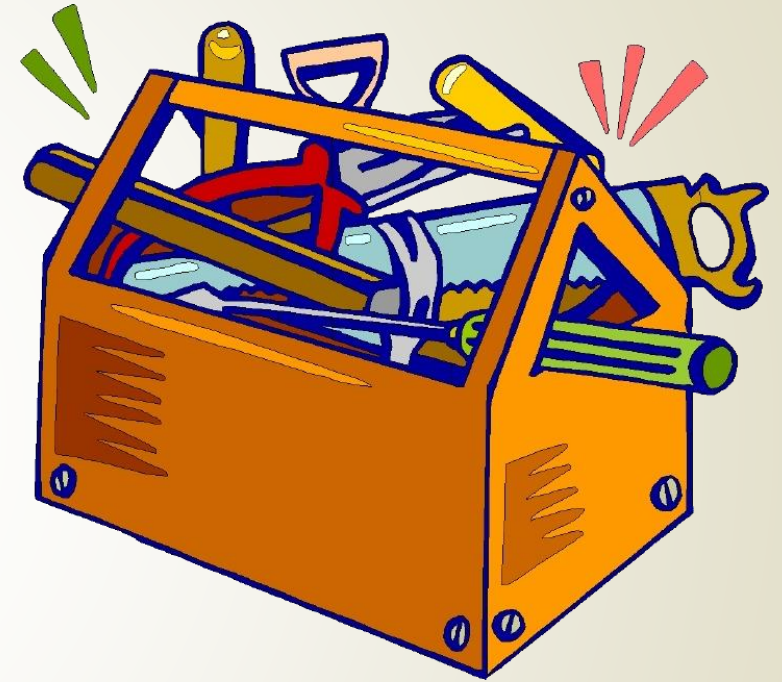
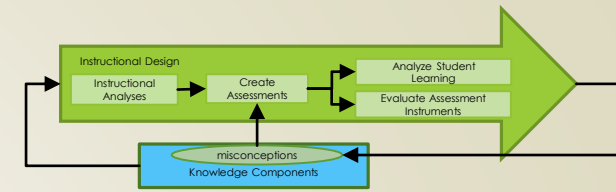
# Identify Student Misconceptions

## Identifying Misconceptions

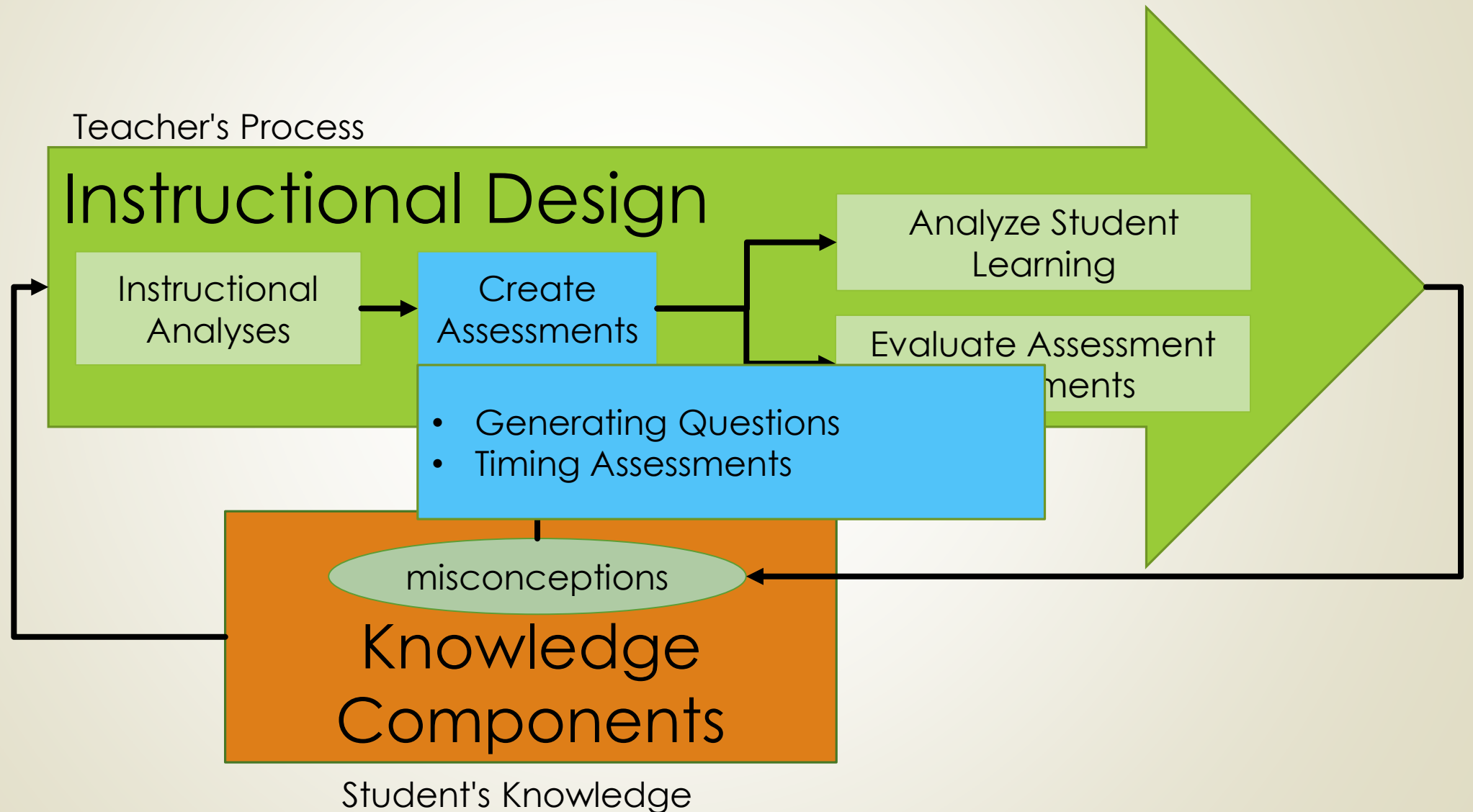
- Classroom Observations
- Personal Experience
- Manual Inspection student work
- Clustering Algorithms

## Why?

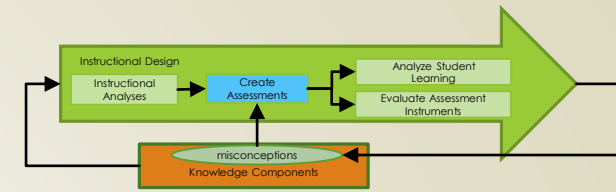
- Pervades everything
- Polish instructional goal
- Helps create assessments
- Student driven – KNOWLEDGE COMPONENTS



# ID + KC: The steps

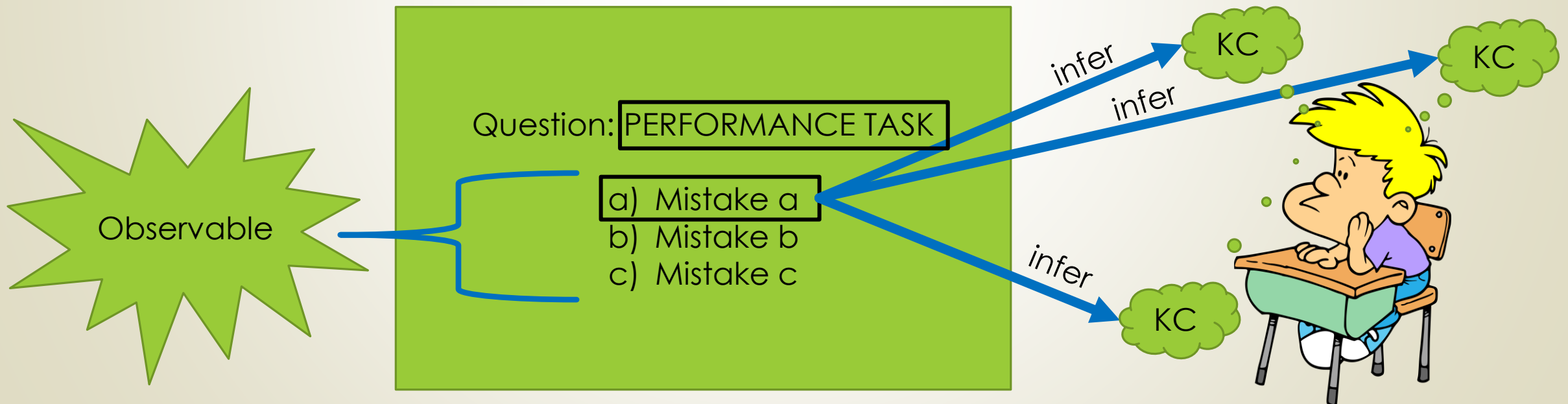


# Generating Questions

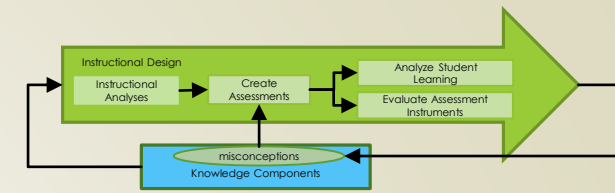


## Why?

- Systematically ties student data to Instructional Goals



# Generating Questions



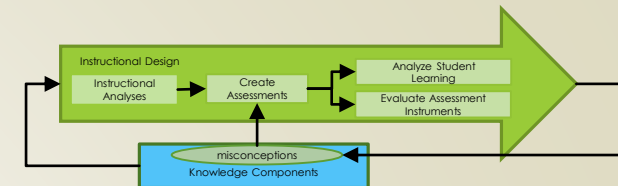
Question: PERFORMANCE TASK

- a) Mistake a
- b) Mistake b
- c) Mistake c

**1.3 Construct the body of the iteration using the iteration property and the properties accumulating values**



# Generating Questions



**1.3 Construct the body of the iteration using the iteration property and the properties accumulating values**

When using the iteration shown below to compute the sum of the numbers in the `distance_list`, which of the following is the correct statement to be in the body of the iteration?

```
distance_sum = 0
for distance in distance_list:
```

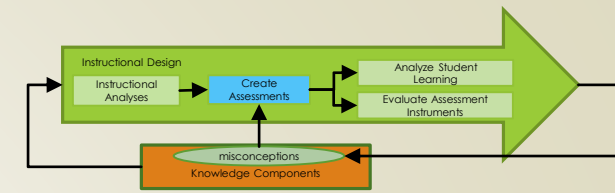
\_\_\_\_\_

- a) `distance_sum = distance_list + distance`
- b) `distance = distance_sum + distance`
- c) `distance_sum = distance_sum + distance_list`
- d) `distance_sum = distance_sum + distance`
- e) `distance_list = distance`
- f) `distance_sum = distance_sum + 1`
- g) `distance_sum = distance_list`

**Instructional Goal**  
Construct an algorithm that outputs a quantitative measure of the values in a given list

The data block in the Blockly canvas below provides a list of the number of students taking the 2015 SAT test in each state. Write an algorithm to compute and print the total number of students taking the SAT test in 2015.

# Timing Assessments



## Pre-test

- Baseline knowledge



Before Instruction

Beginning of Day 3



## Final post-test

- Learning Results



Beginning of Day 4

Beginning of Day 20



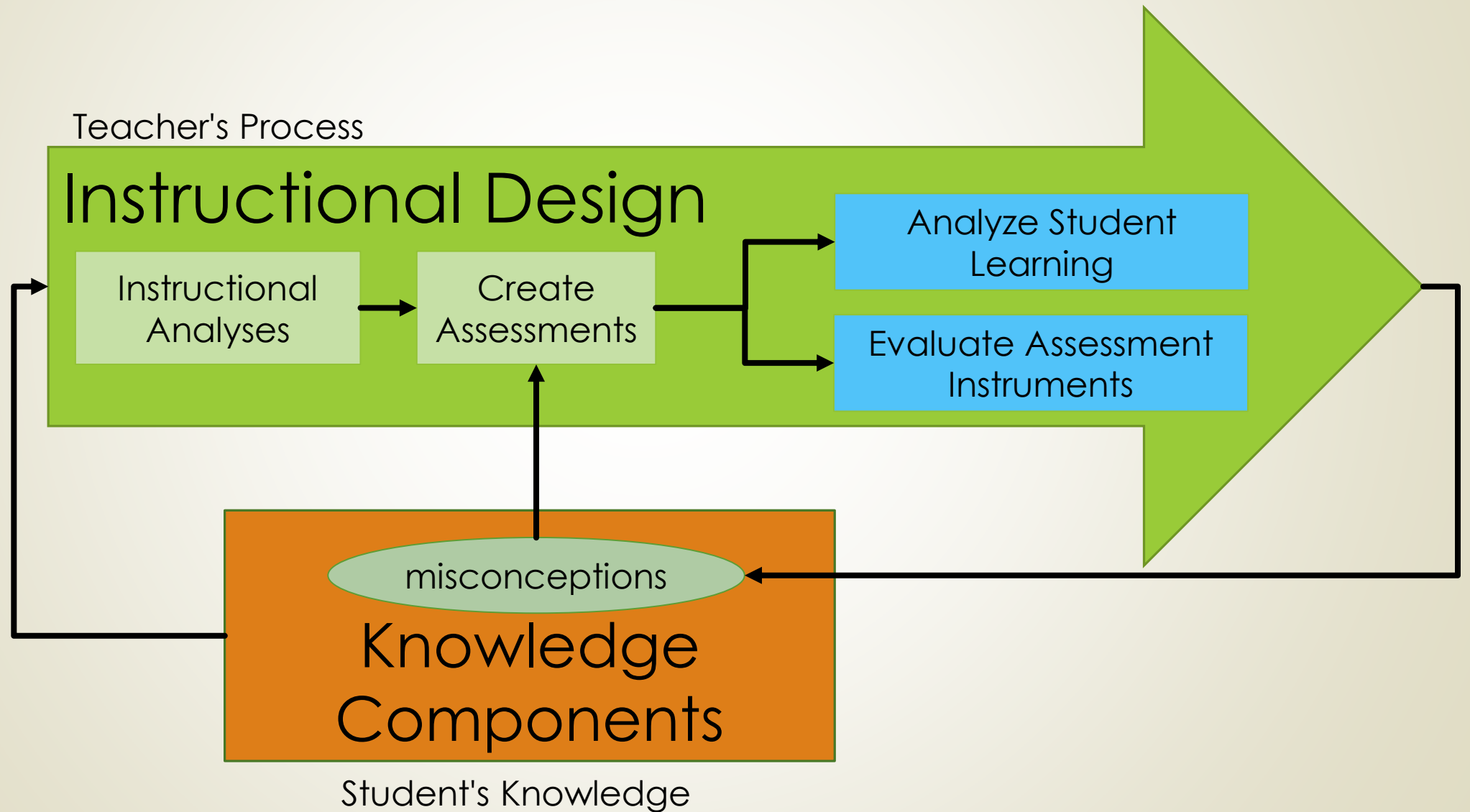
## Embedded post-test

- Improvement over time
- Speed of acquisition

## Far transfer post-test

- Retention

# ID + KC: The steps

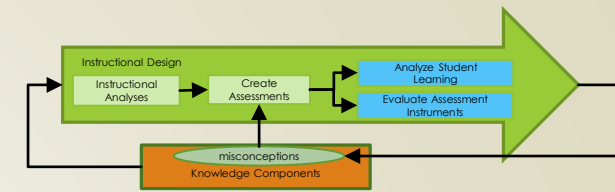


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# Metrics Analysis

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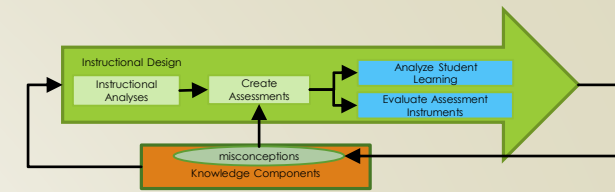


	Percent of Students Correct				Learning Gains			Discrimination
	pre	post1	post2	post3	post1	post2	post3	Average
Question 1	0.65	0.55	0.71	0.59	-0.3	0.18	-0.2	0.59
Question 2	0.63	0.95	1	1	0.86	1	1	0
Question 3	0.33	0.95	0.93	0.94	0.92	0.9	0.91	0.22
Question 4	0.24	0.69	0.71	0.8	0.6	0.62	0.73	0.6
Question 5	0.71	1	1	1	1	1	1	0
Question 6	0.52	0.91	0.88	0.9	0.81	0.74	0.79	0.55
Question 7	0.33	0.47	0.89	0.94	0.21	0.83	0.91	0.4
Question 8	0.37	0.51	0.82	0.73	0.22	0.72	0.57	0.66
Question 9	0.44	0.77	0.93	0.81	0.59	0.88	0.66	0.36



# Analysis – Q1

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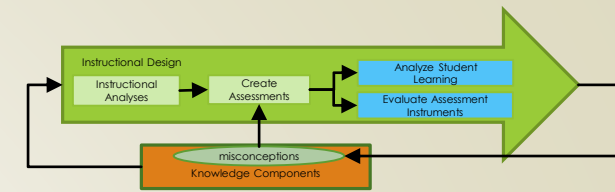


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Question 9	0.44	0.77	0.93	0.81	0.59	0.88	0.66	0.36

# Analysis – Q4

	Percent of Students Correct				Learning Gains			Discrimination
	pre	post1	post2	post3	post1	post2	post3	Average
Question 1	0.65	0.55	0.71	0.59	-0.3	0.18	-0.2	0.59
Question 2	0.63	0.95	1	1	0.86	1	1	0
Question 3	0.33	0.95	0.93	0.94	0.92	0.9	0.91	0.22
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Question 9	0.44	0.77	0.93	0.81	0.59	0.88	0.66	0.36

# Analysis – Q4



When using the iteration shown below to compute the sum of the numbers in the `distance_list`, which of the following is the correct statement to be in the body of the iteration?

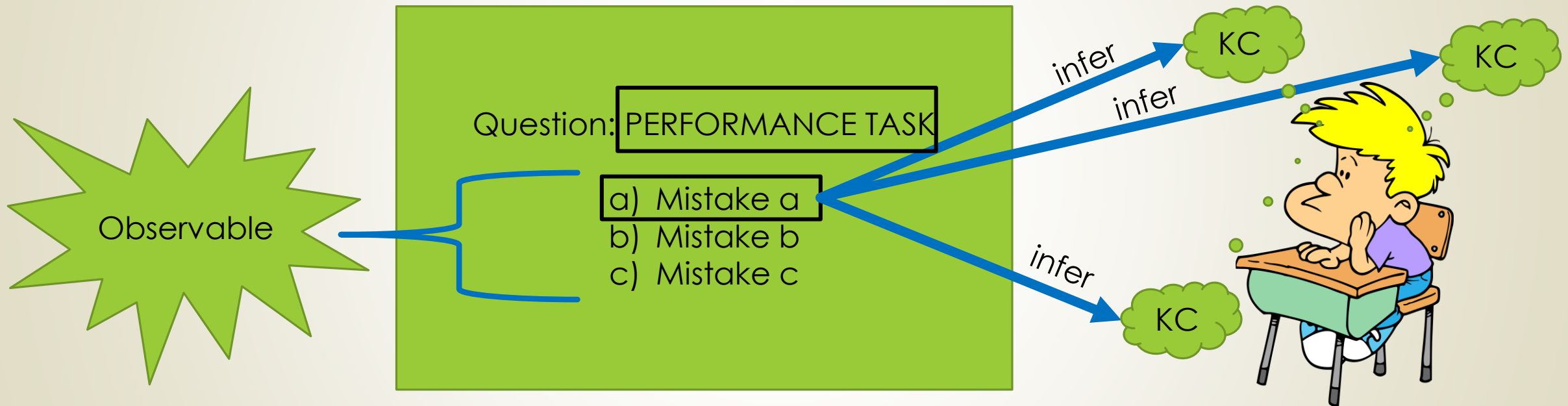
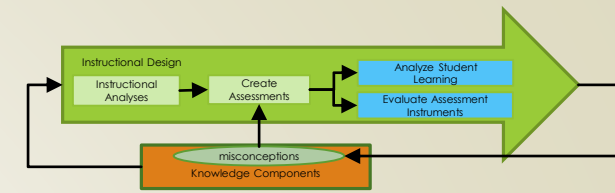
```
distance_sum = 0
```

```
for distance in distance_list:
```

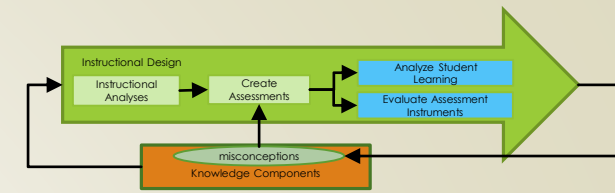
```
    _____
```

- a) `distance_sum = distance_list + distance`
- b) `distance = distance_sum + distance`
- c) `distance_sum = distance_sum + distance_list`
- d) `distance_sum = distance_sum + distance`
- e) `distance_list = distance`
- f) `distance_sum = distance_sum + 1`
- g) `distance_sum = distance_list`

# Question Design



## Question 4



When using the iteration shown below to compute the sum of the numbers in the `distance_list`, which of the following is the correct statement to be in the body of the iteration?

```
distance_sum = 0
```

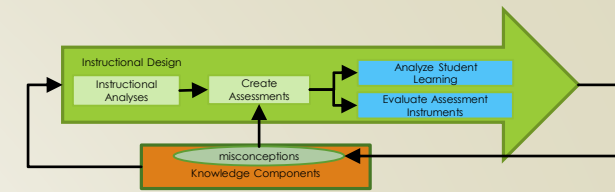
```
for distance in distance_list:
```

```
    _____
```

- a) `distance_sum = distance_list + distance`
- b) `distance = distance_sum + distance`
- c) `distance_sum = distance_sum + distance_list`
- d) `distance_sum = distance_sum + distance`
- e) `distance_list = distance`
- f) `distance_sum = distance_sum + 1`
- g) `distance_sum = distance_list`



# Take Action



a)  $\text{distance\_sum} = \text{distance\_list} + \text{distance}$

## Student Knows

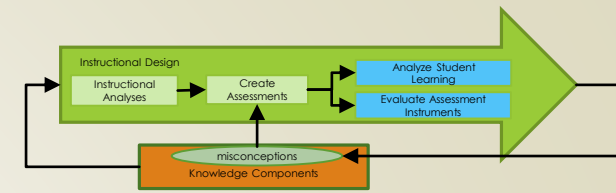
- KC 09: The iteration variable and the list are two different items
- KC 18-1: Need an accumulator variable on the left side
- KC 18-2: Need iteration variable on the right side
- ...

## Student Doesn't know

- KC 08: The list is multiple items
- KC 20: You can't add a list to a number
- KC 13: The sum and the list are two different items
- ...

# Summary

- Decompose a well defined instructional goal into tasks
- Collect Misconceptions
- Create assessments systematically using misconceptions and tasks
- Analyze student learning and assessment instruments using 3 easy to understand metrics



## Questions?

- Contacts:
- Luke Gusukuma: [lukesg08@vt.edu](mailto:lukesg08@vt.edu)
- Dennis Kafura: [kafura@cs.vt.edu](mailto:kafura@cs.vt.edu)
- Austin Cory Bart: [acbart@vt.edu](mailto:acbart@vt.edu)



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# Future Work

- ▶ Looking at specific KCs across questions
- ▶ Incorporation of the ID + KC process into automated systems
- ▶ Misconceptions as assessment tools in open programming problems

# Improvement – Question 4: The Knowledge Components

- KC006: The iteration property takes on each value of the list
- KC007: The iteration property is a single item
- KC008: The list is multiple items
- KC009: The iteration property and the list should be different
- KC012: The sum and the list are two different items
- KC013: The accumulator and the list are two different items
- KC018: Update for sum is  $\text{accumulator} = \text{accumulator} + \text{iteration property}$ 
  - Contains 6 subcomponents
- KC019: Update for accumulation is  $\text{accumulator} = \text{accumulator} + X$
- KC020: You can't add the list to a number
- KC022: The list is not used in accumulation
- KC023: The list is not used as an accumulator
- KC024: The iteration property is not an accumulator
- KC025: for each loop is for iter\_prop in list

# Appendix – Discrimination P-Values

	P-values for discrimination		
	post1	post2	post3
q1	1.05E-07	6.20429E-11	7.78E-09
q2	0.005955	#DIV/0!	#DIV/0!
q3	0.234948	0.023552222	0.008578
q4	6.69E-06	4.66073E-15	2.33E-09
q5	#DIV/0!	#DIV/0!	#DIV/0!
q6	1.91E-07	5.28738E-13	8.74E-05
q7	1.25E-08	0.009457884	0.001904
q8	8E-07	9.9301E-19	1.3E-12
q9	0.002875	0.002527445	8.49E-05

# Item Analysis

## Classical Test Theory

### ► Pros

- Easy to understand
- Easy to use
- Looser Assumptions

### ► Cons

- Less flexible
- Doesn't allow for inter-test comparisons

## Item Response Theory

### ► Pros

- More Versatile
- More Flexible
- More possible Analyses
- Allows inter-test comparisons
- Handles larger populations
- More information

### ► Cons

- Difficult to understand
- Stricter Assumptions