2018

Continuous improvement: How systems design can benefit the data-driven design community

Lomas, James, Patel, Nirmal and Forlizzi, Jodi

Designing for Continuous Improvement in K12

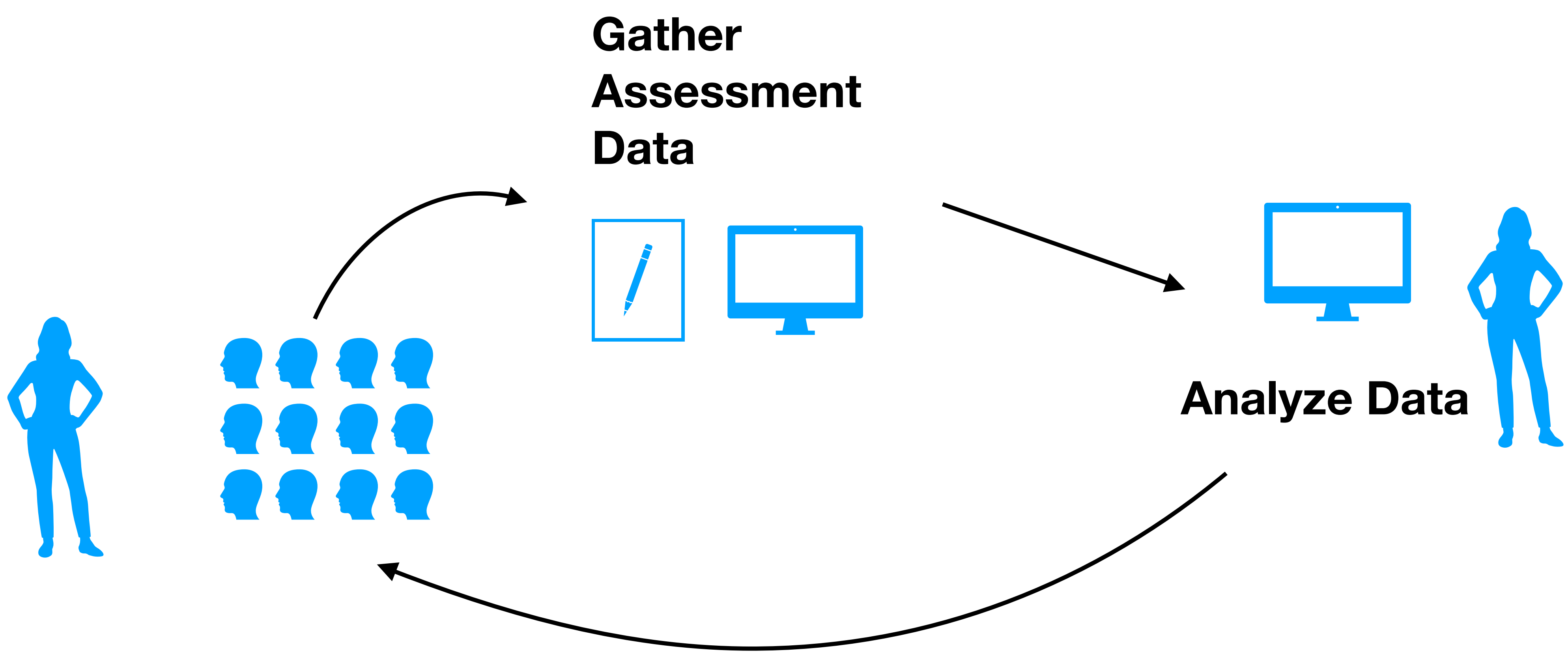
How systems design can help data-driven design in complex-technical systems

Data-Driven
Continuous Improvement in K12

"Data-Driven Decision-Making”

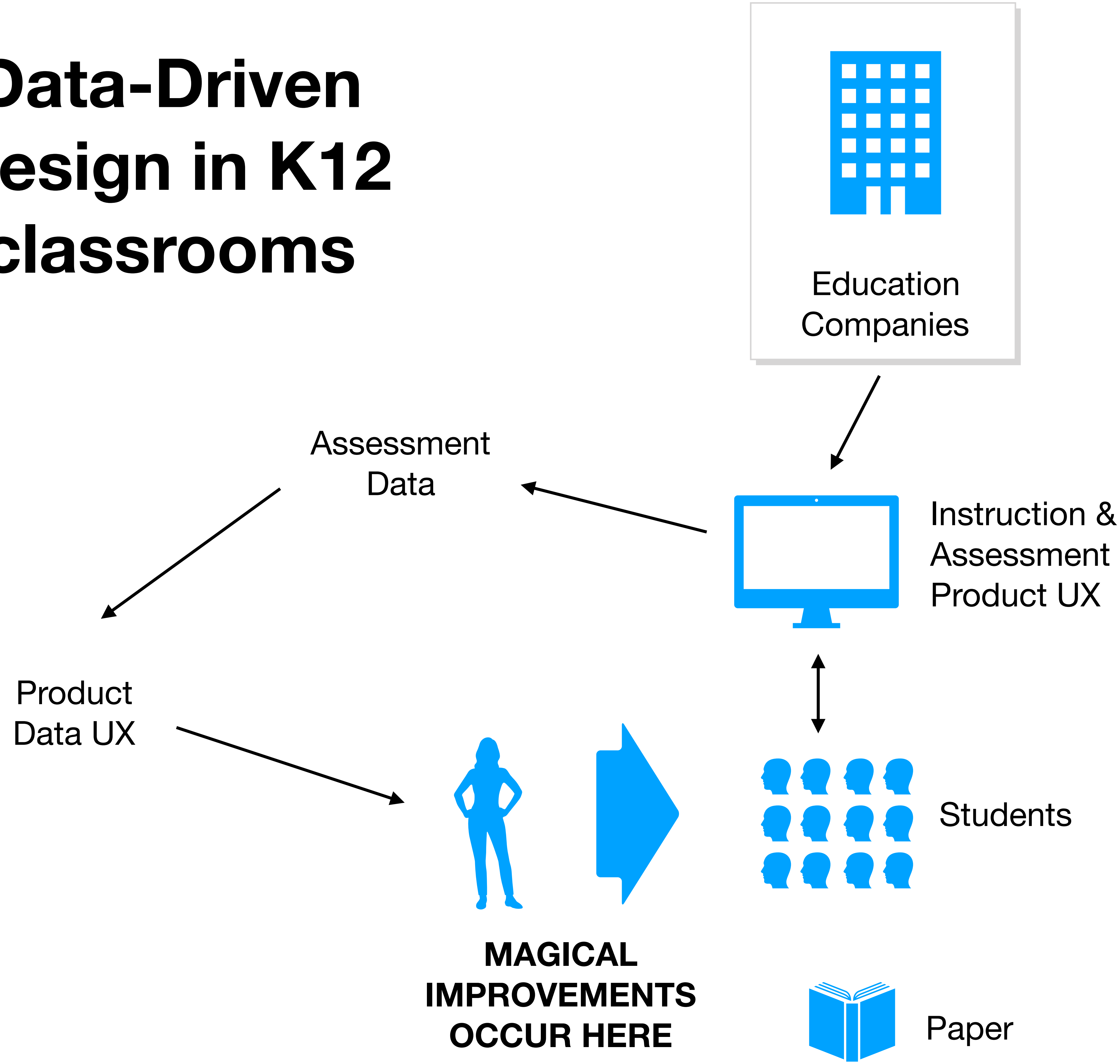
Slavin et al, 2013

1. Gather assessment data
2. Analyze data to identify problems and their causes
3. Select actions to address those problems



Slavin, R. E., Cheung, A., Holmes, G., Madden, N. A., & Chamberlain, A. (2013). Effects of a data-driven district reform model on state assessment outcomes. *American Educational Research Journal*, *50*(2), 371-396.

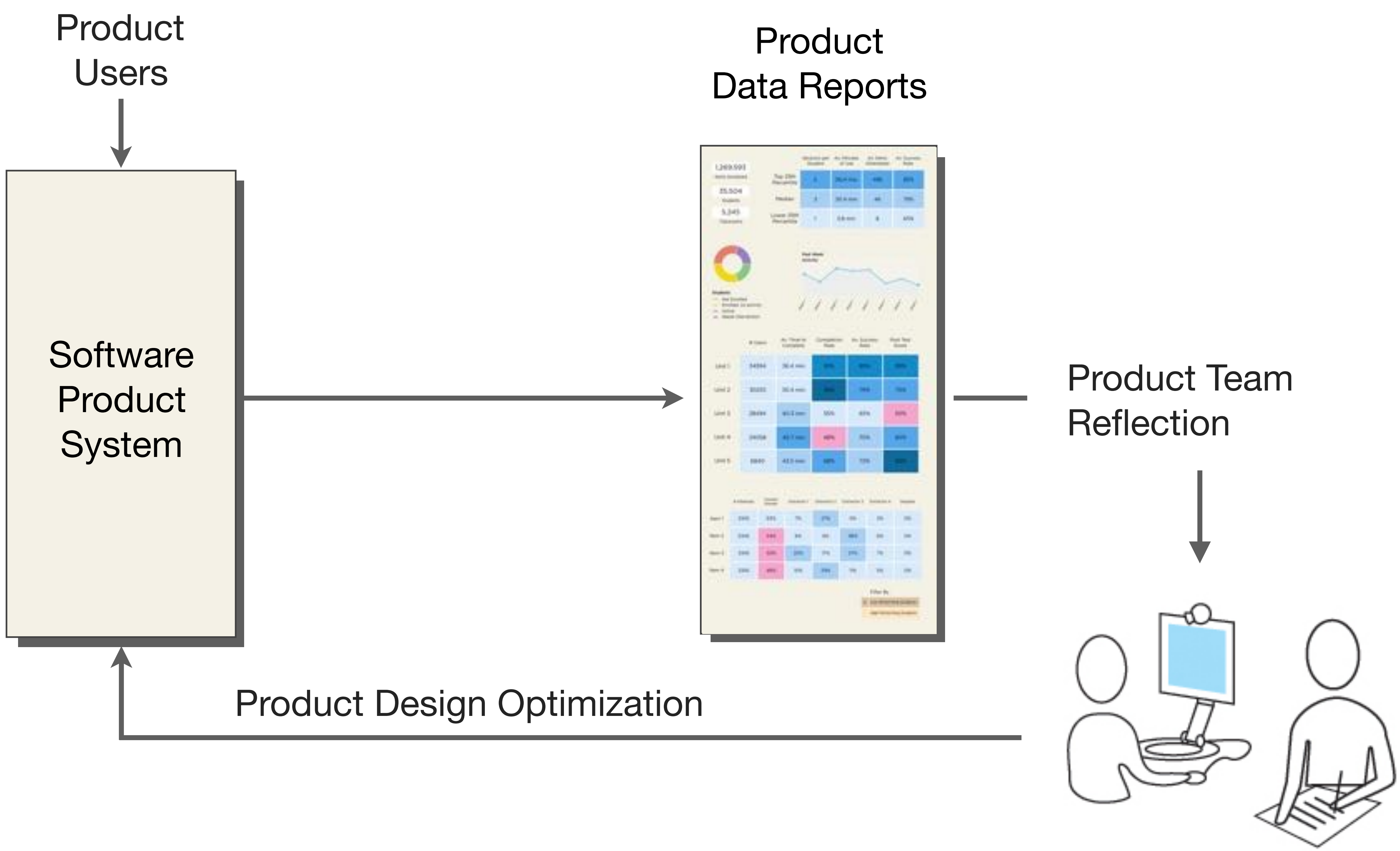
Data-Driven Design in K12 classrooms



What is Data-Driven Design?

1. Define “the right” goals (or needs).
2. Define “the right” measures of those goals.
3. Take actions to modify the current system when goals aren’t met.

Software Model of Data-Driven Continuous Improvement



How Might We Design Systems to Support Data-Driven Continuous Improvement?

Simple Heuristic Advice:
just make it easier to measure and modify

Measure Outcomes

Continuous Improvement Loop

Modify Designs

“What are the areas of need?”

“What can we do about it?”

Online Product Experiments (A/B Tests): A Method for Continuous Improvement

Designs

Users

Metrics

A

B

random assignment

Which design has best effect on outcomes?

Over 10,000/day run by Google, Facebook, Amazon, etc

Continuous Improvement in K12

"Data-Driven Decision-Making”

Slavin et al, 2013

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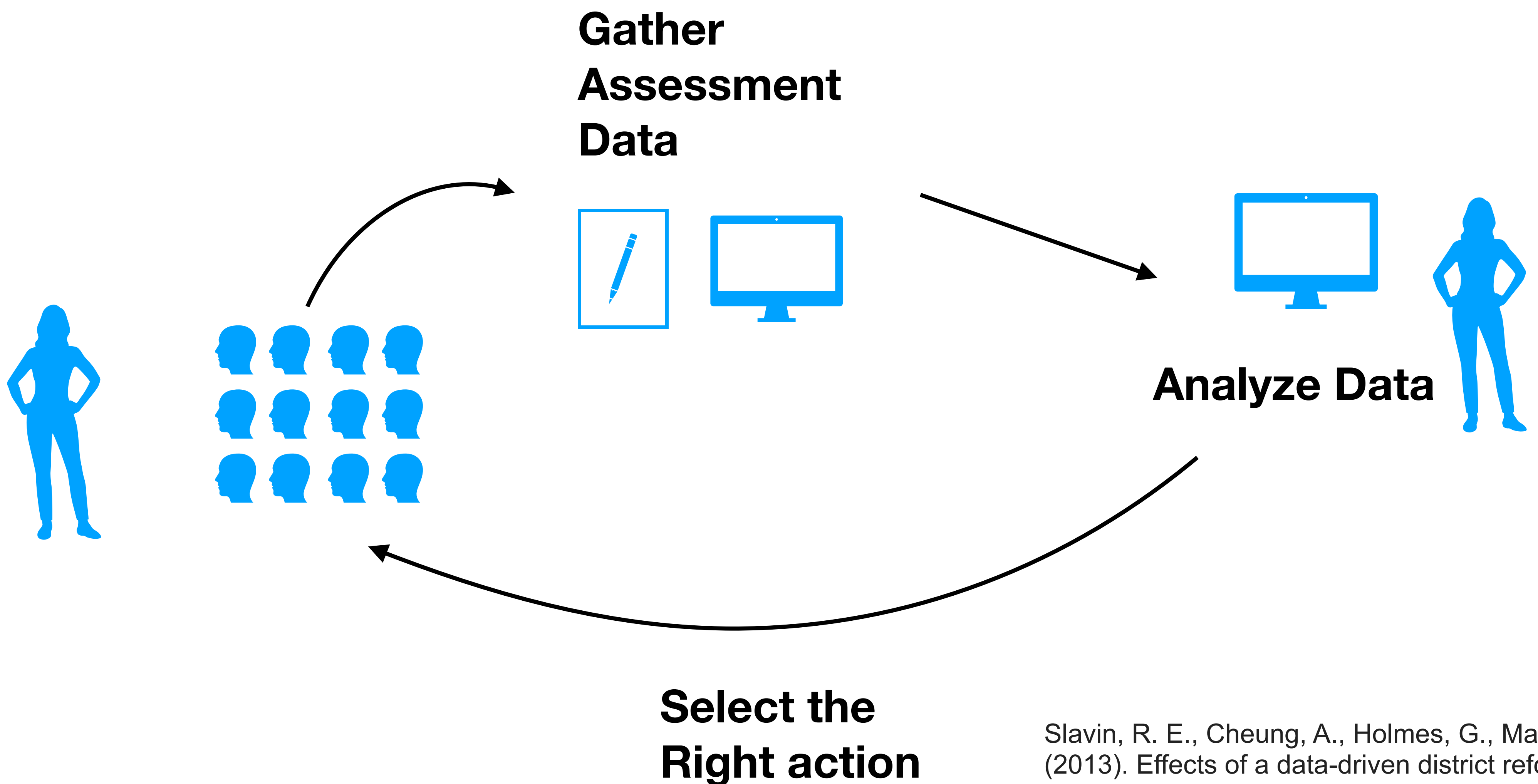

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Why is there desire for "Data-Driven Decision Making" (DDDM) in K12?

Very few interventions have been found to be effective in addressing the poverty achievement gap.

In a review of 196 randomised field experiments, Data-Driven Decision Making was found to be one of the most effective approaches for improving high-poverty schools (Fryer, 2017).

Fryer Jr, R. G. (2017). The production of human capital in developed countries: Evidence from 196 randomized field experimentsa. In Handbook of Economic Field Experiments(Vol. 2, pp. 95-322). North-Holland.

Van Geel, M., Keuning, T., Visscher, A. J., & Fox, J. P. (2016). Assessing the effects of a school-wide data-based decision-making intervention on student achievement growth in primary schools. *American Educational Research Journal*, *53*(2), 360-394.

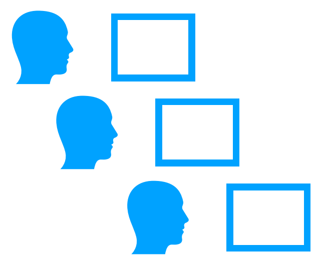
DDDM is not “disruptive” or radical change.

DDDM is all about small incremental improvements… ideal for complex social-technical systems

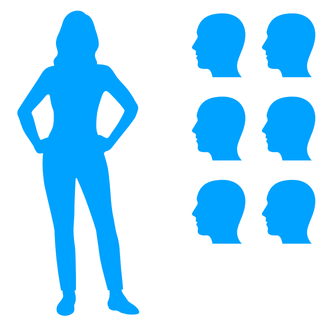
K12 Education is a
Complex-Technical System

K12 Education is a Complex-Technical System

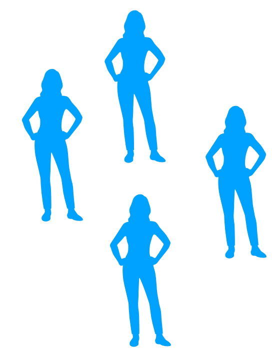
Family Interactions



Computer Interactions



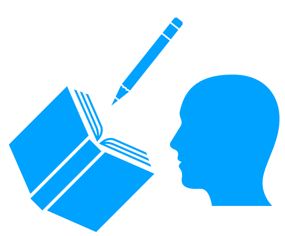
Teacher Interactions



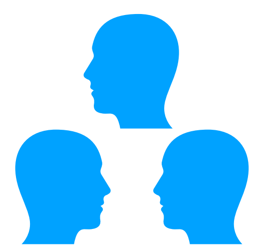
PLCs

Government Policy

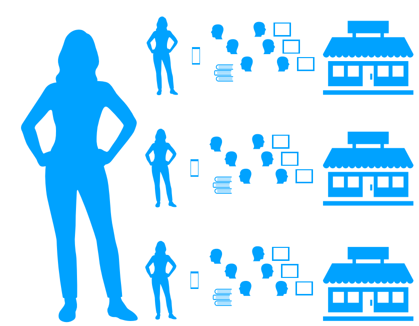
Out-of-School Programs



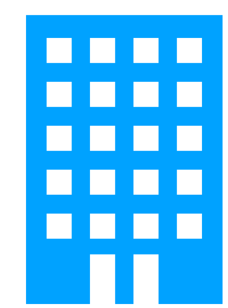
Text Interactions



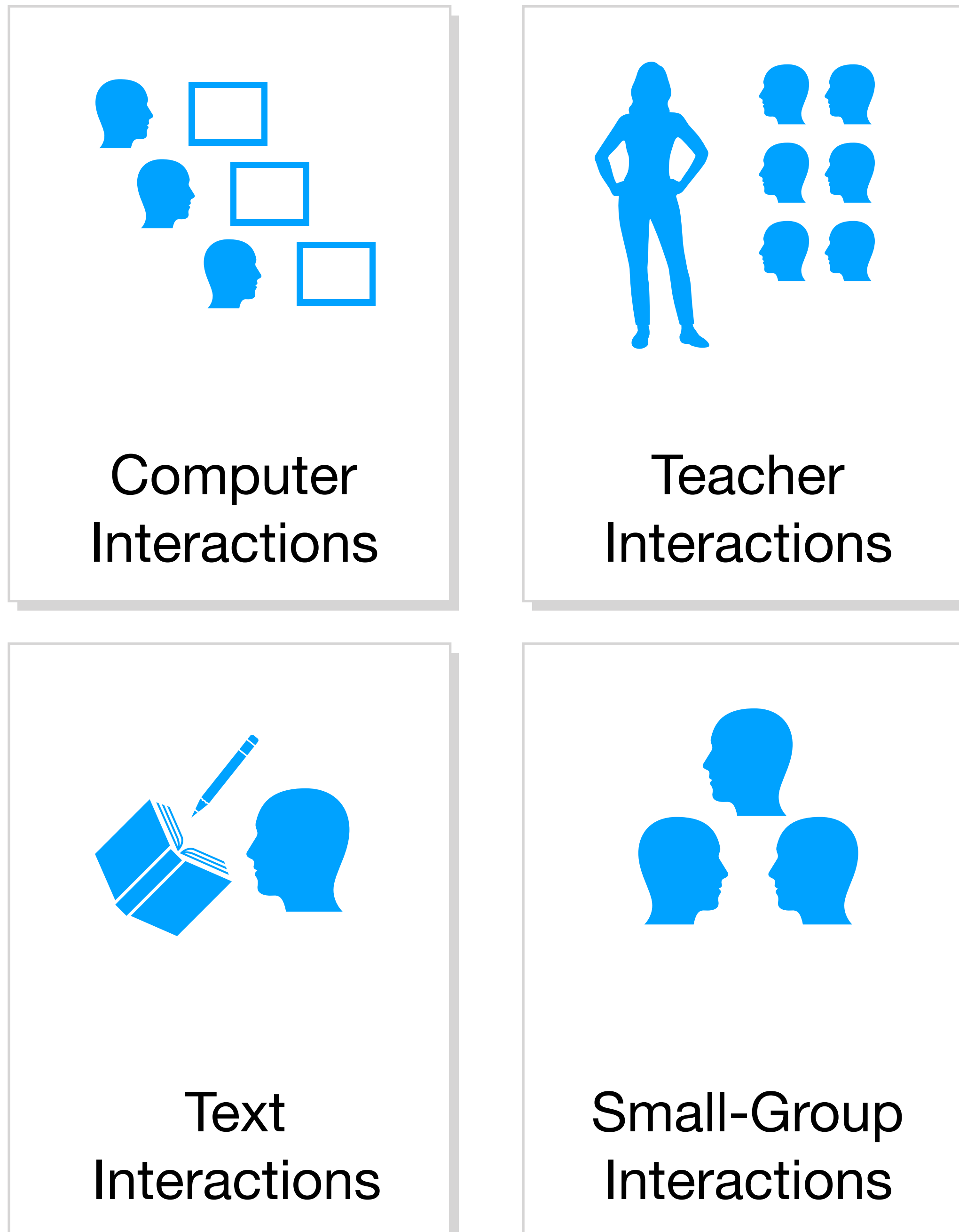
Small-Group Interactions



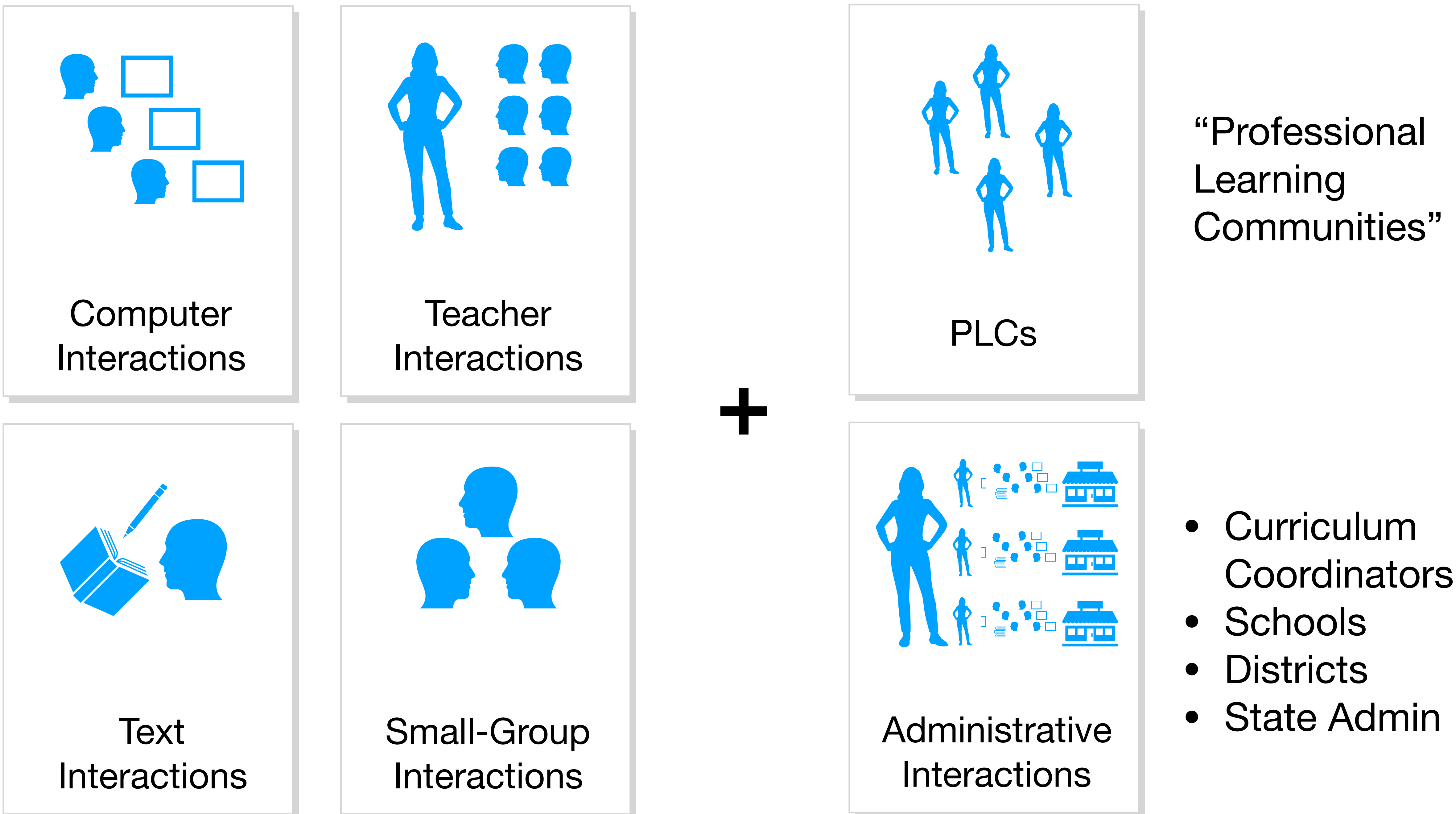
Administrative Interactions

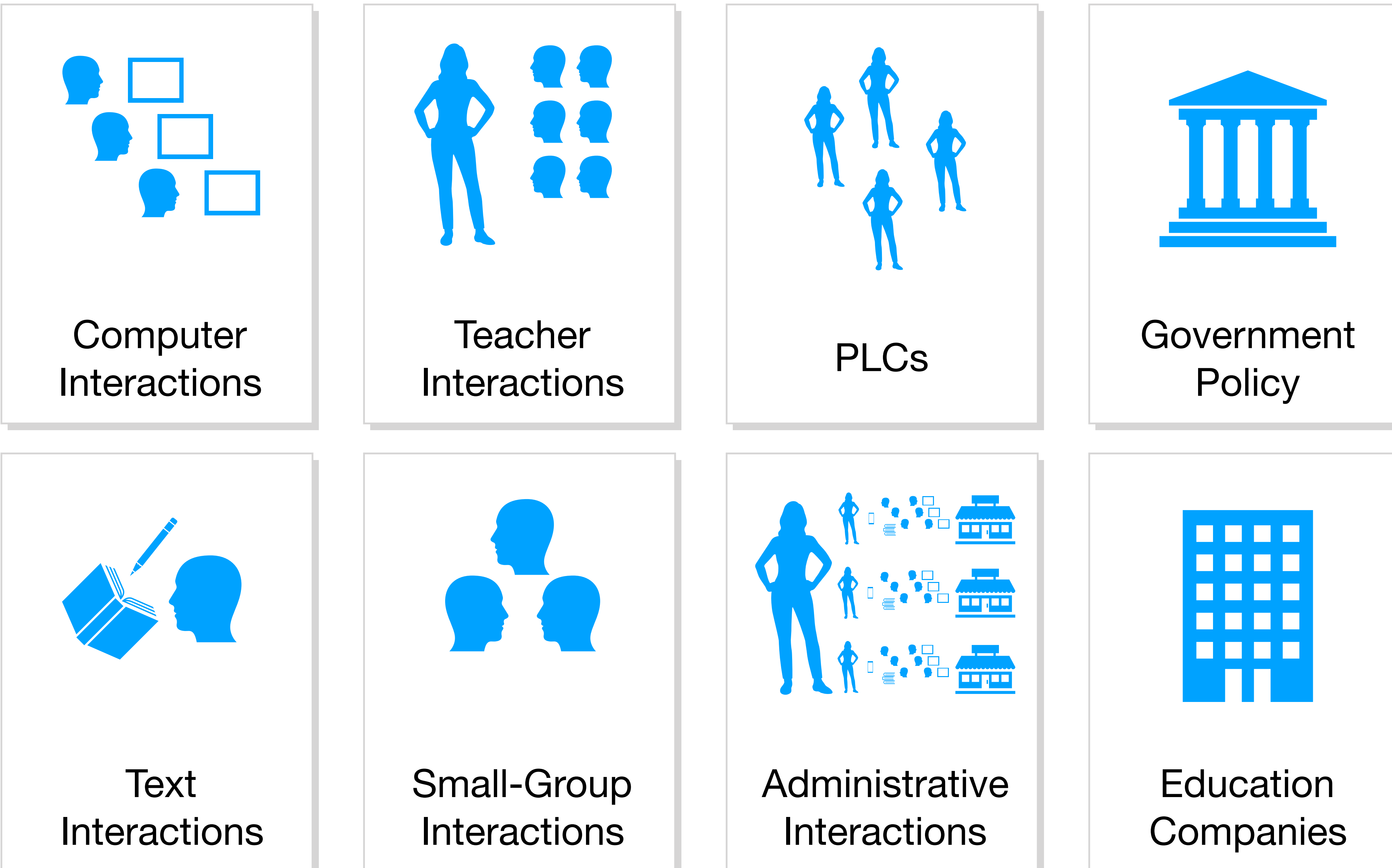


Education Companies



The Modern Classroom


Computer Interactions
Teacher Interactions
Text Interactions
Small-Group Interactions
+
PLCs
"Professional Learning Communities"
Administrative Interactions
• Curriculum Coordinators
• Schools
• Districts
• State Admin



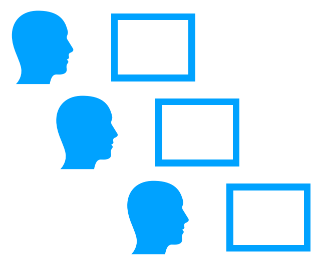
- Learning Standards

- Textbooks
- Assessments
- Paper & Digital Products

K12 Education is a Complex-Technical System

Opportunities from Systems Design?

Family Interactions



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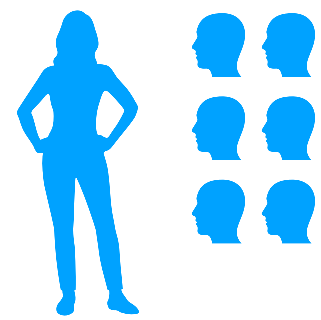
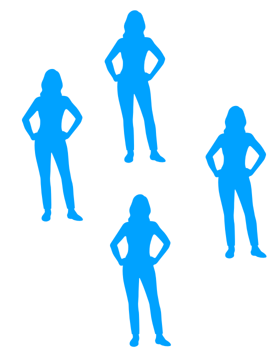


Teacher Interactions



PLCs

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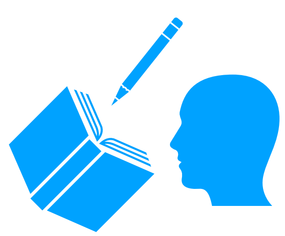
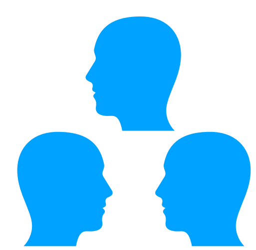
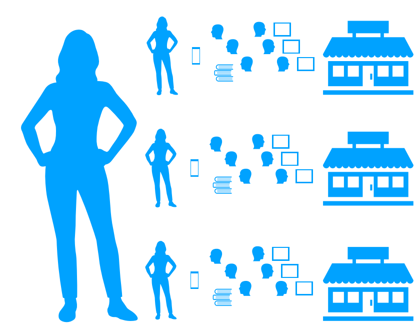


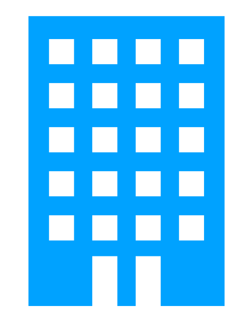
Text Interactions



Small-Group Interactions



Administrative Interactions



Education Companies

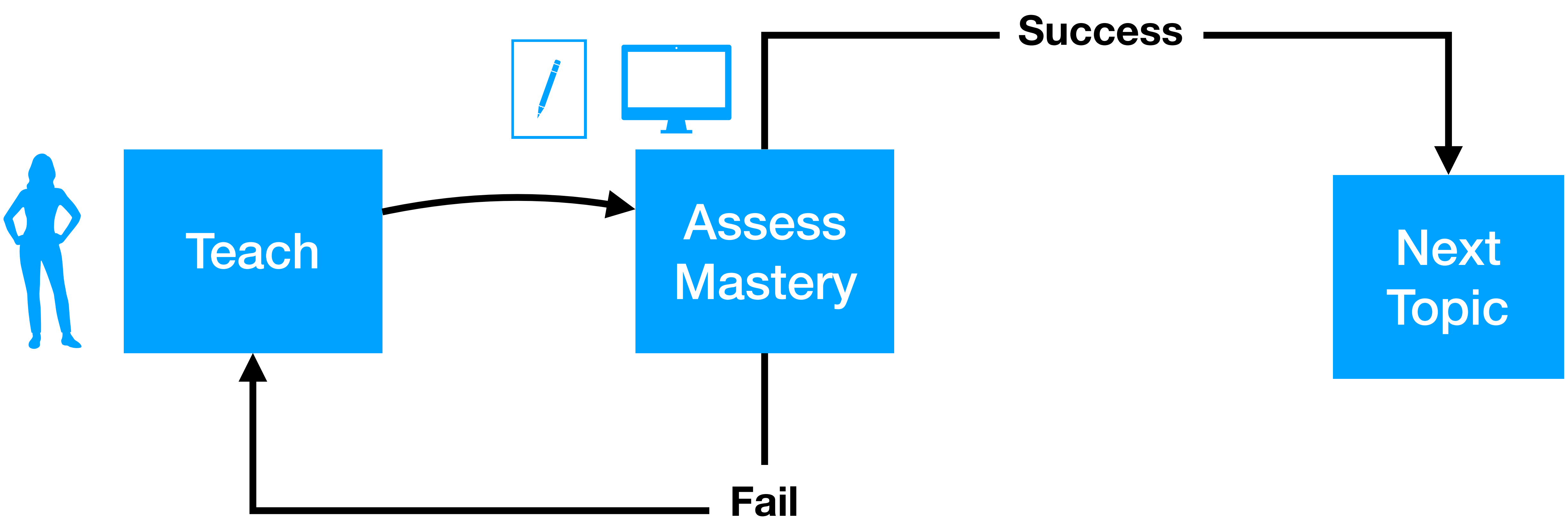
Systems Design

Role of data in systems design

- Systems use data as feedback to guide action.
- Measurements provide data to inform systems whether goals have been achieved.
- Cybernetic systems?

Mastery Learning

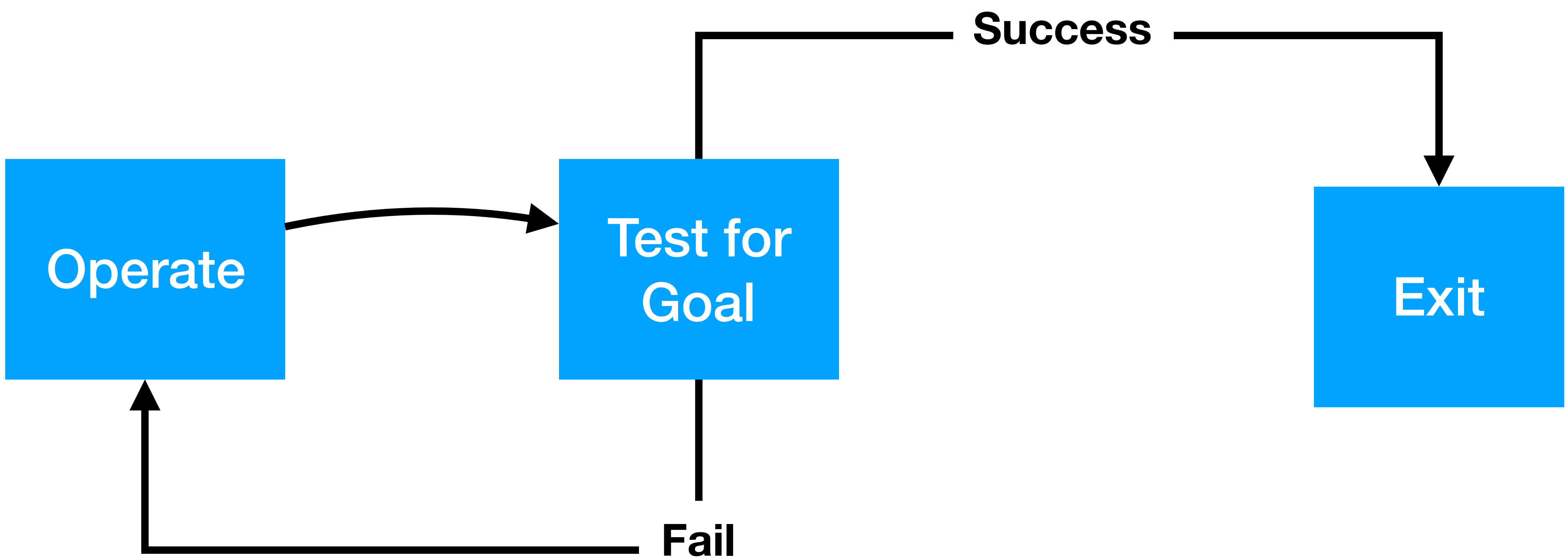
as a cybernetic system



Closed System

TEST, OPERATE, TEST, EXIT

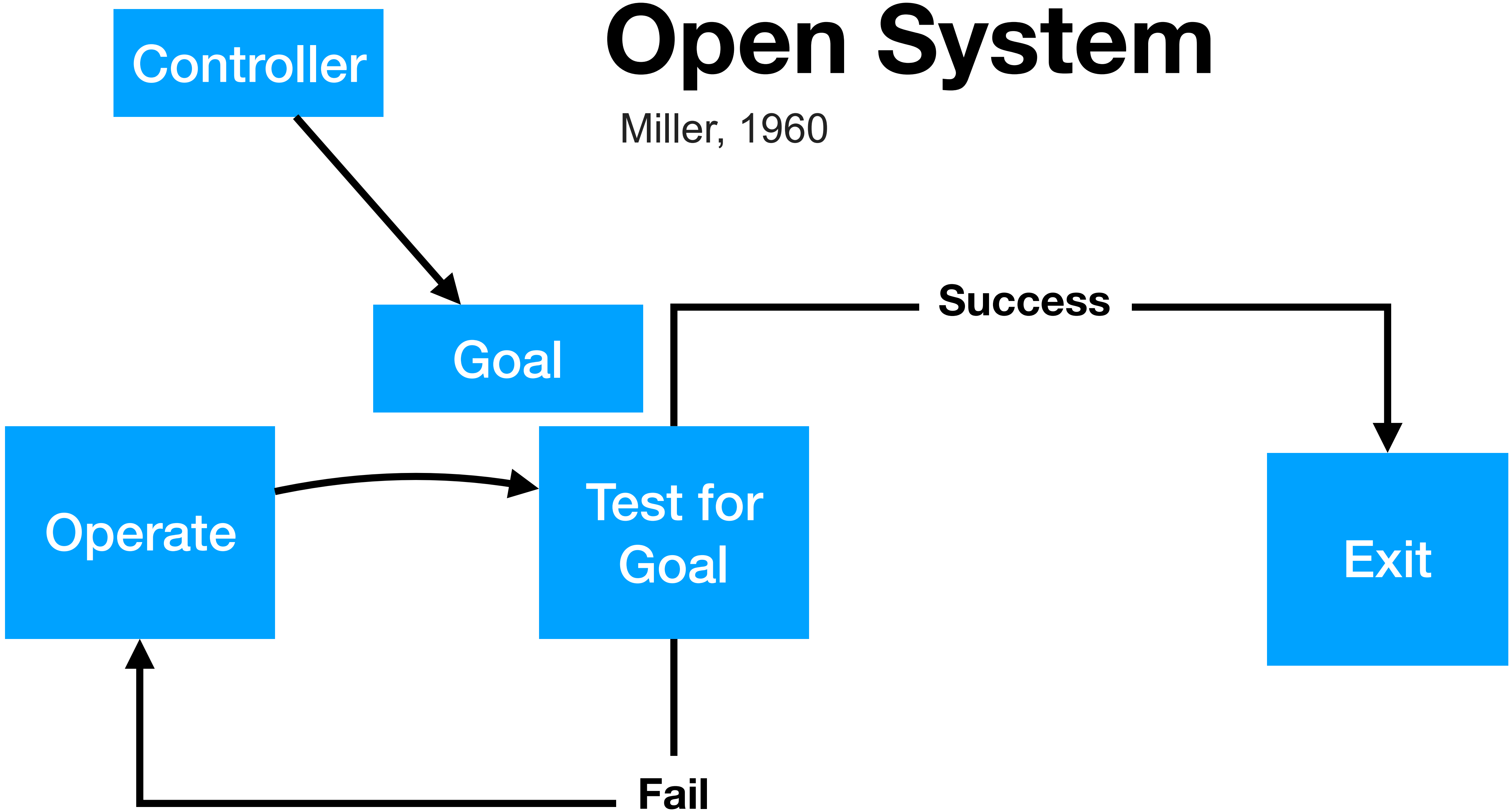
Miller et al, 1960



Miller, G. A., Galanter, E., & Pribram, K. H. (1960). Plans and the structure of behavior. New York, NY, US: Henry Holt and Co.

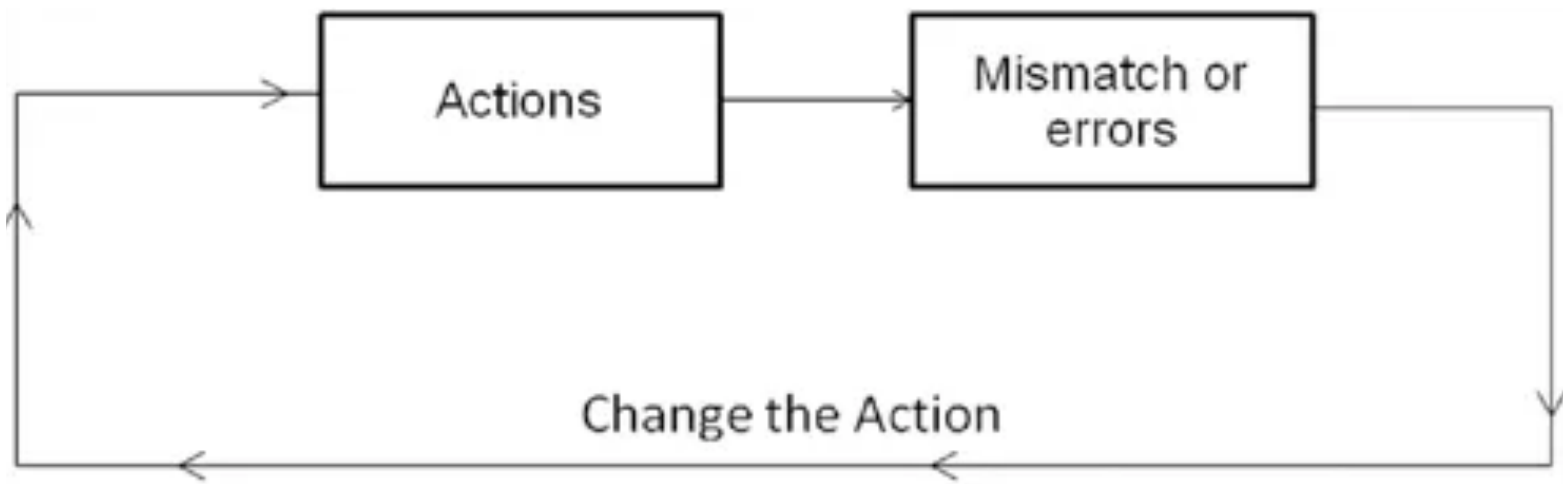
Open System

Miller, 1960



Single and Double Loop Learning

Argyris 1990



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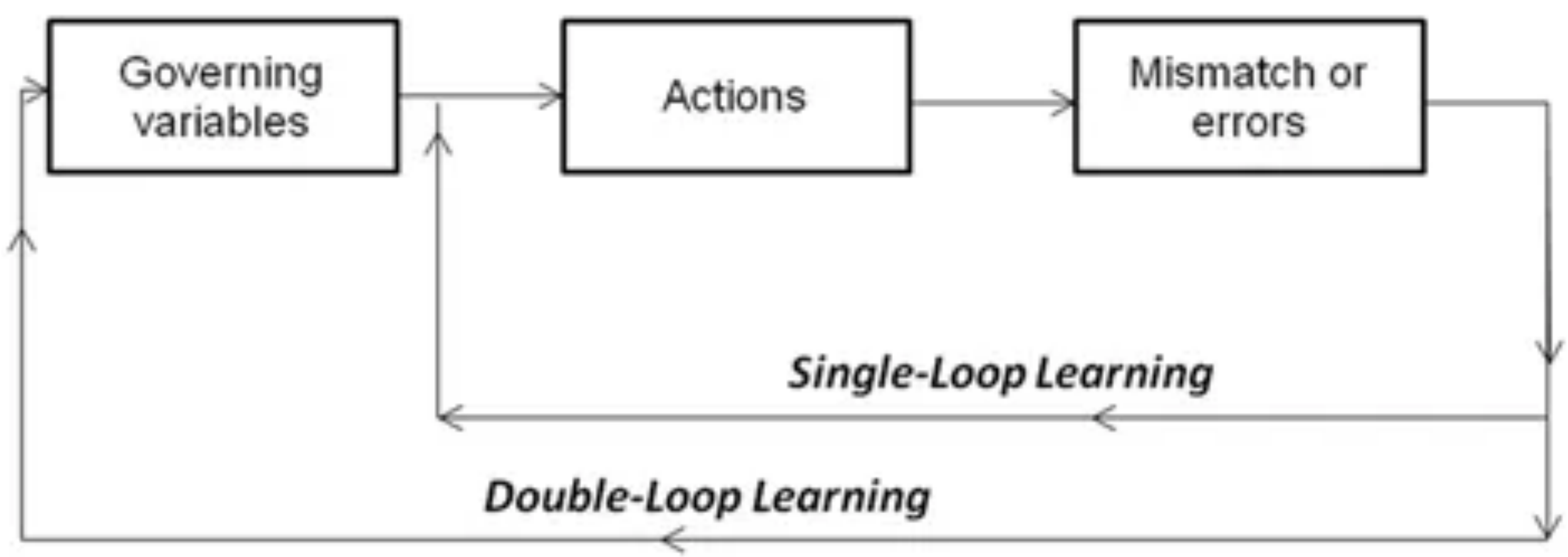

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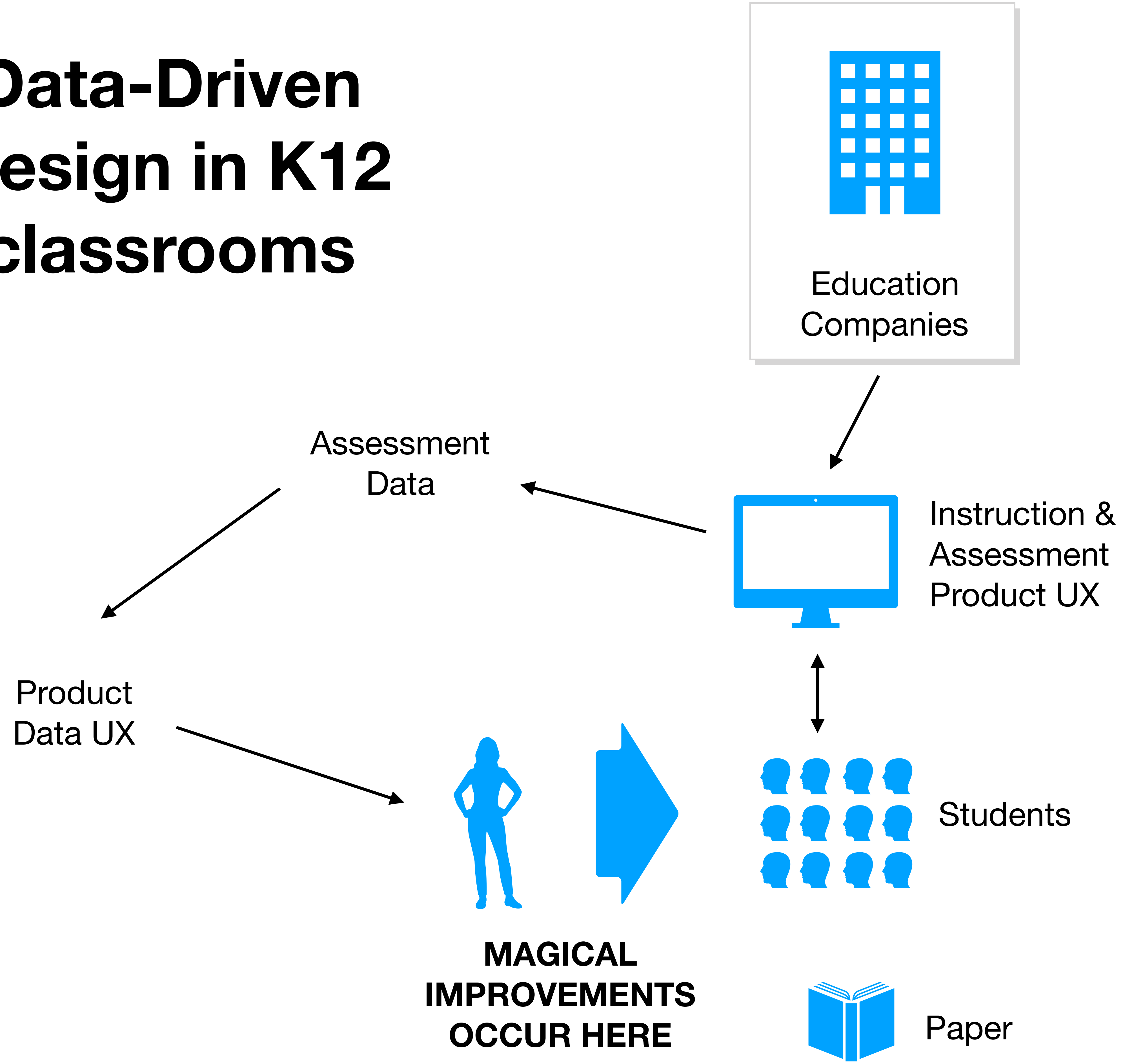
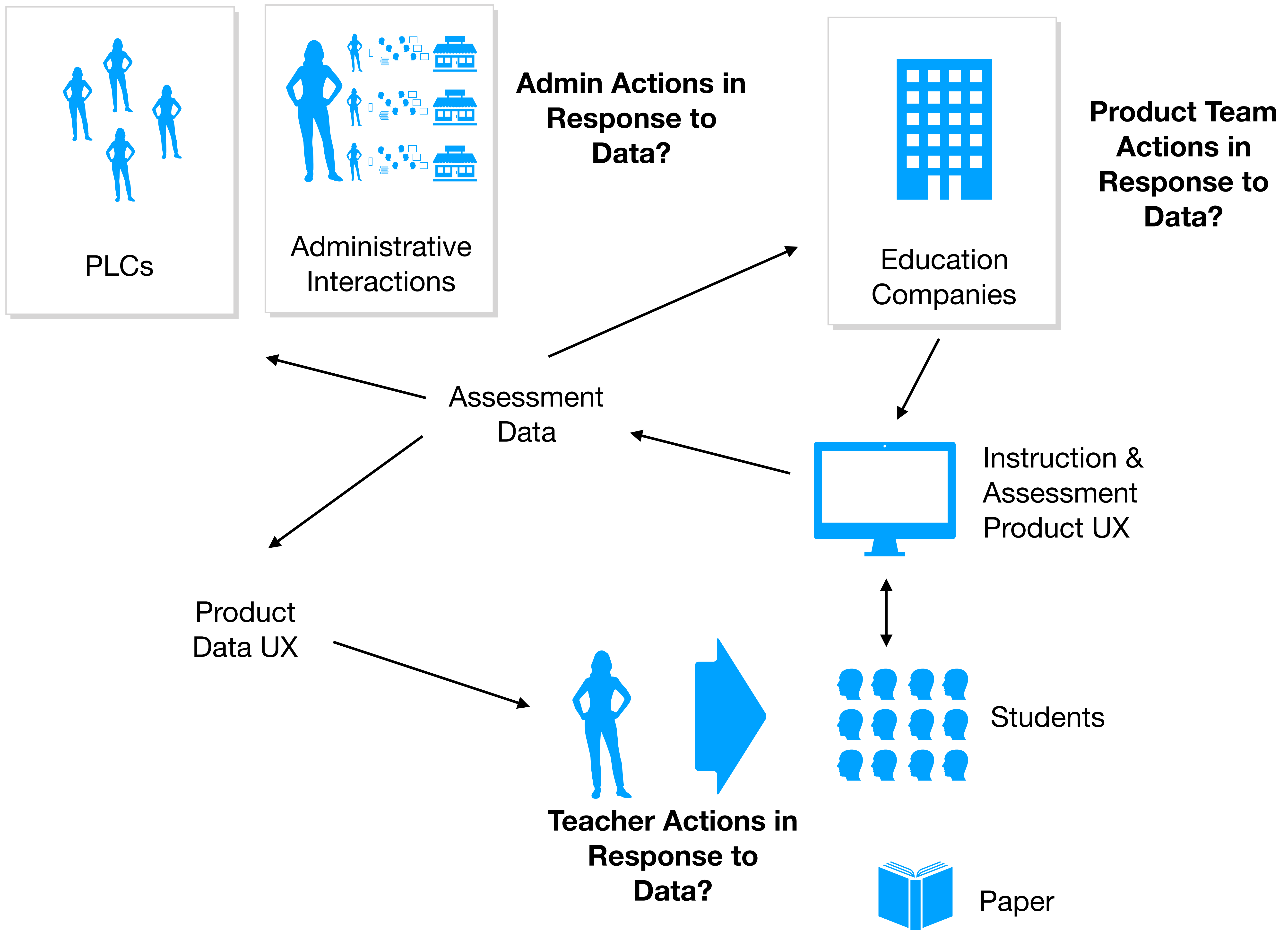
Argyris C 1990 ‘Overcoming Organisational Defences: Facilitating Organisational Learning’ Prentice-Hall: New Jersey, US

Data-Driven Design in K12 classrooms



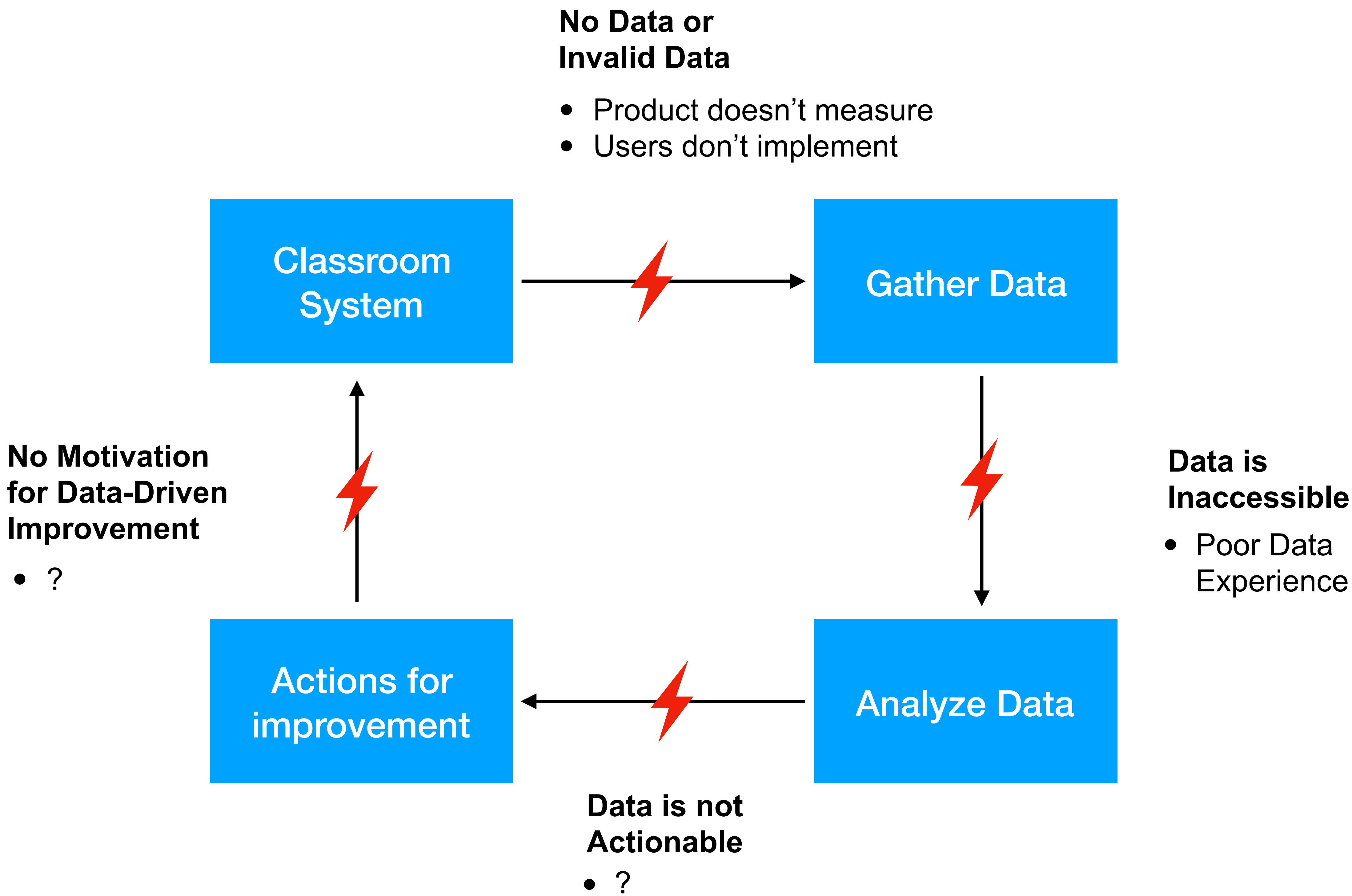

PLCs
Administrative Interactions
Admin Actions in Response to Data?
Education Companies
Product Team Actions in Response to Data?
Assessment Data
Instruction & Assessment Product UX
Product Data UX
Students
Teacher Actions in Response to Data?
Paper

Case #1:

Supporting Data-Driven Improvement in Educational Product Companies

Common Barriers to DDDM

And some root causes



"Backwards Design" Methodology

(cite Understanding by Design)

What are the educational goals?

Goals

How do we assess we've achieved our goals successfully?

Assessments

What instructional designs might improve the assessments?

Instruction

Key Question #1:

Is the system capable of measuring success?

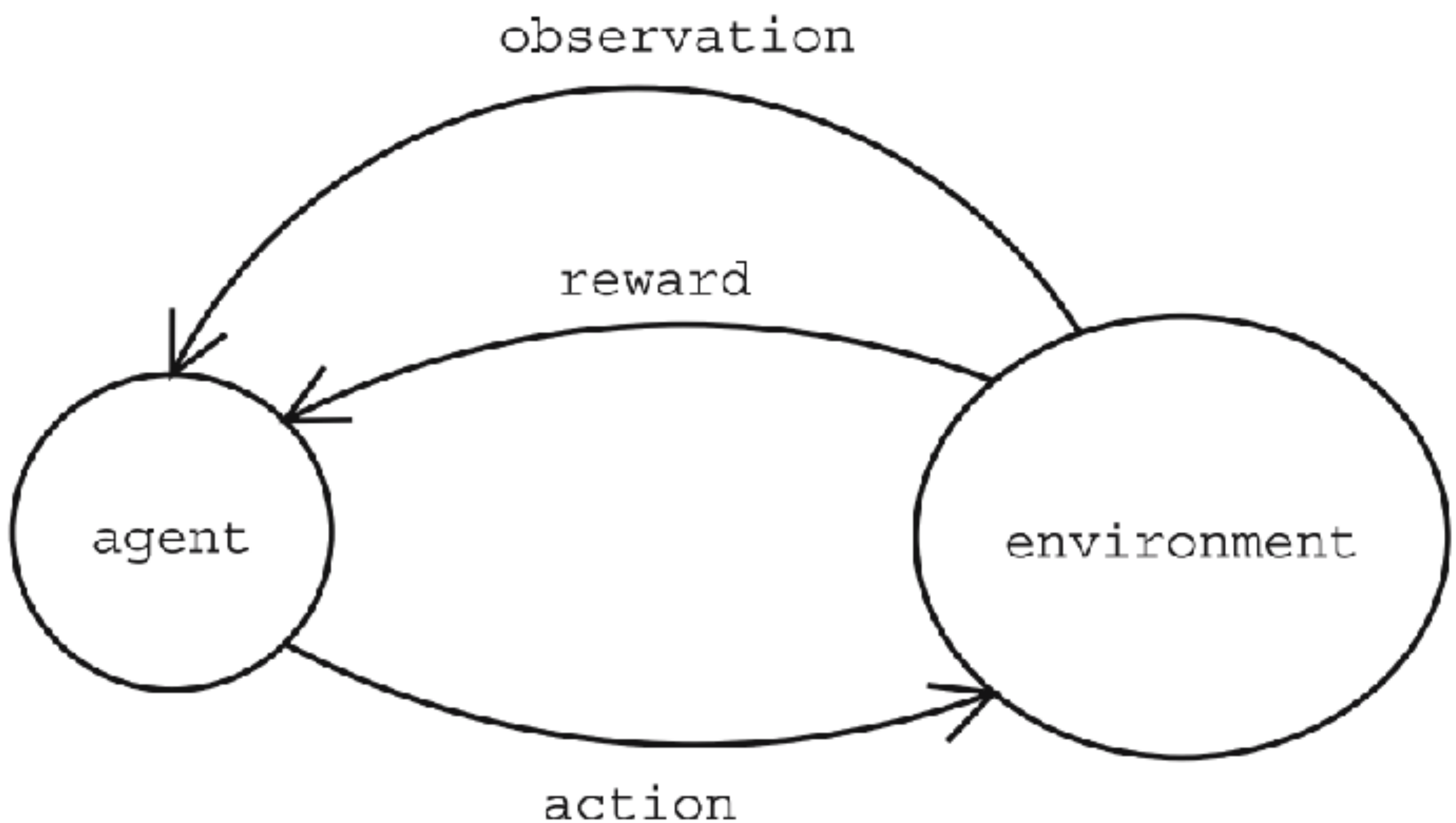
Can the system measure whether it is achieving its goals?

“If we want to report on student mastery for topic A, we need to collect valid test data on topic A”

Case #2:

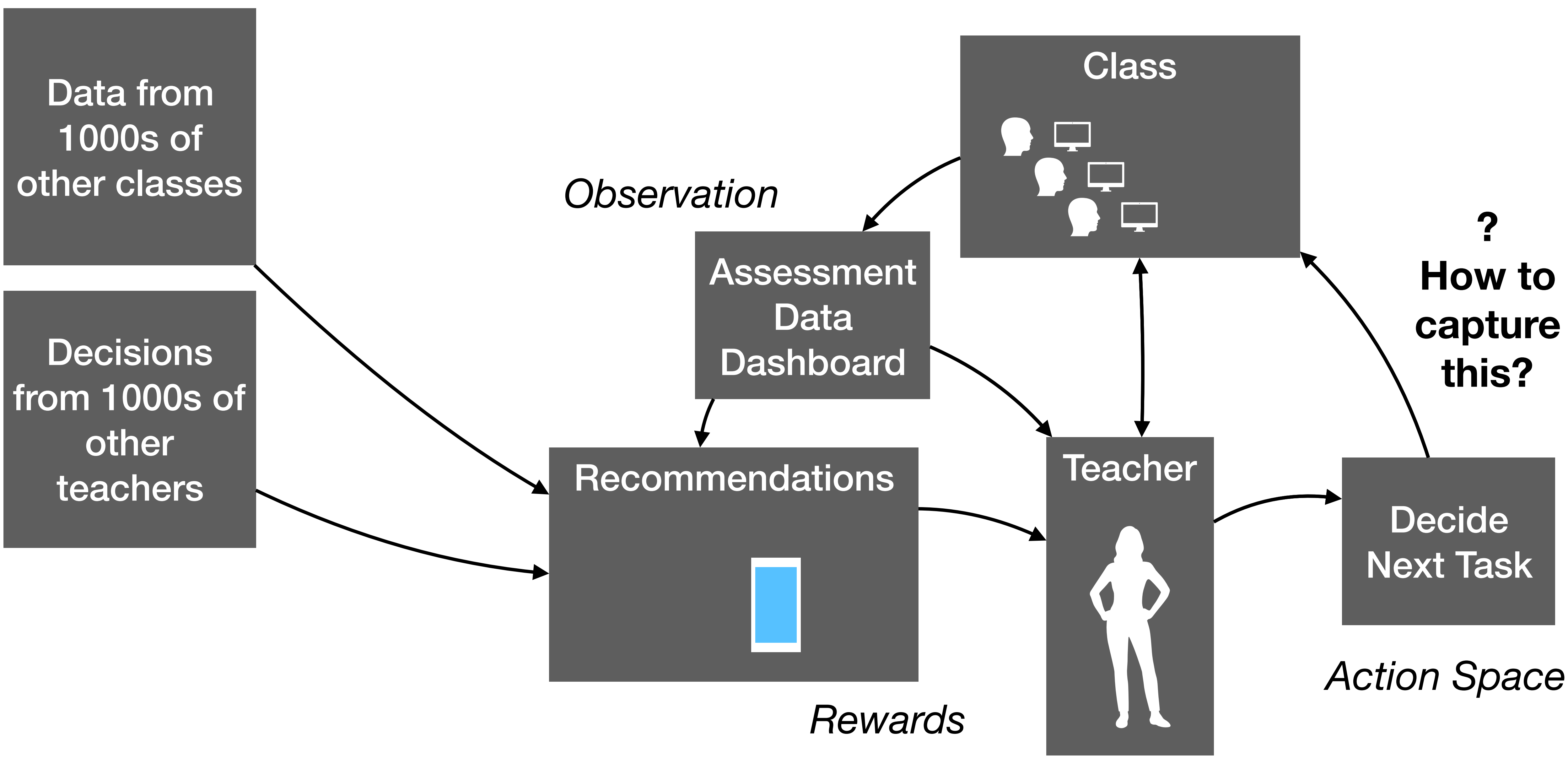
Development plans for a *teacher-facing* recommendation system

Mapping the System to Reinforcement Learning



- What is the space of possible observations? (what we measure?)
- What is the space of possible actions? (what can we do?)
- What is the reward metric? (how do we quantify our goals?)

Mapping Classrooms to Reinforcement Learning



1. Assessment Data Dashboard (*Observation*)
2. Digital Assignment Possibilities (*Action Space*)
3. Recommendation Success (*Rewards*)

Key Question #2:

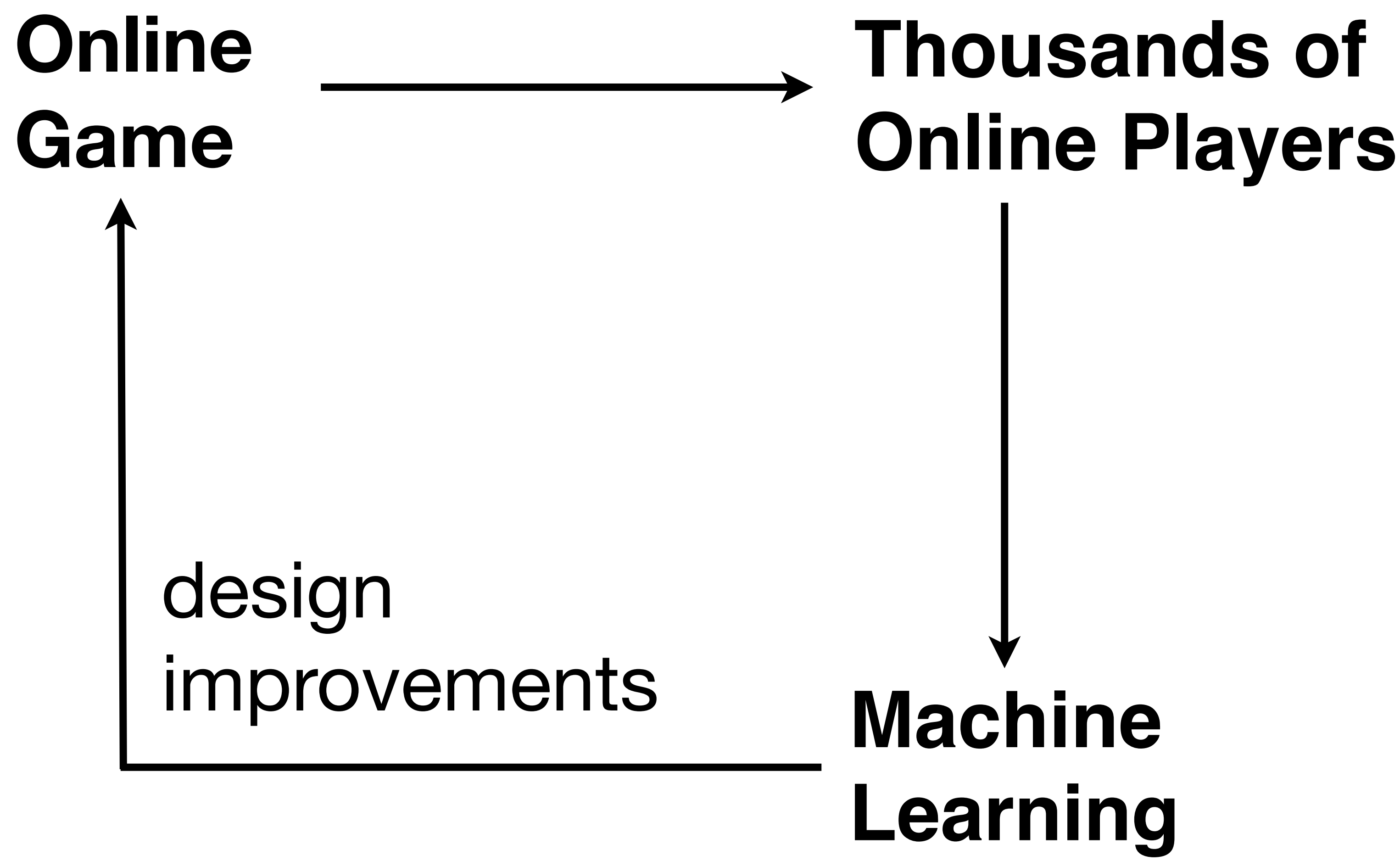
Is the action space sufficiently defined?

The right data might be gathered and analysed appropriately …but is there a defined action in response?

NEED methods for scaling-up system learning from rich human decision-making

Case #3:

Automated Machine-Learning Optimization of an Educational Game



An AI system for design optimization successfully increased game engagement…

…but then spun out of control!

Lomas, D., Forlizzi, J., Poonwala, N., Patel, N., Shodhan, S., Patel, K., Koedinger, K., Brunskill, E. (2016) Interaction Design as a Multi-Armed Bandit Problem. *ACM CHI*

Multi-Armed Bandit Problem

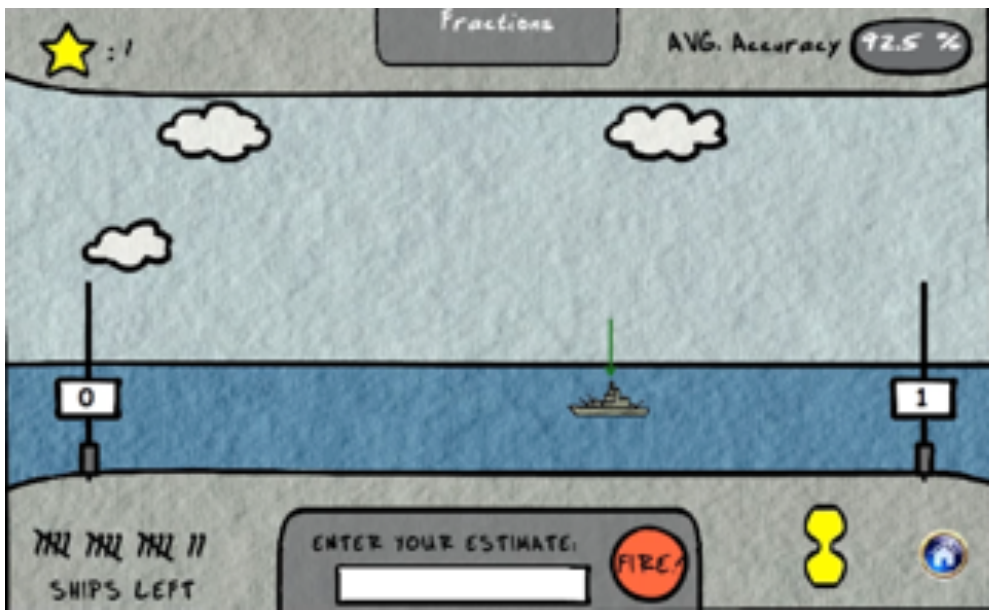
Goal is to maximize payout from row of slot machines with unknown rates of reward (some machines pay out more)

Need to balance *exploration* with *exploitation*

Interface design as a multi-armed bandit problem…

Lomas, J. D., Forlizzi, J., Poonwala, N., Patel, N., Shodhan, S., Patel, K., Koedinger, Brunskill, E. (2016). Interface Design Optimization as a Multi-Armed Bandit Problem. In CHI'16.

Instructional Design of “Battleship Numberline”

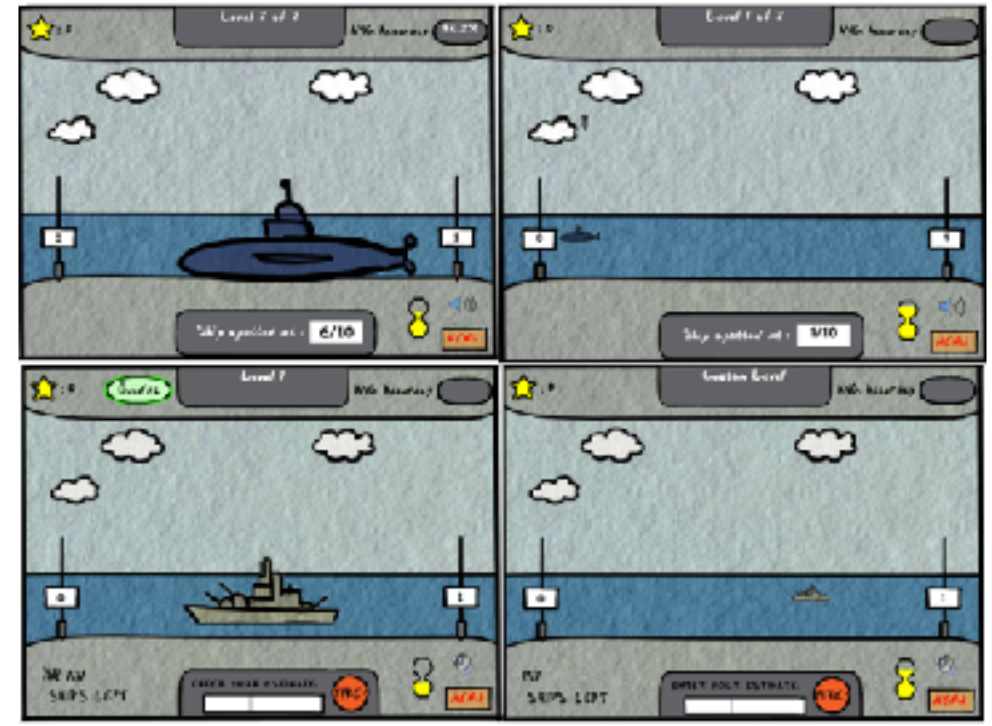


Ship targets
Type to name a fraction

Submarine targets
Click to locate a fraction

Target Size

Target Type



Design Factors

Target Type: Ship or Sub

Target Size: Small to large targets

Time Limits: Small to large time limits

Item Sets: The fractions to be estimated

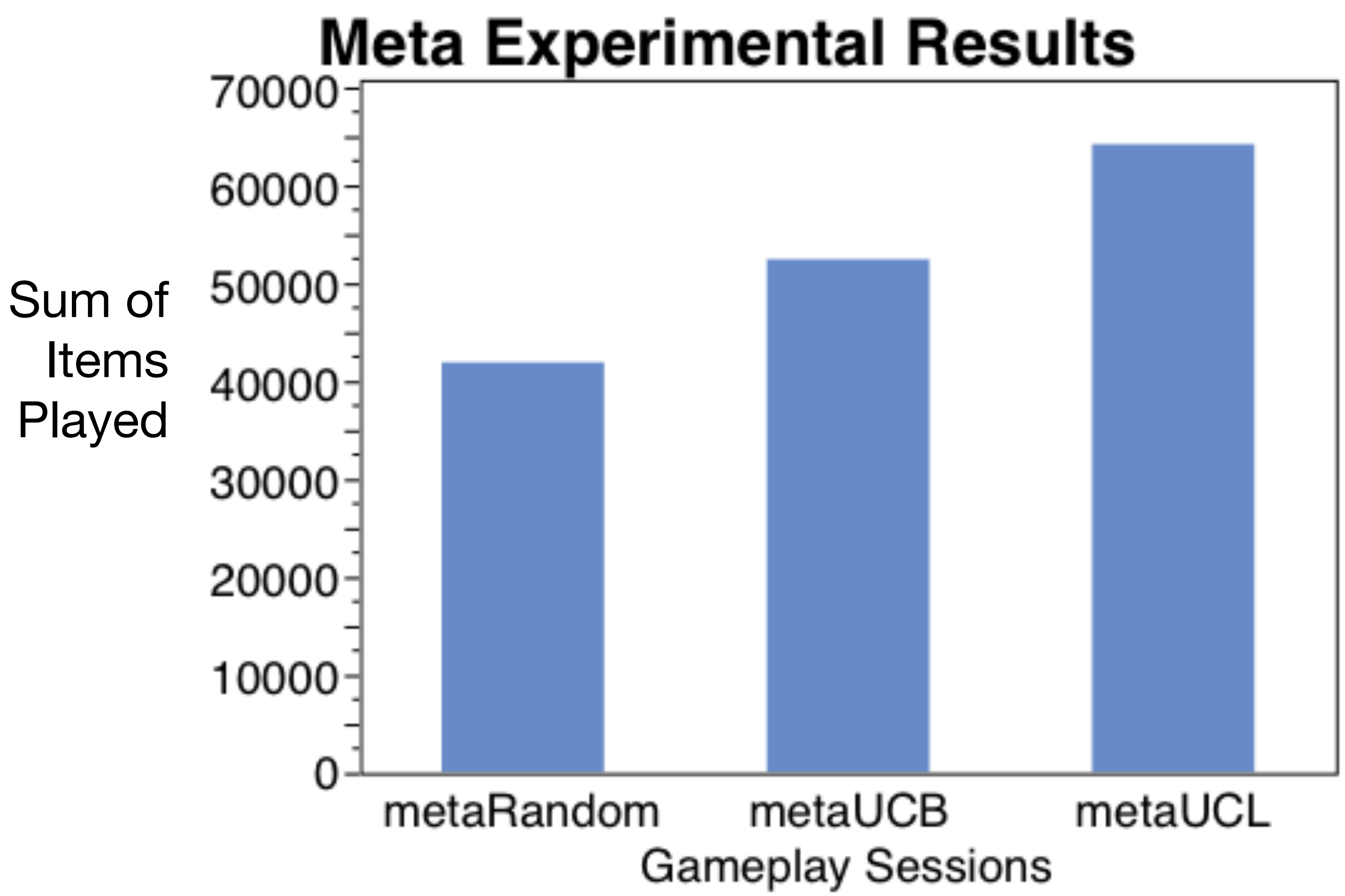
Tickmarks: Scaffolds for estimating

Sequencing: Algorithms for presentation

Experiment 1: Assigned 10,832 players to 3 simultaneous experiments, each testing 6 different design factors (2x3: target type and target size)

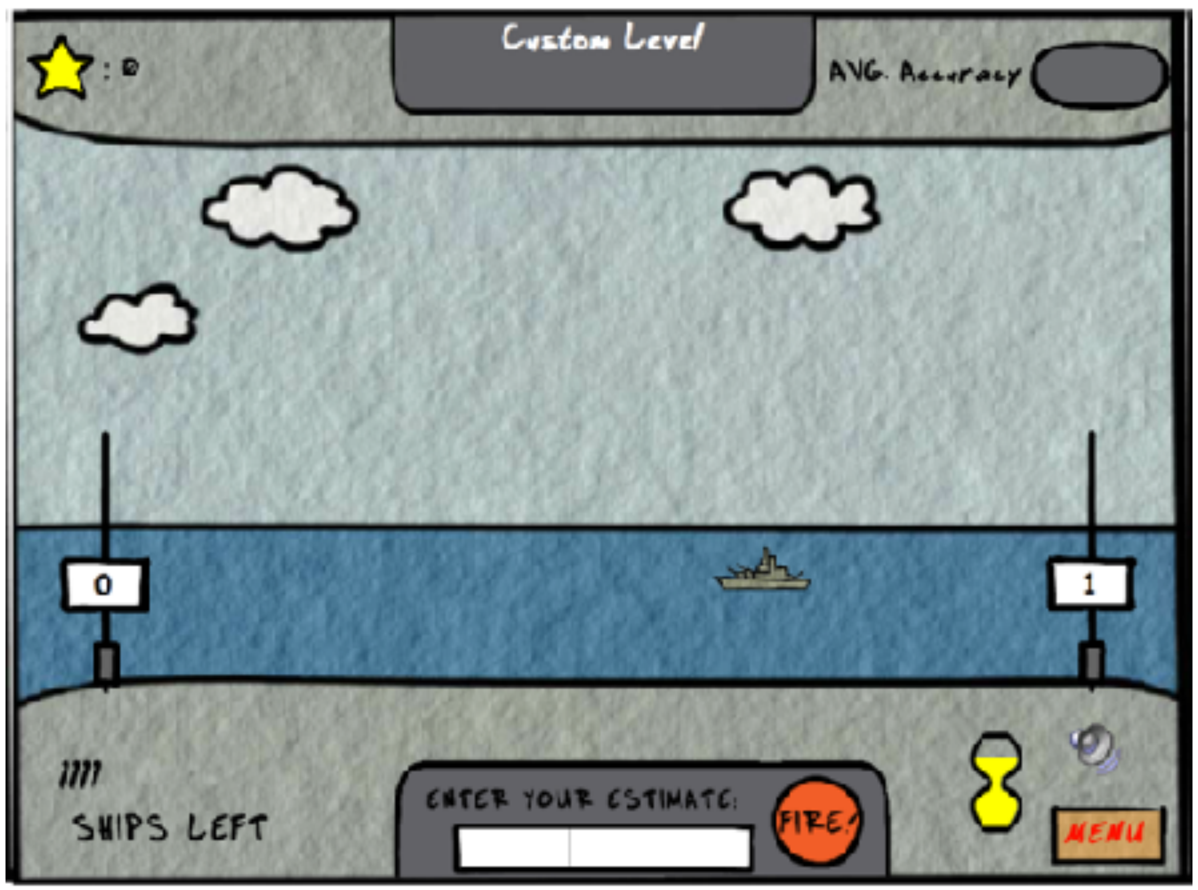
Success!

Automatic optimization algorithms produced more engagement

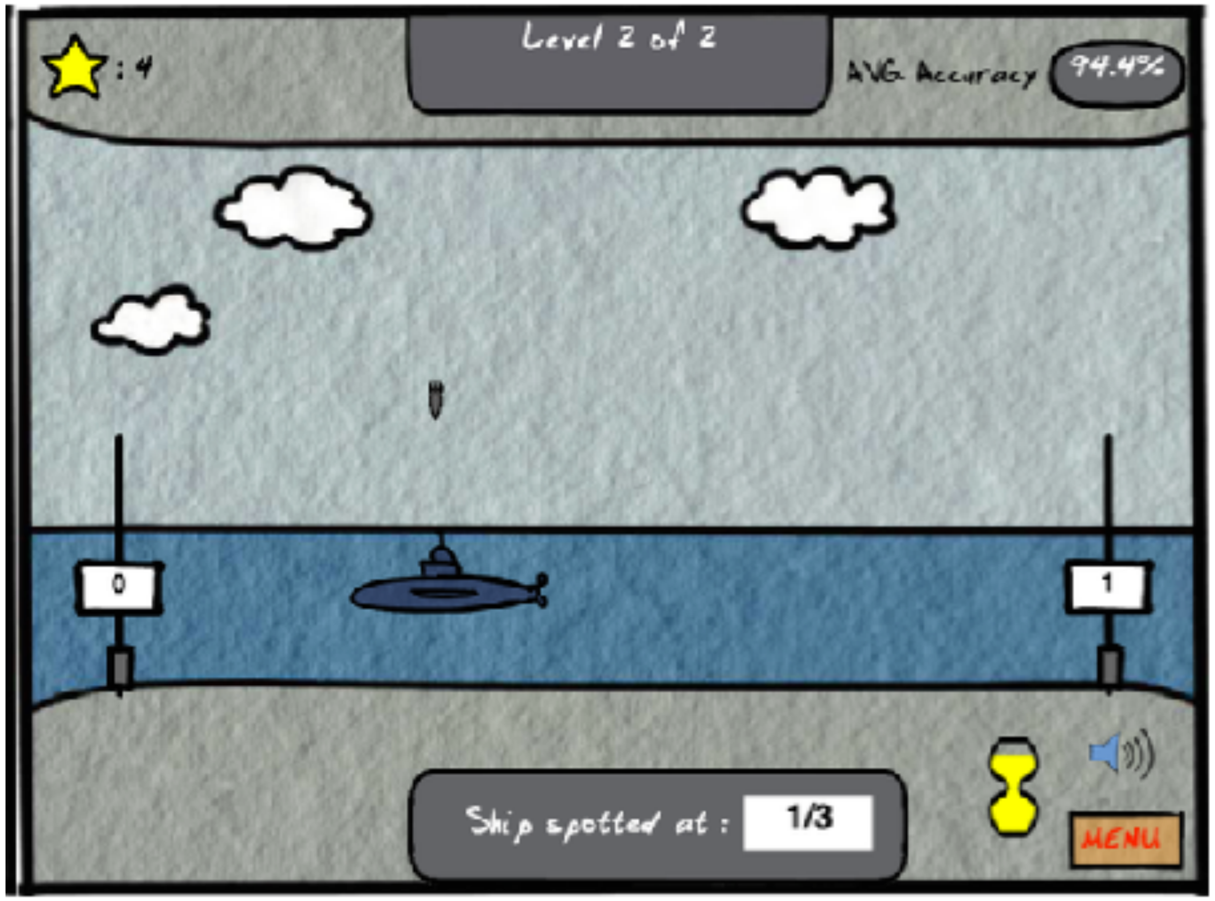


Bandit experiments produce greater total engagement

Meta Experiment 1



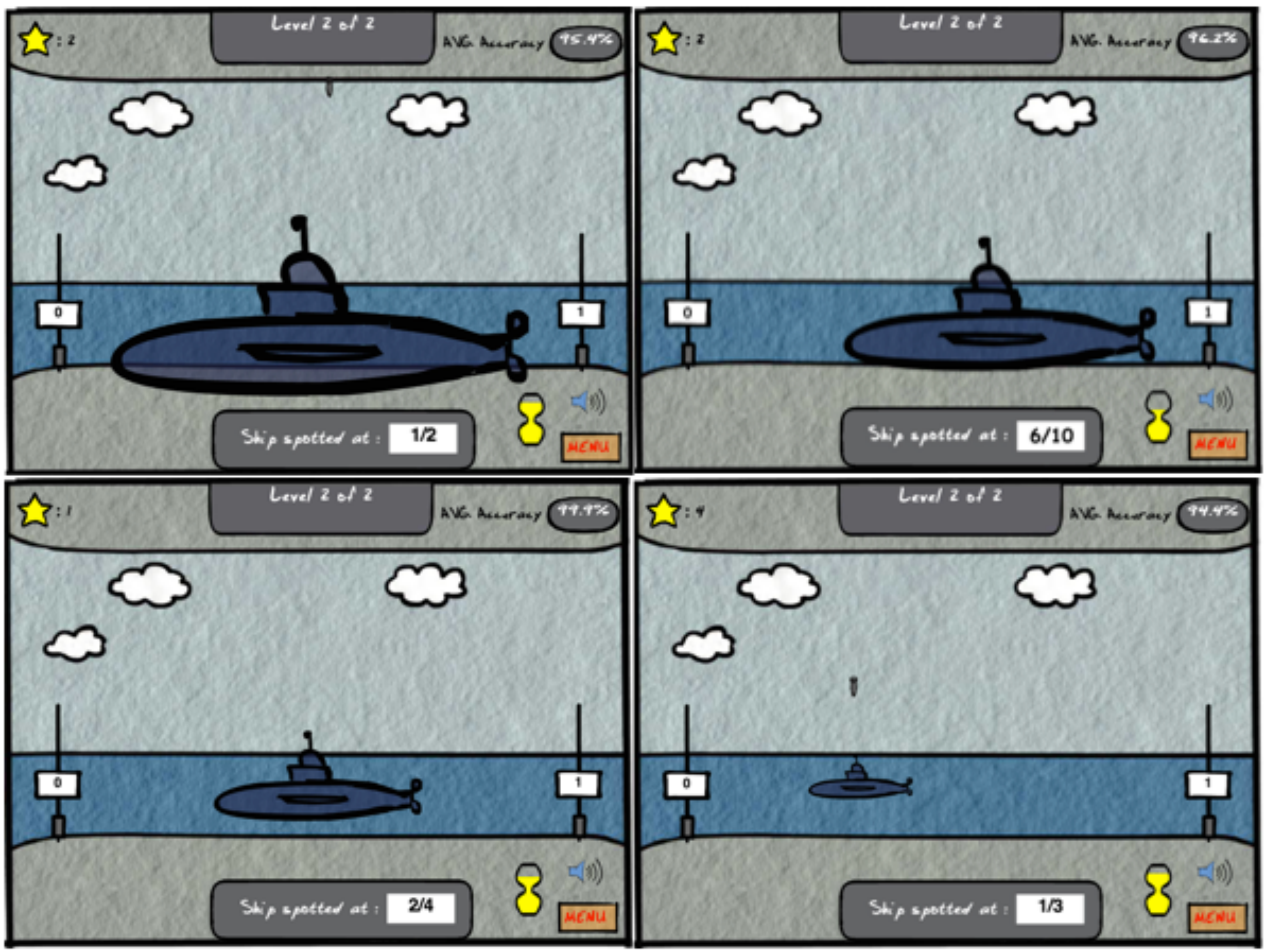
Worst Design
Ship 97

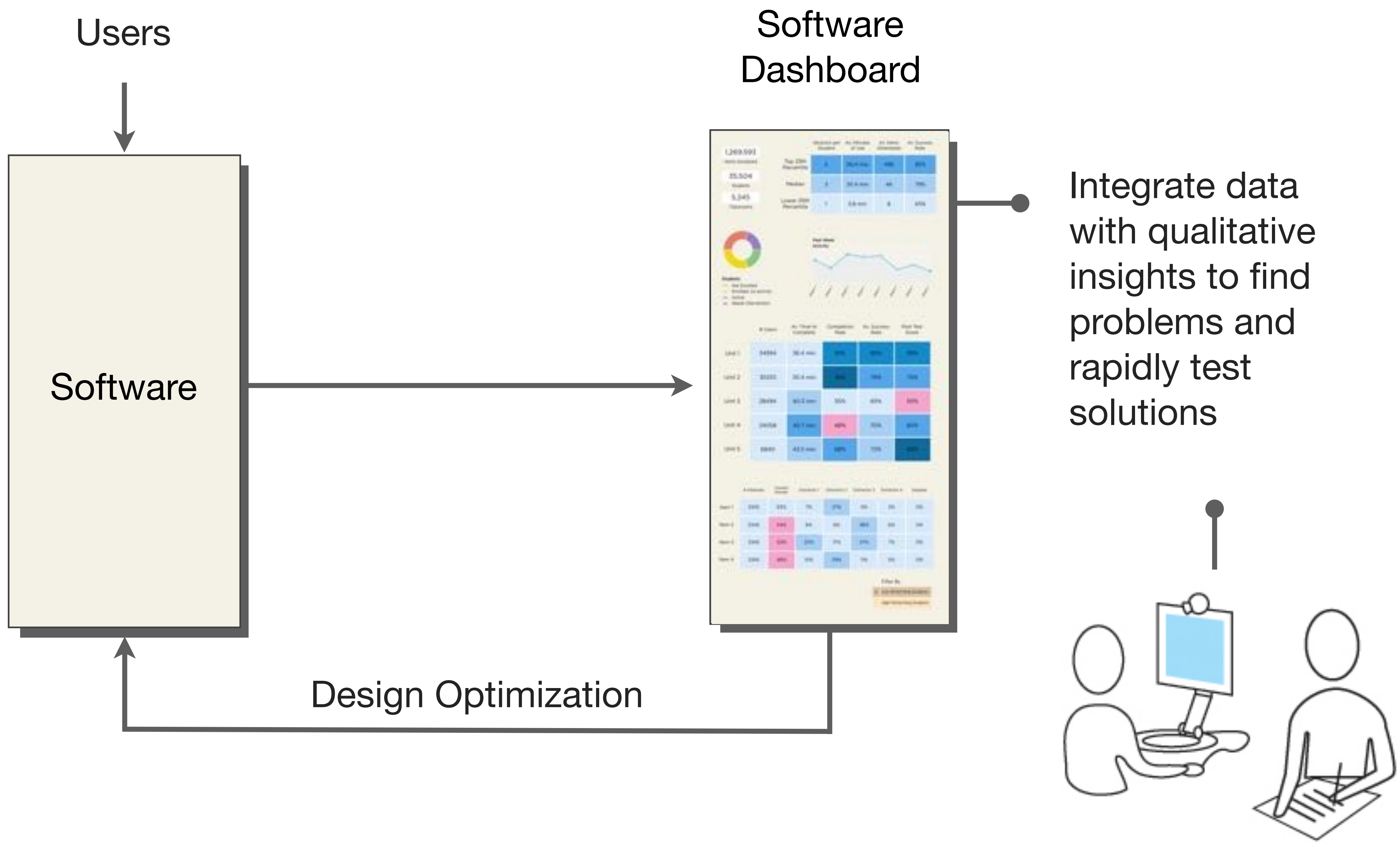


Best Design
Ship 90

Meta Experiment 2

Introduced ridiculously large “Bad Designs"





The Data-Experience Dialectic

Data and qualitative insights must be integrated

With 10,000 subjects a day, we could run thousands of experiments each year

But setting up, analyzing and acting upon experiments is hard.

How might AI get involved? Could we partially automate design optimization and scientific experimentation?

Key Question #3:

Is there a human-in-the-loop to keep alignment?

If continuous improvement metrics are not aligned to goals and values, data-driven improvement (teams or AI) will produce unintended consequences

NEED feedback loops about suitability of success metrics

Conclusions

Takeaways

- From Designing Artificial Intelligence to Designing Intelligent Systems
  - Collaboration between teams and algorithms

(not just for AI but for products)

A Definition of Intelligence used in AI

"Intelligence measures an agent's ability to achieve goals in a wide range of environments."

—Legg & Hutter, 2007

"an individual's intelligence is related to their ability to succeed…"

- Robert Sternberg

What can go wrong?

- Poor goals (misalignment with values)
- Poor metrics (misalignment with goals)
- Poor actions responding to data
- Mis*leading* data and mis*reading* data
- Conflicting interests in stakeholders

Unintended consequences!

Accountability can create perverse incentives

e.g. schools encourage low-performing students to drop out or to cheat (Schildkamp et al, 2012).

How can system designers help build the human into the loop?

- UI for User Goal Setting
- System mapping & communicating future systems
- Processes to Negotiate Metrics for Success

(not just for AI but for products)

What should I do?

Did it work?

How should I do it?

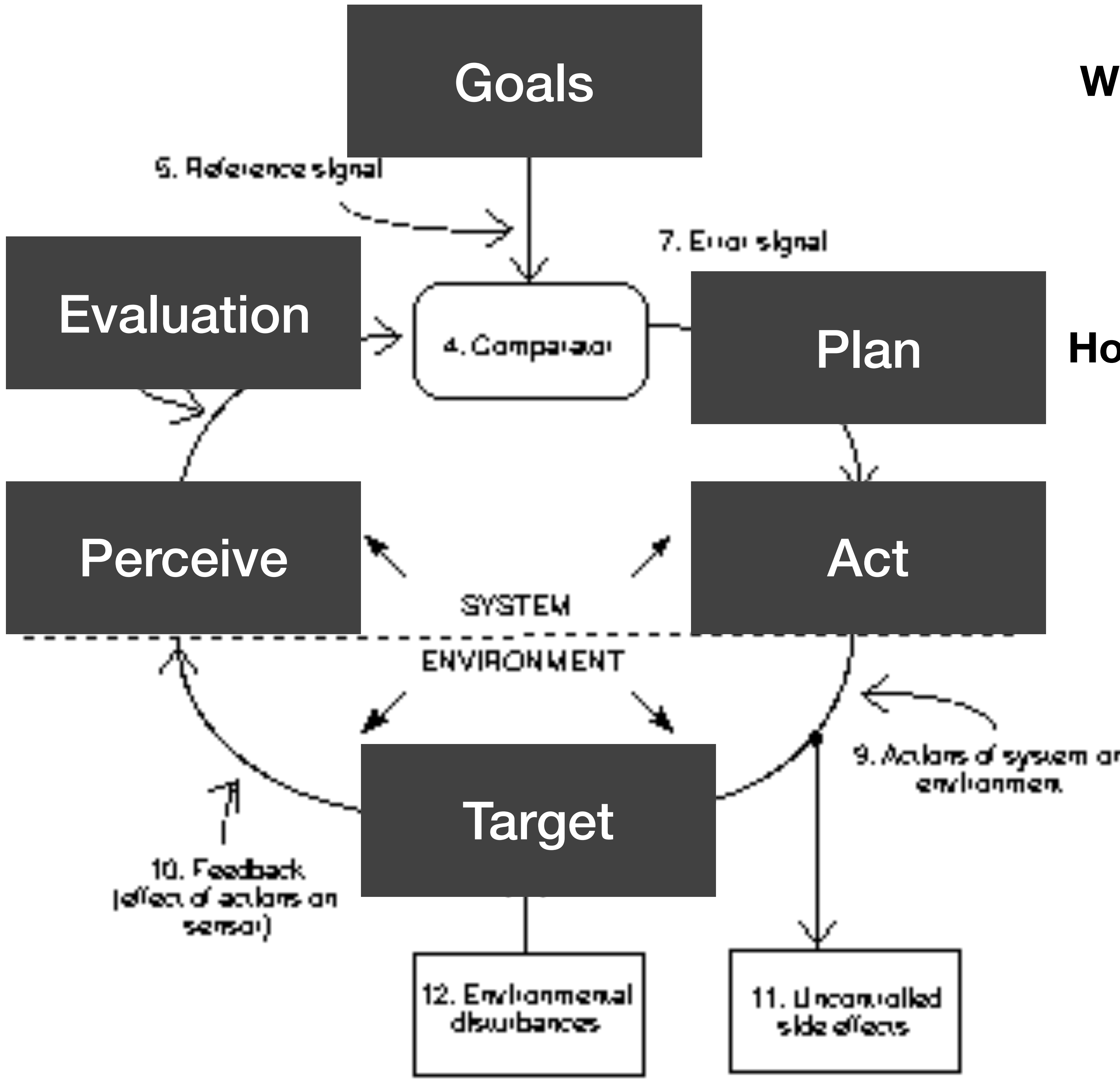
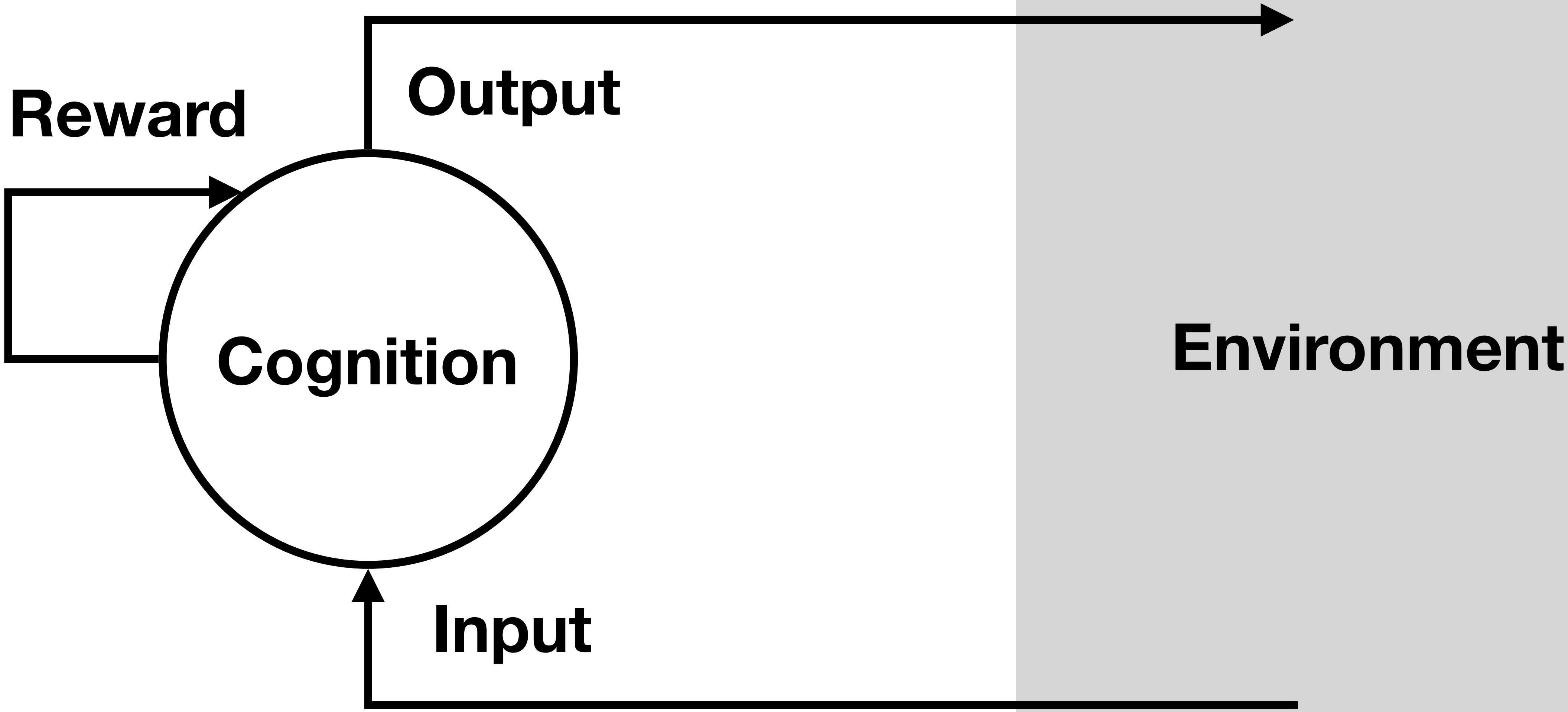


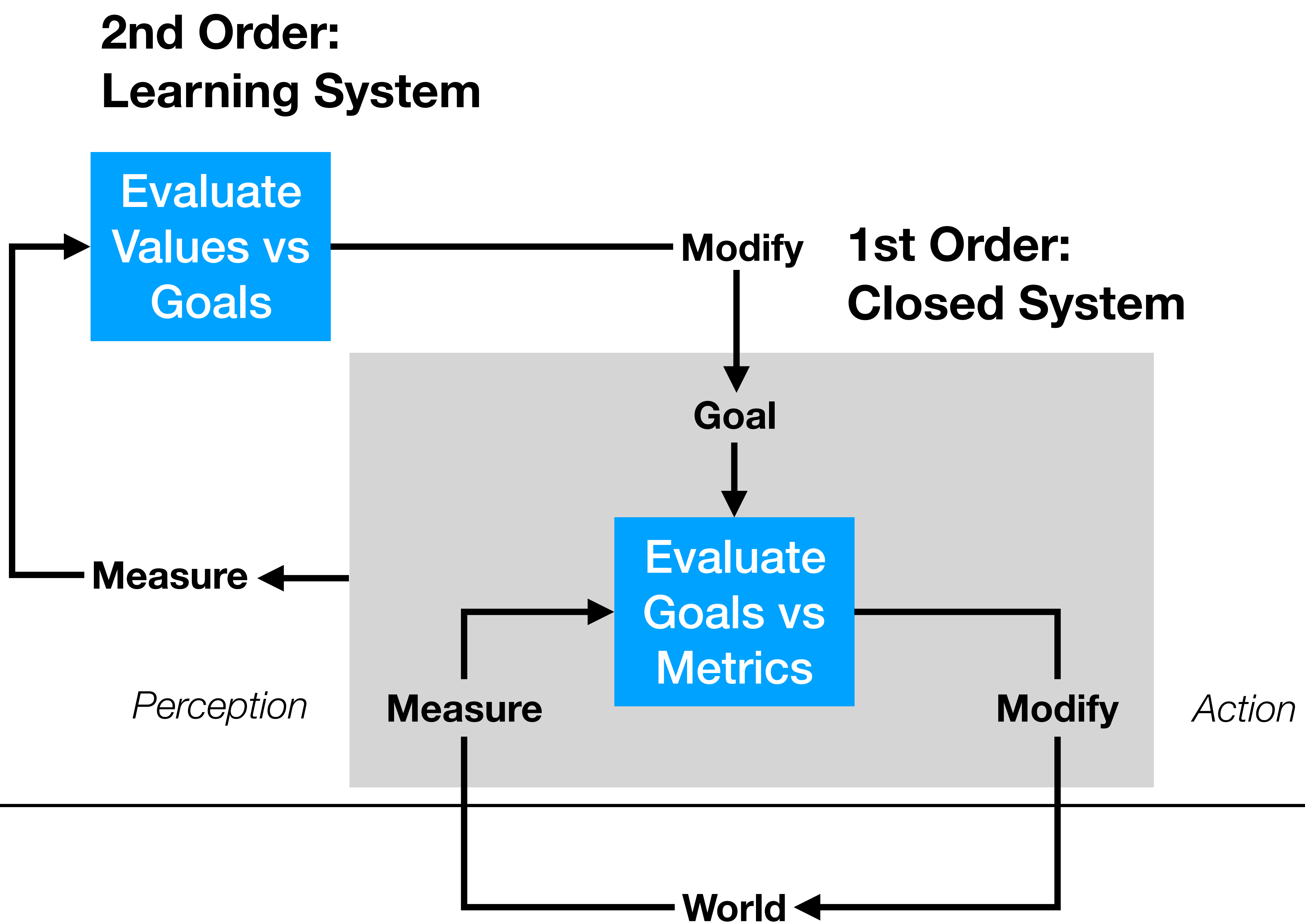
Figure 6.2
Elementary control system

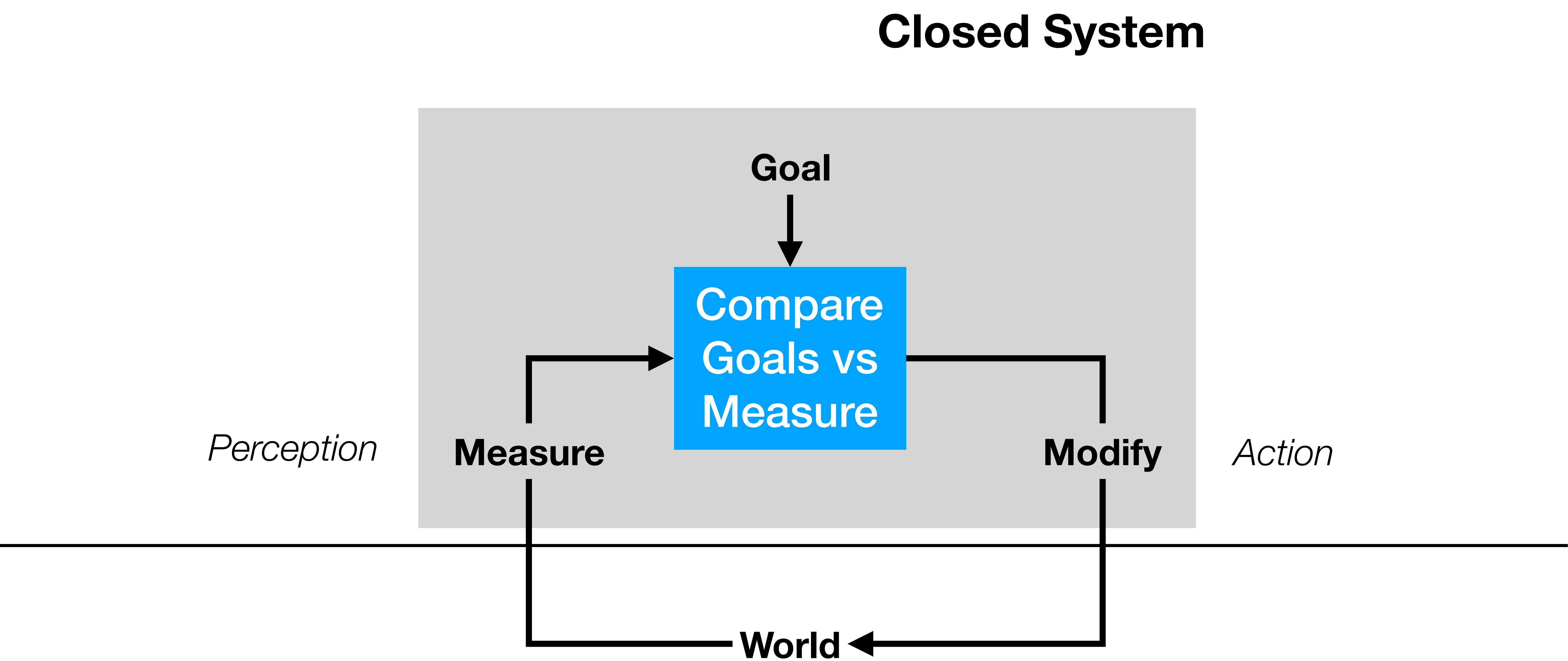


Reinforcement Learning

AI Definition of Intelligence

“Intelligence measures an agent’s ability to achieve goals in a wide range of environments.”


2nd Order:
Learning System
Evaluate Values vs Goals
Modify
1st Order:
Closed System
Goal
Measure
Evaluate Goals vs Metrics
Perception
Measure
Modify
Action
World


Closed System
Goal
Compare Goals vs Measure
Perception
Measure
Modify
Action
World