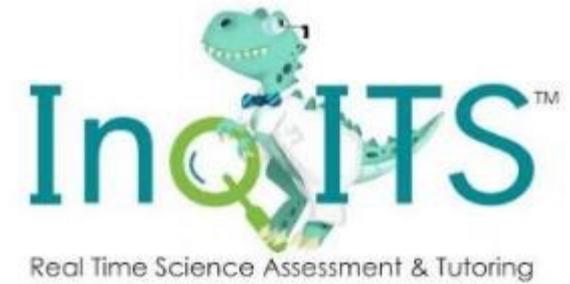




RUTGERS



Inq-ITS: AI-based technology for real time assessment, scaffolding, and instruction of science practices

**Dr. Janice Gobert, Professor,
Rutgers Graduate School of Education
&
Founding CEO, Inq-ITS**



Overview

- The context of the problem
- Goal & Intro to Inq-ITS and Inq-Blotter
- Design & Development
- Fire hose Study 1: Identifying the Messy Middle
- Fire hose Study 2: Testing for Transfer of Rex
- Fire hose Study 3: Alerting & transfer
- Fire hose Study 4: TIPS
- Questions

Context: US & many others face a STEM crisis



Int'l rank on science (PISA), 2018

Science Inquiry Learning & Assessment

- NGSS and other state frameworks require that students learn these practices and teachers must provide evidence of students' competencies

Asking questions

Developing and using models

Planning and carrying out investigations

Analyzing and interpreting data

Using mathematics and computational thinking

Constructing explanations

Engaging in argument from evidence

Communicating findings





BILLY



JOHN

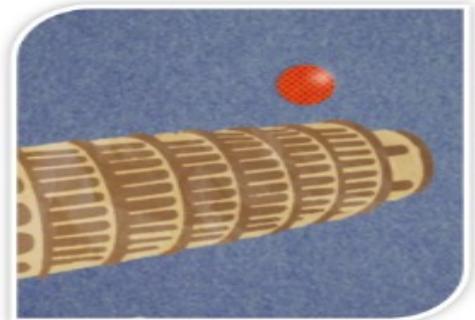
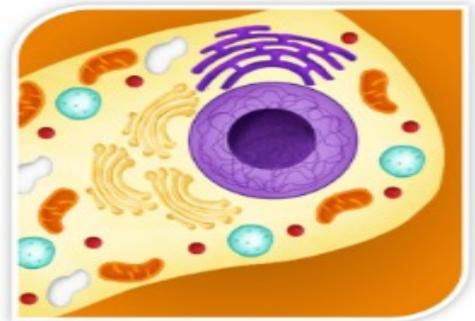
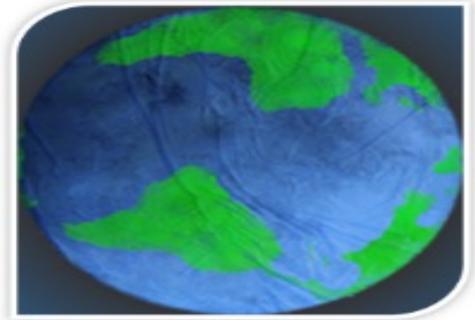
BILLY

Our Goal

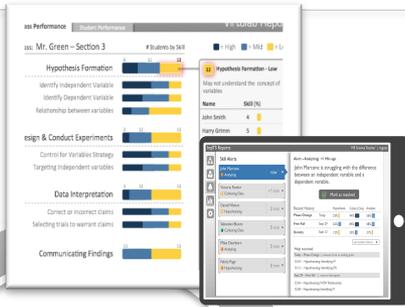
- We wanted to *rigorously* assess science practices, *at scale*
- We wanted to *better support teachers*:
 - *In their instruction of science practices*
 - *In their assessment of science practices*
- We wanted to *better support students*:
 - *In their learning of science practices*

Inq-ITS Overview & Components

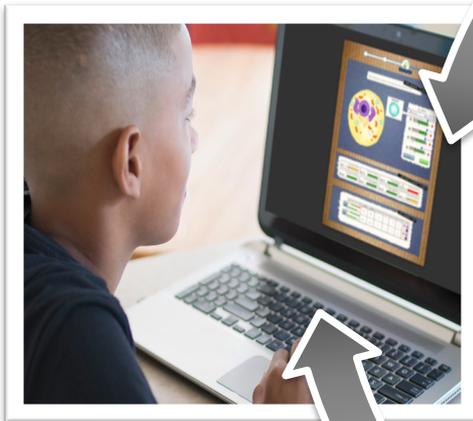
- **Simulation-based assessments (157) for science (4-10 grade)**
 - to assess science practices designed with the assessment triangle (Pellegrino et.al.,2001) and Evidence-Centered Design (Mislevy et al, 2012)
 - include content variables based on students' misconceptions & difficulties with practices (Kuhn, 2005)
 - piloted and refined with think alouds with individual students & teachers (Gobert & Sao Pedro, 2017)
- **Simulations, widgets, and tools capture students' interactions in Inq-ITS**
 - these elicit & capture student performances
- **Performance assessments, reports, scaffolds, & alerts on students' inquiry practices/skills are generated**
 - required operationalizing each inquiry practice into its respective sub-skills
- **Data-mined and knowledge-engineered rules**
 - to assess & scaffold students' practices, and alert teachers on who needs help & how



FOR TEACHERS:
ACTIONABLE
REPORTS &
IMMEDIATE ALERTS



REPORTS ALERTS & TIPS

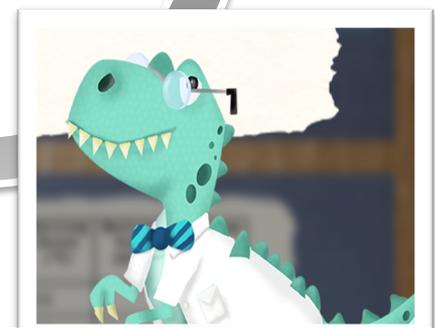


STUDENT

FOR STUDENTS:
REAL TIME
FEEDBACK JUST
WHEN IT IS NEEDED



Inq-ITS™



VIRTUAL TUTOR

Gobert, Sao Pedro, Baker, &
Betts, *US Patent nos.*
9373082, 9564057, 10186168

The Assessment Triangle & ECD

- First corner is Cognition
 - *making explicit the conceptions of how people learn and the knowledge and skills that are associated with the targeted knowledge/competencies.*
- Since all assessments are based in an underlying theoretical framework about how people learn (Gotwals & Songer, 2009; Scardamalia & Bereiter, 2008),
 - *it is necessary to specify or operationalize the knowledge and or cognitive processes underlying the targeted performance/skill/conceptual knowledge within its respective domain,*
 - *this includes both observable cognitive processes and those that are proposed as underlying cognitive activities associated with those processes.*

2nd corner: Observation

- The second corner is *observation*.
 - *The way(s) by which a student's knowledge or competencies are observed for a target conception or skill/practice.*
 - *The key to eliciting observations is designing an assessment item/task that will give students/learners opportunities to demonstrate their knowledge and/or competencies*
 - *The tasks must also elicit a broad range of competencies, which is important for assessment partial and developing competencies.*

3rd corner: Interpretation

- This refers to how people, i.e., researchers, *infer* students' internal knowledge, cognitive processes, and mental states (i.e., representations) from their observable behavior(s)/actions.
 - these were elicited by the tasks/items the student engages in
- *The knowledge, processes, and mental states to be interpreted are those that have been made explicit in the cognition corner of the assessment triangle.*
- *It is critical that researchers attend to how the data will be analyzed as part of the early part of the assessment design, otherwise, one runs the risk of not being able make strong claims about students' knowledge and competencies (Mislevy et al., 2020).*

Evidence-Centered Design

- Evidence-centered design (ECD, Mislevy, et al., 2003) builds off of Pellegrino's, assessment triangle.
- ECD specifies the evidence to support the intended inference including data aggregation and data interpretation (Mislevy, et al., 2003; Mislevy, et al., 2009; Mislevy et al., 2020).
- Specifically, ECD provides fine-grained details guiding the design of the computational objects (key to eliciting observations) and the computational processes (key to interpretation) that are to be carried out in the assessment system in order to generate fine-grained, rigorous assessment data on students' competencies.
- ECD has been used for a wide range of topics, including simulation-based assessments and ITSs (e.g., Clarke-Midura, Code, Dede, Mayrath, & Zap, 2012; Mislevy et al., 2014; Shute, 2011; Mislevy et al., 2020).

ECD, cont'd

- ECD is critically important to unpack and specify all aspects of the assessment process from start to finish, particularly for the assessment of science inquiry because of its ill-defined nature (cf., Kuhn, 2005).
- In brief, taken together, these two frameworks provide a way to understand end-to-end assessment design that can inform assessments needed for teachers' needs for formative assessment and instruction of science practices reflected in reform documents (NGSS, 2013).

Inq-ITS targets students' known difficulties with inquiry

- Some specific student difficulties are...
 - Identifying variables to target and observe
 - Conducting controlled experiments
 - Using data to determine relationships between variables
 - Doing mathematics associated with science inquiry
 - Using and explaining data (evidence and reasoning) while communicating results
 - Linking data with explanations
- Teachers spend considerable time scaffolding students' processes (Aulls, 2002)
 - Real time assessment and monitoring can help this, and improve students' learning

Inq-ITS' virtual simulations (cont'd)

- Simulations permit authentic science inquiry learning and assessment
 - *because they share many features with real apparatus, leveraging perceptual affordances (Norman, 1983)*
- With simulations students:
 - *develop a hypothesis/ask questions*
 - *use models to plan and carry out investigations*
 - *analyze data (w or w/o mathematics)*
 - *warrant claims*
 - *construct explanations*
 - *argue from evidence*

Benefits of virtual simulations for cognition, observation, interpretation, (& instruction)

- Affordances of authenticity(HPL)
 - offer greater validity than m/c tests
 - currently not used fully to assess the skills/knowledge they were designed to foster!
- Generate rich, high fidelity log files
 - used performance assessment
- Work products & inquiry processes can be used for assessment (*Rupp et al, 2010*)
- Can give immediate feedback; blending learning and assessment
 - extra assessment time is not use
 - could replace summative tests



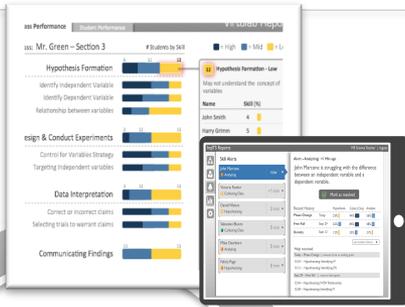
But there are challenges to inquiry assessment in interactive environments ...

- Complex tasks take longer => if fewer measures of “one type”, could have *reduced reliability* (Shavelson et al, 1999)
- More than one way to conduct inquiry => variability in student responses
- Sub-tasks are not independent from each other => assumptions of conditional independence do not hold (i.e., *Classical test theory*; Mislevy et al, 2012)
- Traditional measurement methods tough to apply due to changing skill level as students learn in real time (cf. Levy, 2012)
- Theory needed to both distill/aggregate data (Gobert et al., 2013), and to design categories a priori (critical to interpretation)
 - so that results are pedagogically meaningful to key stakeholders, i.e., teachers, parents, students, & policy-makers.

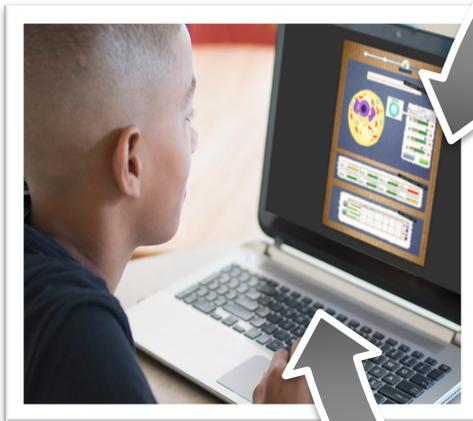
The opportunity for real time performance assessment, scaffolding, & alerting

- **Methodological advances in computational techniques**, i.e., data mining offer analytical leverage on students' learning *processes (not just products)*,
 - *done in real time,*
 - *done at scale,*
 - None of which were possible before.
- Also computational techniques:
 - *can handle the 4 V's of log data (volume, veracity, velocity, and variability in data)*
 - *are desirable for ill-defined problems, like science inquiry*
 - *are transformative for both stealth assessment and real time scaffolding*
 - *Important to democratizing learning*
 - offer scalability, important to Education reform

FOR TEACHERS:
ACTIONABLE
REPORTS &
IMMEDIATE ALERTS

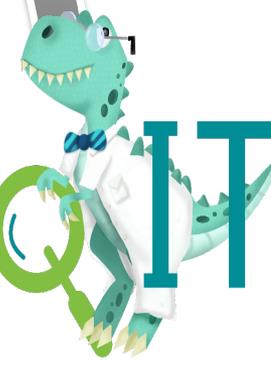


REPORTS ALERTS & TIPS

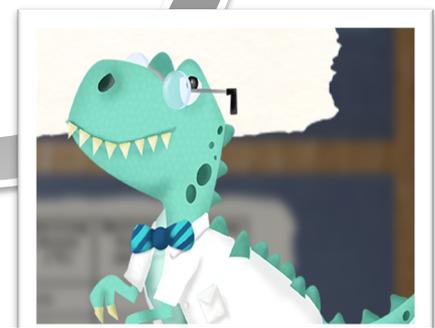


STUDENT

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Inq-ITS™

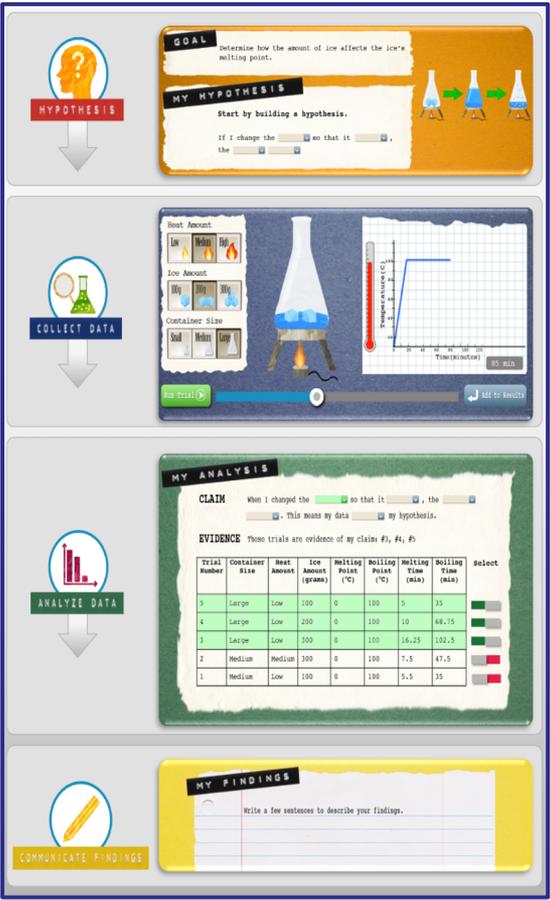


VIRTUAL TUTOR

Gobert, Sao Pedro, Baker, &
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Components for Students

Authentic Inquiry



HYPOTHESIS

GOAL Determine how the amount of ice affects the ice's melting point.

MY HYPOTHESIS
Start by building a hypothesis.
If I change the [] so that it [], the [] [] [].

COLLECT DATA

Heat Amount: Low Medium High
Ice Amount: [] [] []
Container Size: Small Medium Large

ANALYZE DATA

MY ANALYSIS

CLAIM When I changed the [] so that it [], the [] [] - this means my data [] my hypothesis.

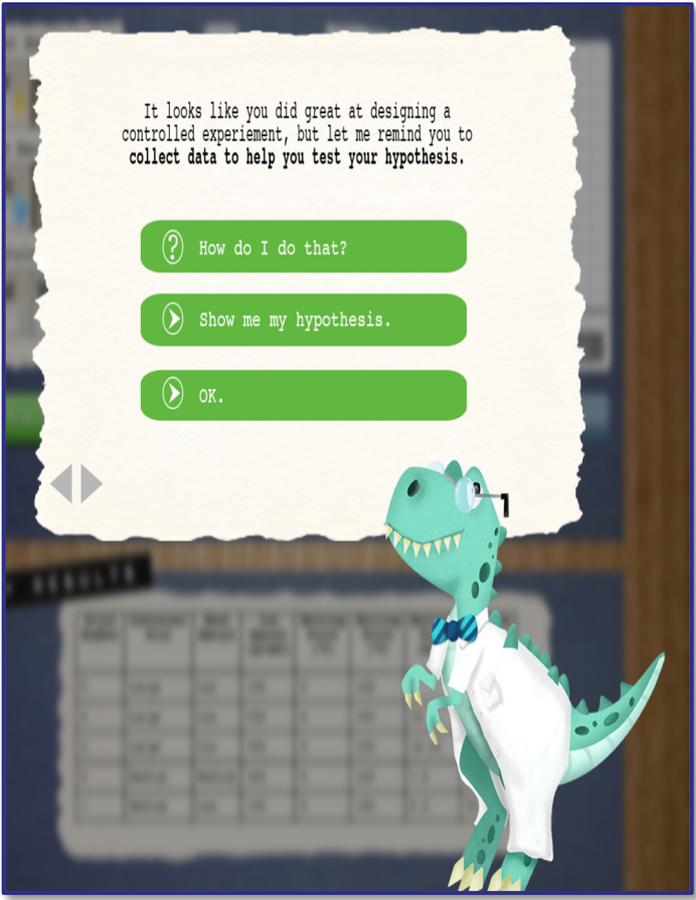
EVIDENCE These trials are evidence of my claim: #1, #4, #5

Trial Number	Container Size	Heat Amount	Ice Amount (grams)	Melting Point (°C)	Boiling Point (°C)	Melting Time (min)	Boiling Time (min)	Select
5	Large	Low	100	0	100	5	35	<input checked="" type="checkbox"/>
4	Large	Low	200	0	100	10	69.75	<input checked="" type="checkbox"/>
3	Large	Low	300	0	100	16.25	102.5	<input checked="" type="checkbox"/>
2	Medium	Medium	300	0	100	7.5	47.5	<input type="checkbox"/>
1	Medium	Low	100	0	100	5.5	35	<input type="checkbox"/>

MY FINDINGS
Write a few sentences to describe your findings.

COMMUNICATE FINDINGS

Rex, Personal Tutor

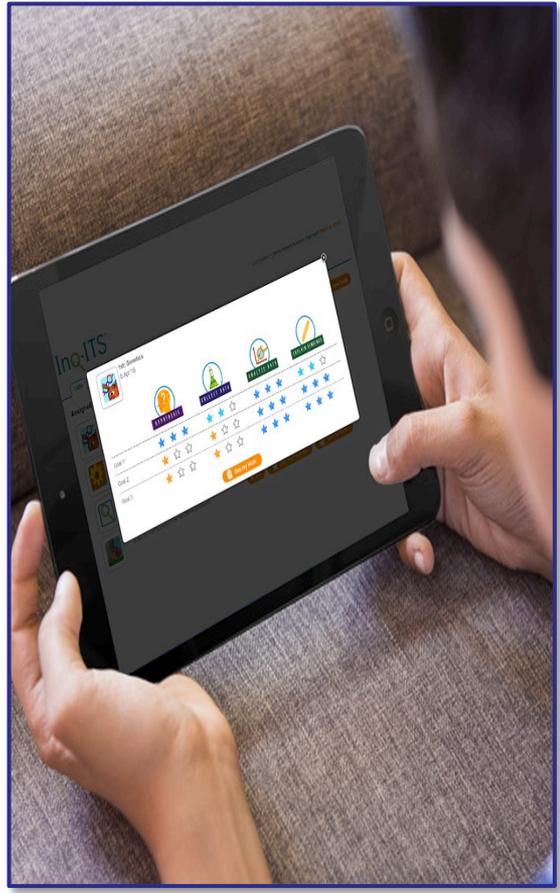


It looks like you did great at designing a controlled experiment, but let me remind you to collect data to help you test your hypothesis.

- How do I do that?
- Show me my hypothesis.
- OK.



Student Reports



Inq.ITS

The Dashboard

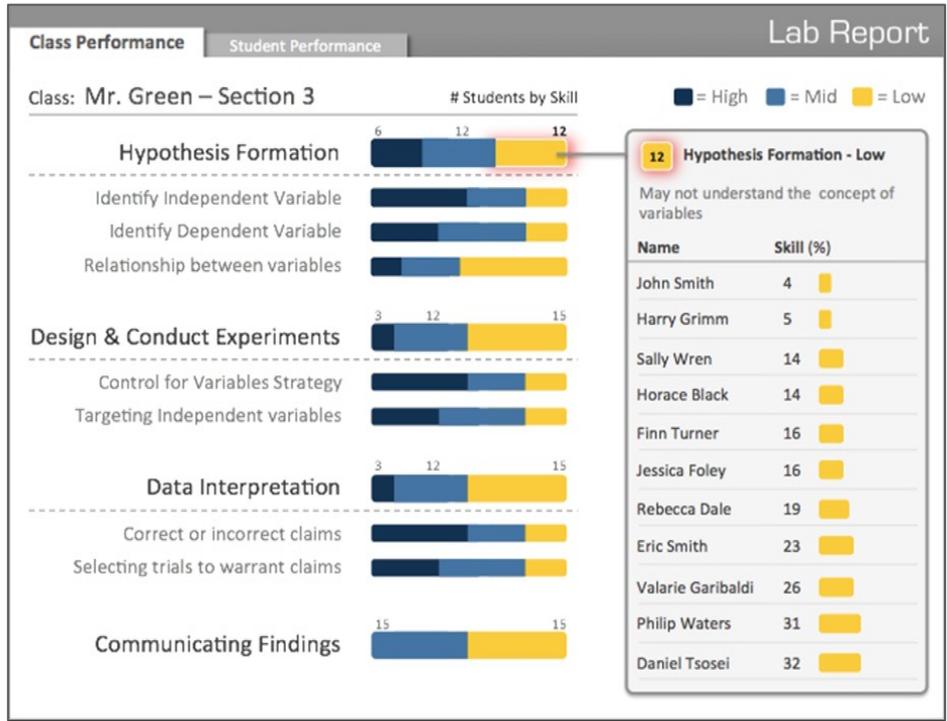
- HYPOTHESIS
- COLLECT DATA
- ANALYZE DATA
- COMMUNICATE FINDINGS

Home

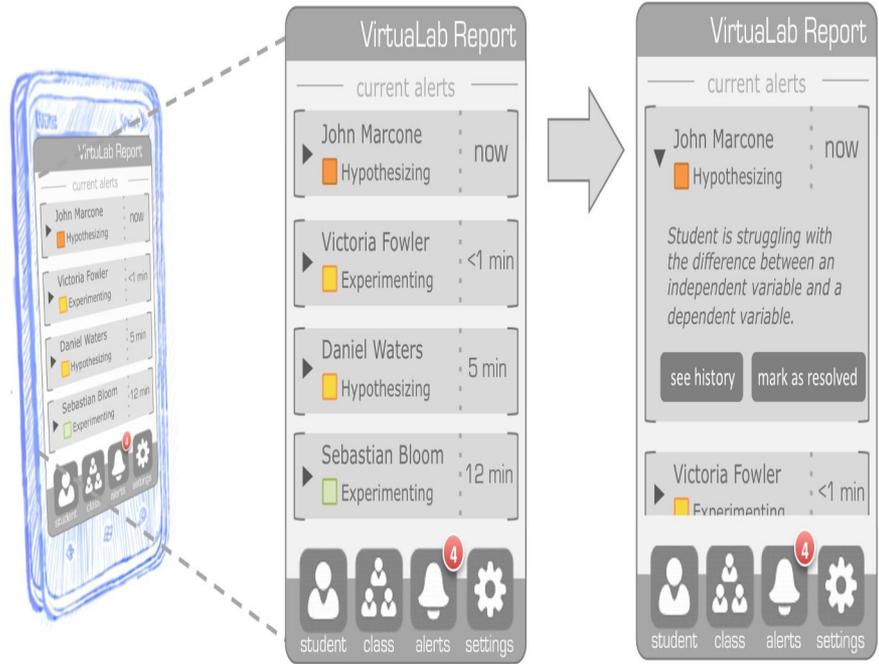
Logout

Components for Teachers

Real-Time Reports for Assessment



Real-Time Alerts for Instruction



- 🍏 Classes
- 👤 Students
- 🔔 Alerts
- ⚙️ Settings

🔔 Recent Alerts

John Marcone
Hypothesizing
now

Victoria Fowler
Hypothesizing
1 min

Daniel Waters
Collecting Data
3 min

Sebastian Bloom
✔️ Collecting Data
5 min

Miles Dearborn
Collecting Data
5 min

Homer Wells
Collecting Data, Hypothesizing
5 min

Sarah Bree
Collecting Data
6 min

Felicia Page
Hypothesizing
8 min

Erasmus Trey
Hypothesizing
10 min

Simon Cole
Hypothesizing
12 min

Alerts are generated in real-time, as your students work in Inq-ITS. If an alert is resolved it will disappear from this list after 5 minutes.

Alert - Hypothesizing | now

John Marcone is struggling to understand what an independent variable is.

✔️ Mark as Resolved

About this lab

Phase Change | amount of ice vs melting point

Independent Variables	Dependent Variables
Container Size	Melting Time
Amount of Ice	Melting Point
Amount of Heat	Boiling Time
	Boiling Point

Today's Performance

Hypothesizing	Collecting Data	Analyzing
12% <div style="width: 12%; height: 10px; background-color: #f4a460; border: 1px solid #ccc; display: inline-block;"></div>	86% <div style="width: 86%; height: 10px; background-color: #0070c0; border: 1px solid #ccc; display: inline-block;"></div>	56% <div style="width: 56%; height: 10px; background-color: #00a0e6; border: 1px solid #ccc; display: inline-block;"></div>

Today's Alerts

Phase Change | amount of ice vs melting point

13:24 🚩 Hypothesizing: Identifying IV
Struggling to understand what an independent variable is

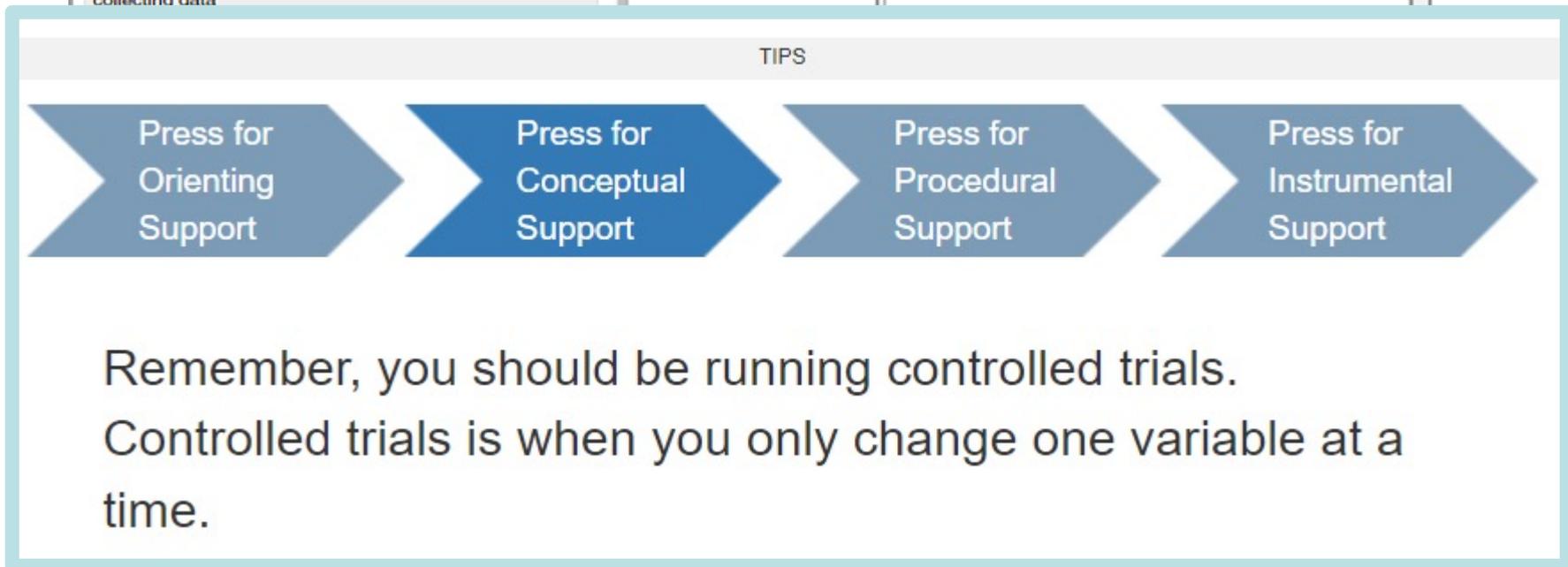
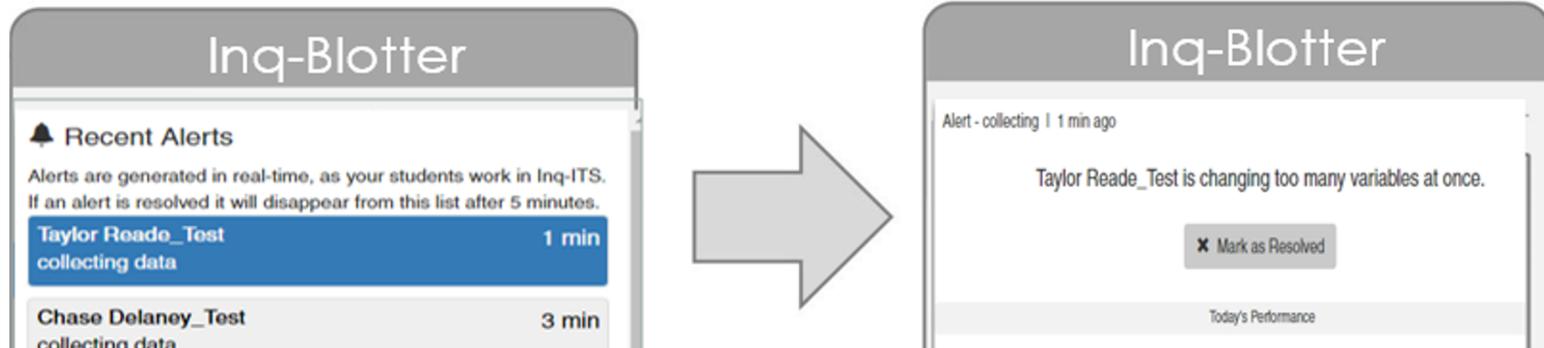
13:12 ✔️ Hypothesizing: Identifying DV
Struggling to understand what a dependent variable is

Phase Change | container size vs boiling time

13:24 ✔️ Hypothesizing: Identifying IV
Struggling to understand what an independent variable is

13:12 ✔️ Hypothesizing: Identifying DV
Struggling to understand what a dependent variable is

Components for Teachers: TIPS (Teacher Inquiry Practice Supports)

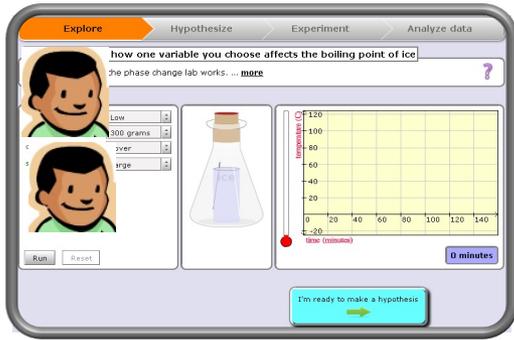


Machine learning/EDM “under the hood” is used for real time assessment, scaffolding, and alerting

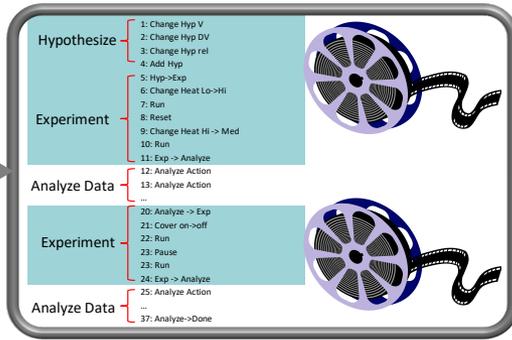
- Data mining & text replay tagging (Baker et al., 2006) are used to develop canonical models of what it means to demonstrate skill, and in turn, develop algorithms,
 - *These can handle variability of students’ processes used in inquiry*
 - *We have done this for all inquiry practices; very close match to human scorers (90%+) (Gobert & Sao Pedro, 2016).*
- Our algorithms *built on diverse student data & validated over multiple topics (Gobert et al., 2013, 2015)*
 - *Generalizability tested on new students not used to build models (Paquette et al., 2014)*

Summary of EDM development & validation

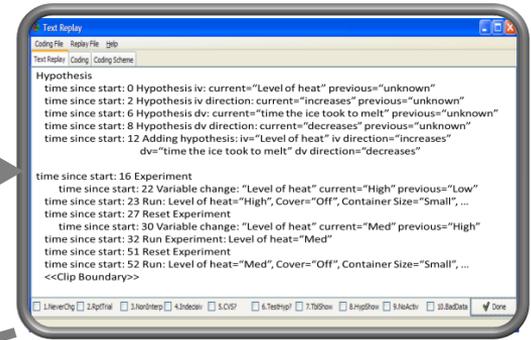
Collect Data



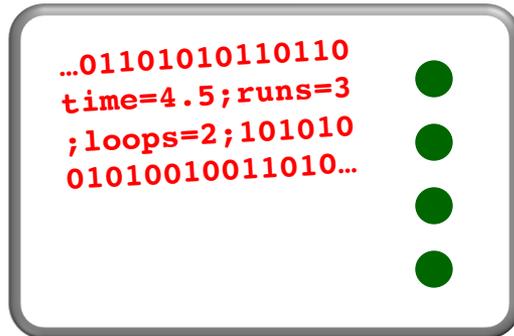
Build Text Replay Clips



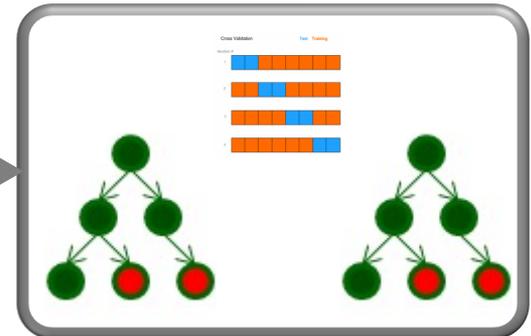
Tag Clips for Skills



Define Features w Rapid Miner



Build & Validate Detectors



Study 1: Identifying the messy middle



“Doing” Science vs Explaining Science

Doing

- Generating a research question
- Forming a hypothesis
- Collecting, analyzing, & interpreting data
- Selecting data to warrant a claim
- Etc.

NGSS, 2013

vs

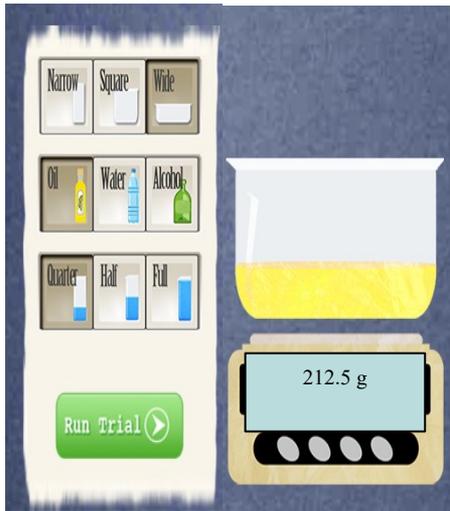
Writing

- Claim
- Evidence
- Reasoning
- etc.

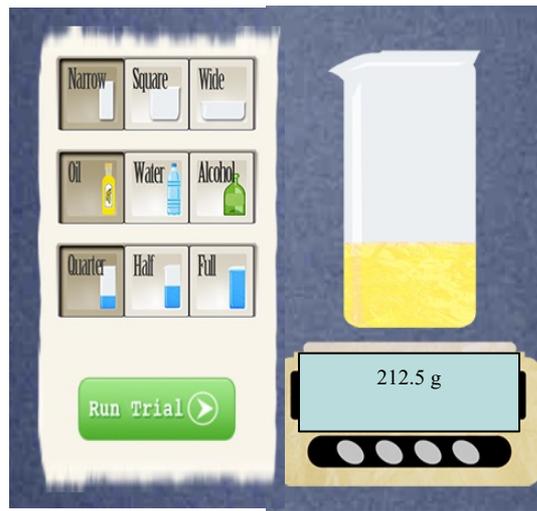
Toulmin, 1958; McNeill et al., 2006

Participants and Materials

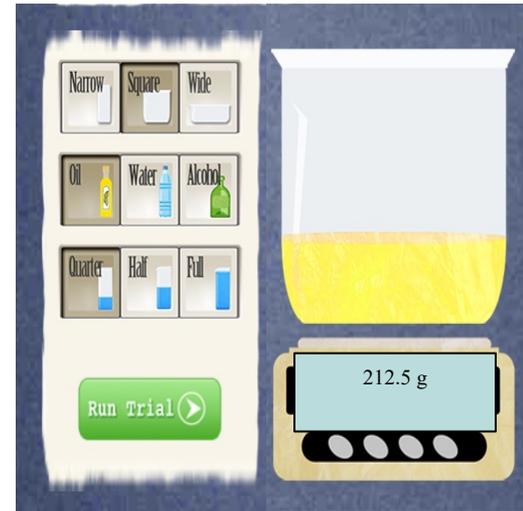
- 293 middle school students, 6 public middle schools
- Materials:
 - Inq-ITS: Density Virtual Lab
 - Shape of the Container Activity



Wide



Narrow



Square

Measures

1. Experimental-Doing in Inq-ITS

- a. All student actions (clickstream inquiry data) are stored in log files
- b. Automated scoring using Educational Data Mining and Knowledge Engineering for hypothesizing, collecting data, & analyzing data
-13 sub-practices scored as present (1 point) or not (0 points)*



Measures

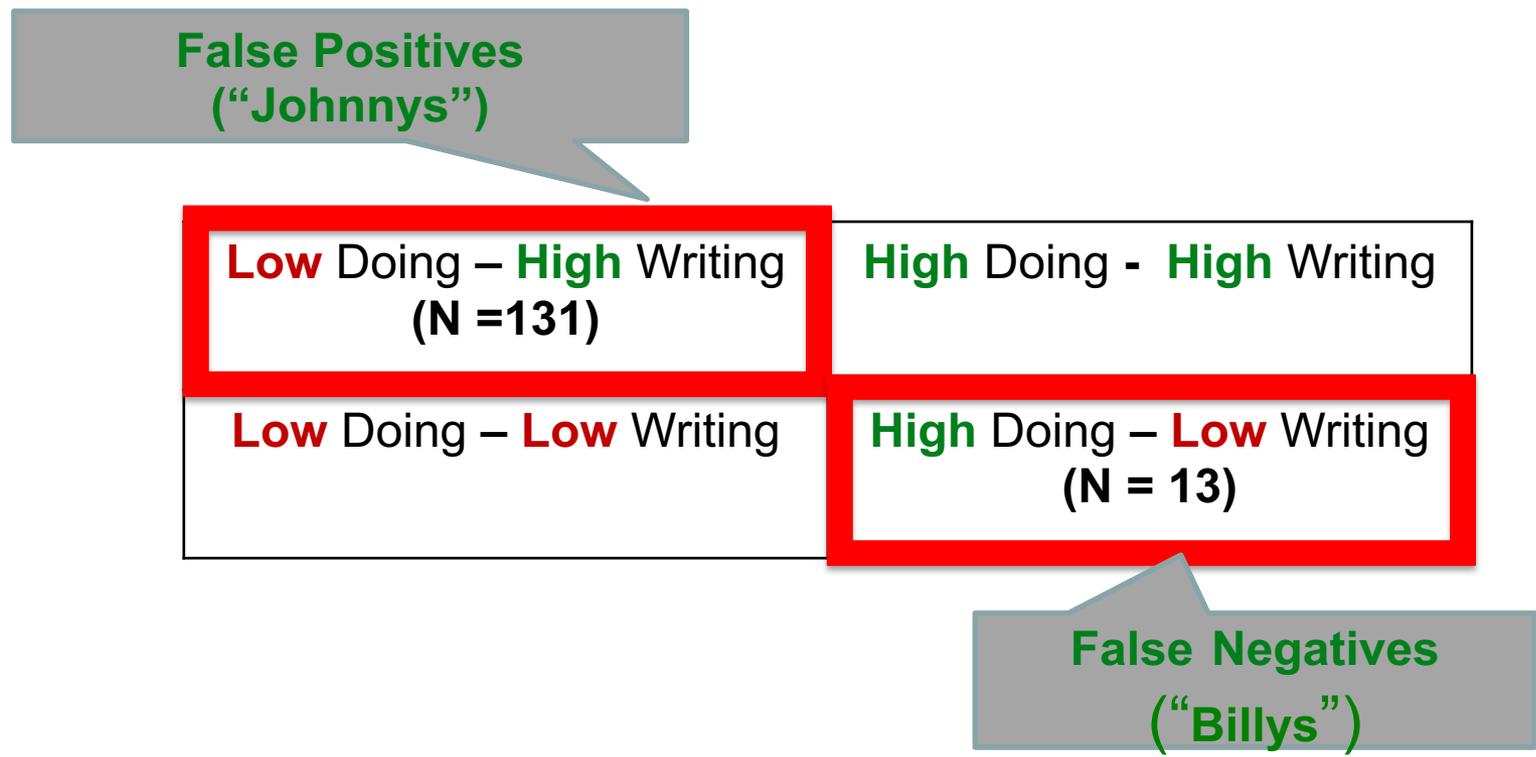
2. Explanatory Writing in Inq-ITS

- b. Students' CER explanations were extracted from database
- c. Used rubrics developed and validated by Li et al. (2017b)
 - Two raters hand scored student explanations from final Inq-ITS' stage according to sub-components of claim, evidence, and reasoning (CER)
- d. Inter-rater reliabilities were: claim ($\kappa = 0.964$), evidence ($\kappa = 0.973$), and reasoning ($\kappa = 0.774$)
- e. *now autoscoring CER based on NLP (with very high correlations b/w humans and algorithms, .90, .94, .86 for C-E-R, respectively).



Analyses

- K-means clustering was used to group students
- 144 of 293 students (49%) were in the messy middle:



Billys (False Negatives) cont.

- Ran a successful investigation and analyzed the data correctly, but did not know what to write:

CER	Writing
Claim	I already did this part
Evidence	the answer to this is in my claim. I think
Reasoning	I don't know

Johnnys (False Positives)

- Wrote about an experiment that he did not conduct:

Doing

Select	Trial #	Container Shape	Liquid Type	Container Filled To	Liqu Ma (g)
✓	1	narrow	oil	quarter	212
✓	2	narrow	water	quarter	212
✓	3	narrow	alcohol	quarter	112

Writing

Claim:

The shape of the container the liquid is in does not affect the overall density of the liquid.

Evidence:

if you change the shape of the container to wide to square the

Select	Trial #	Container Shape	Liquid Type	Container Filled To	Liqu Mas (g)
✓	1	wide	oil	quarter	212
✓	2	wide	oil	quarter	212
✓	3	wide	oil	quarter	212

Johnnys (False Positives)

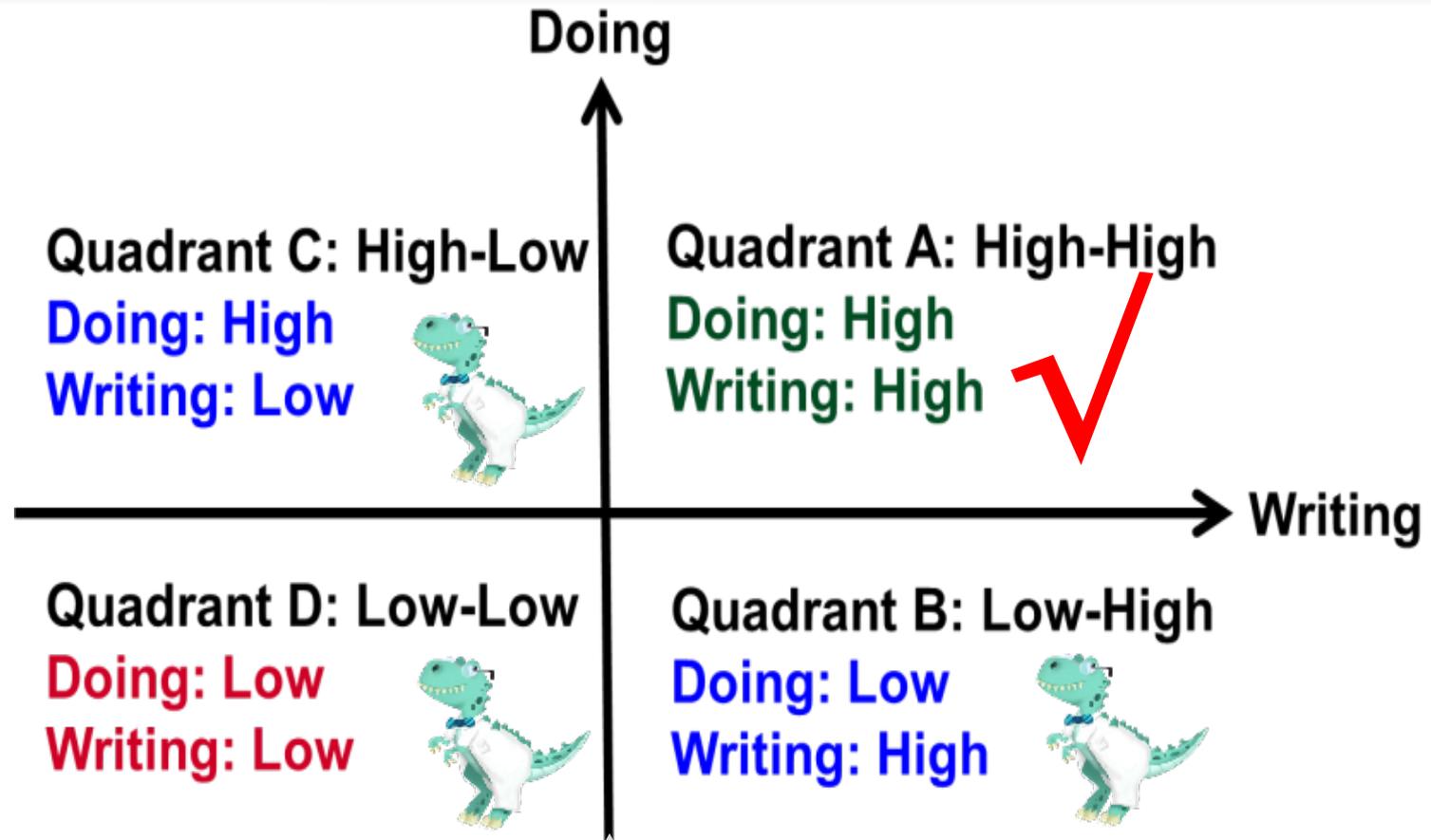
- Miscalculated data, but reported correct data:

Doing

Trial #	Container Shape	Liquid Type	Container Filled To	Liquid Mass (g)	Liquid Volume (ml)	Liquid Density (g/ml)
1	narrow	oil	quarter	212.5	250	62500
2	narrow	oil	quarter	212.5	250	53125

Written Claim

When the container was both narrow and wide the density was 0.85.



Discrepancy (30-60%) can exist between skills for **doing** inquiry and skills for **explaining** their inquiry.

Discussion: Study 1

- Our findings demonstrated that a messy middle (Gotwals & Songer, 2010) exists in students' inquiry performances,
 - *these can result in false negatives and false positives if there is an over-reliance on written assessments.*
- When replication, a misalignment in competencies was found for between 30-60% of students
 - *writing alone may not be sufficient for a number of reasons (poor communication skills or parroting)*
 - *what people say or write is not necessarily ground truth about what they know or can do, especially in STEM!*
- Assessments need to assess the full complement of inquiry practices expected in science policy documents such as the Next Generation Science Standards (2013)

Study 2: Scaffolding in Inq-ITS

- Rex Supports Students on common difficulties with practices, triggered by algorithms in real time, when student needs it (not on-demand)
 - *Students don't know they need help*
- Delivered via a pedagogical agent named Rex, a cartoon dinosaur
- Provide students with multiple levels of support



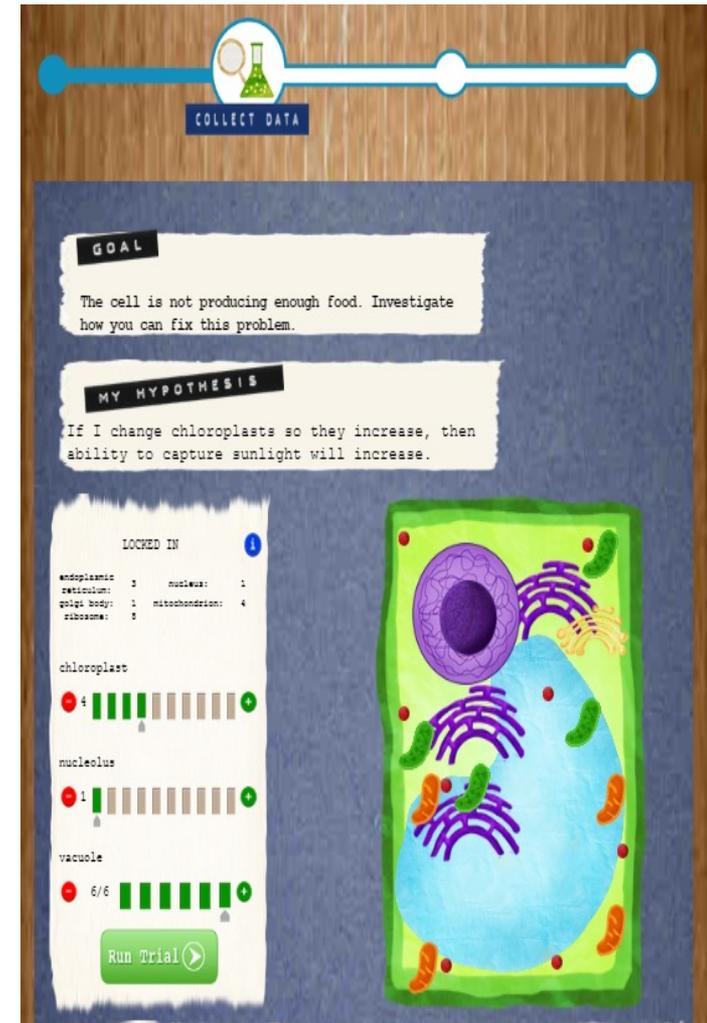
Participants

- 107 6th grade students completed four Inq-ITS virtual labs over the course of 170 days:



Materials: Inq-ITS

- Students' complete four inquiry stages in each virtual lab investigation:
 - Asking Questions/Hypothesizing
 - Carrying Out Investigations/Collecting Data
 - Analyzing and Interpreting Data
 - Explaining findings
- Each Inq-ITS lab (Animal Cell, Plant Cell, Genetics, Natural Selection) has 3-4 driving question activities
- Students received scaffolding **only** in the Animal Cell activity



Materials: Inq-ITS Animal Cell Virtual Activity



HYPOTHESIS



COLLECT DATA



ANALYZE DATA



EXPLAIN FINDINGS

Ask Questions/Hypothesize

GOAL

The golgi body is not receiving enough protein. Investigate how you can fix this problem.



WHAT I WILL CHANGE

<ul style="list-style-type: none"> <input checked="" type="radio"/> endoplasmic reticulum <input type="radio"/> produces proteins <input type="radio"/> transports materials outside cell 	<table border="1" style="margin: auto;"> <tr> <td style="padding: 2px;">Decrease</td> <td style="padding: 2px;">-</td> <td style="padding: 2px;">Increase</td> <td style="padding: 2px;">+</td> </tr> </table>	Decrease	-	Increase	+	<ul style="list-style-type: none"> <input type="radio"/> golgi body <input type="radio"/> ribosome <input type="radio"/> transports protein to golgi bodies
Decrease	-	Increase	+			

WHAT WILL HAPPEN

<ul style="list-style-type: none"> <input checked="" type="radio"/> transports protein to golgi bodies <input type="radio"/> ribosome <input type="radio"/> golgi body 	<table border="1" style="margin: auto;"> <tr> <td style="padding: 2px;">Decrease</td> <td style="padding: 2px;">-</td> <td style="padding: 2px;">No Change</td> <td style="padding: 2px;">0</td> <td style="padding: 2px;">Increase</td> <td style="padding: 2px;">+</td> </tr> </table>	Decrease	-	No Change	0	Increase	+	<ul style="list-style-type: none"> <input type="radio"/> transports materials outside cell <input type="radio"/> produces proteins <input type="radio"/> endoplasmic reticulum
Decrease	-	No Change	0	Increase	+			

Collect Data

GOAL

The golgi body is not receiving enough protein.
Investigate how you can fix this problem.

MY HYPOTHESIS

If I change the endoplasmic reticula so they increase, then the transportation of protein to golgi bodies will increase.

LOCKED IN ⓘ

nucleus:	1	lysosome:	2
mitochondrion:	4	nucleolus:	1
vacuole:	1		

endoplasmic reticulum

8 

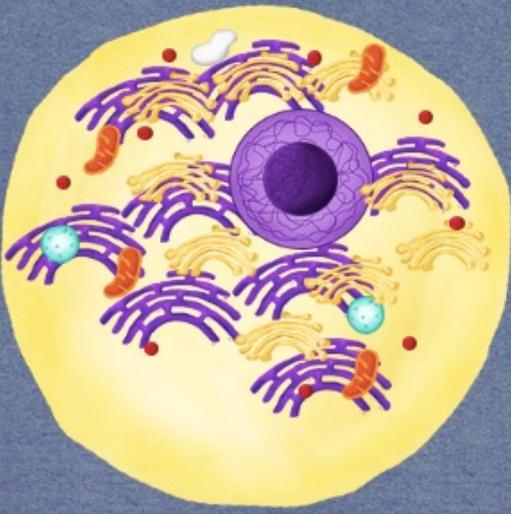
golgi body

9 

ribosome

9 

Run Trial ▶



Analyze and Interpret Data

WHAT I CHANGED

endoplasmic reticulum
 produces proteins
 transports materials outside cell

Decrease ⊖

Increase ⊕

golgi body
 ribosome
 transports protein to golgi bodies

WHAT HAPPENED

transports protein to golgi bodies
 ribosome
 golgi body

Decrease ⊖

No Change ⊙

Increase ⊕

transports materials outside cell
 produces proteins
 endoplasmic reticulum

MY ANALYSIS



Supports my hypothesis

What I observed:



Does not relate to my hypothesis



Refutes my hypothesis

Warrant Claims

Evidence

These trials are evidence of my claim: 4, 5, 6,

Select	Trial #	Endoplasmic Reticulum	Golgi Bodies	Ribosomes	Production of Proteins	Transportation of Protein to Golgi Bodies	Transportation of Nutrients Outside Cell	Cell Health
<input type="checkbox"/>	1	4	4	8	100%	133%	400%	
<input type="checkbox"/>	2	4	1	5	63%	133%	100%	
<input type="checkbox"/>	3	8	9	9	113%	267%	900%	
<input checked="" type="checkbox"/>	4	8	9	9	113%	267%	900%	
<input checked="" type="checkbox"/>	5	5	9	9	113%	167%	900%	
<input checked="" type="checkbox"/>	6	2	9	9	113%	67%	900%	

Explain Findings (not discussed here)



GOAL
Determine how the shape of the container affects the density of the liquid.

MY HYPOTHESIS
If I change the shape of the container so that it goes from narrow to square, the density of the liquid will stay the same.

MY ANALYSIS
Now that you have collected and analyzed your data, you write an argument that explains how your experiment answers your question. There are three parts: claim, evidence, and reasoning.

CLAIM

Write a sentence that states what you found out about the scientific question you just investigated. Provide enough detail so that a friend who did not do the experiment could learn from your description.

EVIDENCE

Provide and describe scientific evidence from your data table that supports (or refutes) your claim. Remember to provide enough detail so that a friend who did not do the experiment could learn from your description.

REASONING

Explain why your evidence (what you wrote in Box 2) supports your claim (what you wrote in Box 1). Remember to provide enough detail so that a friend who did not do the experiment could learn from your description.

Materials: Inq-ITS Scaffolding in Animal Cell

The scaffolds become increasingly specific:

- Orient students to the current task
- Remind students of the steps to engage in the practice
- Give students necessary conceptual information
- Provide direct instructions on how to complete steps

“Check your claim. Remember the point of your experiment is to evaluate your hypothesis”

“Make sure the variables in your hypothesis match those in your claim.”

“Your claim independent variable should be [IV]. Your claim dependent variable should be [DV]. This makes it so your claim matches your hypothesis.”

Measures

- Students' inquiry performance is captured and assessed at the practice level (and sub-practice level) using KE- and EDM-based algorithms:
 - *Forming Questions/Hypothesizing*
 - *Carrying Out Investigations/Collecting Data*
 - *Analyzing and Interpreting Data*
 - *Warranting Claims*



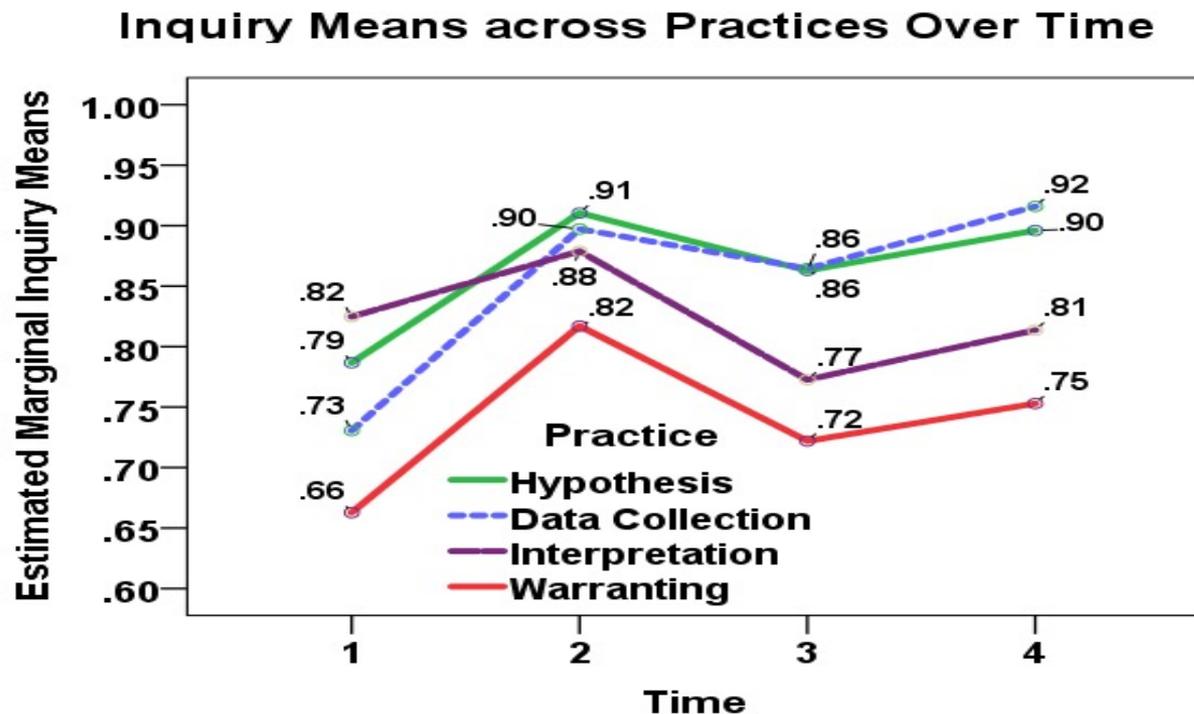
Analyses

- Repeated Measures ANOVAs were performed to investigate whether students' performance on each of the four inquiry practices was robust over time and across topics after scaffolding was removed



Results: Time x Practices

- Repeated measures multivariate analyses showed a significant two-way interaction between time and inquiry practice: $F(9, 98) = 11.00, p < .001, \eta^2 = .503$
- Tests of within-subjects effects were also significant for this interaction: $F(9, 954) = 9.28, p < .001, \eta^2 = .080$



Discussion: Study 2

- Task design, infrastructure, & algorithms enable real-time assessment & scaffolding by Rex
 - Targeted scaffolding in one topic *can* benefit student inquiry practices even after scaffolding is removed
 - Robust across topics and time (tested 170 days later)
 - Scaffolding for inquiry practices by Rex greatly supports the acquisition and refinement of competencies, which undergirds students' inquiry performance
- Sao Pedro, 2013; Moussavi, 2016; Gobert et al., 2018; Li et al, 2018; Gobert et al., in press

Study 3: Using the Inq-Blotter Dashboard to Support Teachers and Students on Science Practices

- There are many dashboards that use coarse-grained multiple choice items to help teachers...
- Few dashboards have the capacity to fully assess students' inquiry competencies at a fine-grained level
 - *(Lajoie et al., 2020; Martinez-Maldonado et al., 2015; Matuk et al., 2016; Tissenbaum & Slotta 2019; VanLehn et al., 2019).*
- Inq-ITS provides fine-grained alerts based on AI-based assessments, important for real time instruction of NGSS practices.

- 🍏 Classes
- 👤 Students
- 🔔 Alerts
- ⚙️ Settings

🔔 Recent Alerts

John Marcone
Hypothesizing
now

Victoria Fowler
Hypothesizing
1 min

Daniel Waters
Collecting Data
3 min

Sebastian Bloom
✔️ Collecting Data
5 min

Miles Dearborn
Collecting Data
5 min

Homer Wells
Collecting Data, Hypothesizing
5 min

Sarah Bree
Collecting Data
6 min

Felicia Page
Hypothesizing
8 min

Erasmus Trey
Hypothesizing
10 min

Simon Cole
Hypothesizing
12 min

Alerts are generated in real-time, as your students work in Inq-ITS. If an alert is resolved it will disappear from this list after 5 minutes.

Alert - Hypothesizing | now

John Marcone is struggling to understand what an independent variable is.

✔️ Mark as Resolved

About this lab

Phase Change | amount of ice vs melting point

Independent Variables	Dependent Variables
Container Size	Melting Time
Amount of Ice	Melting Point
Amount of Heat	Boiling Time
	Boiling Point

Today's Performance

Hypothesizing	Collecting Data	Analyzing
12% <div style="width: 12%; height: 10px; background-color: #ffc107; display: inline-block;"></div>	86% <div style="width: 86%; height: 10px; background-color: #0070c0; display: inline-block;"></div>	56% <div style="width: 56%; height: 10px; background-color: #00bcd4; display: inline-block;"></div>

Today's Alerts

Phase Change | amount of ice vs melting point

13:24 🚩 Hypothesizing: Identifying IV
Struggling to understand what an independent variable is

13:12 ✔️ Hypothesizing: Identifying DV
Struggling to understand what a dependent variable is

Phase Change | container size vs boiling time

13:24 ✔️ Hypothesizing: Identifying IV
Struggling to understand what an independent variable is

13:12 ✔️ Hypothesizing: Identifying DV
Struggling to understand what a dependent variable is

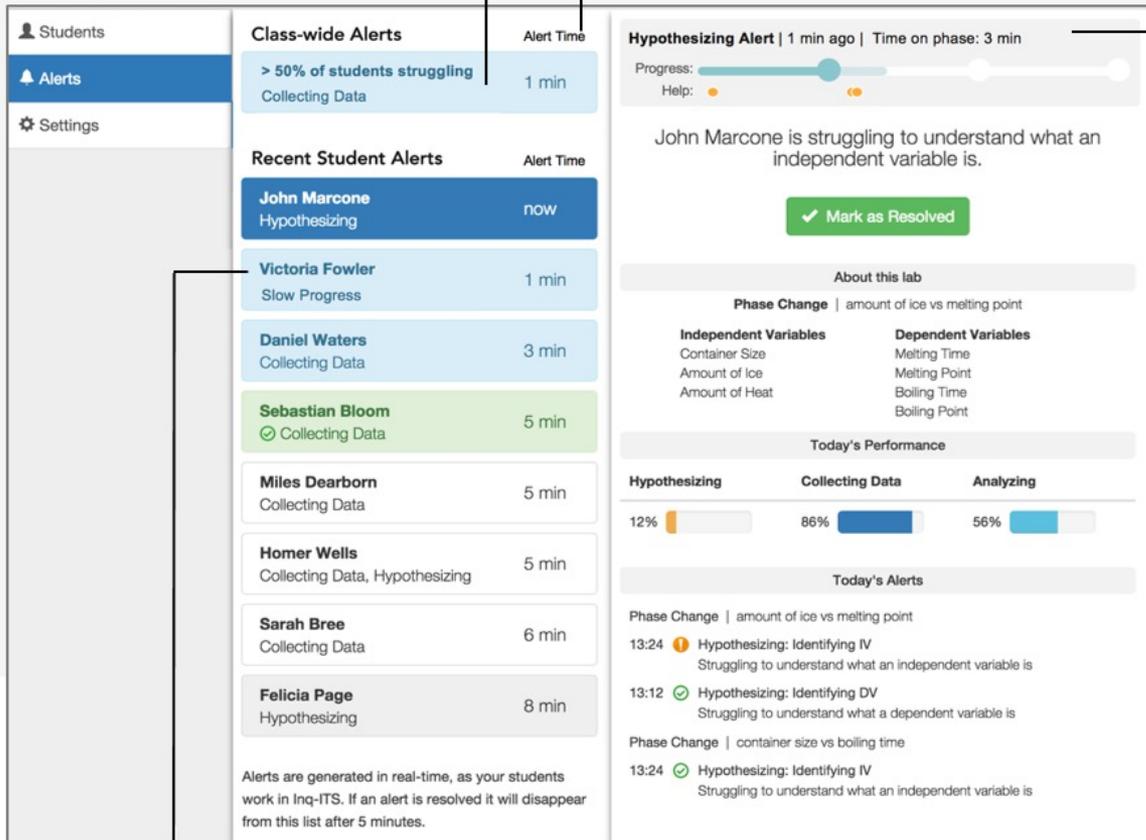
Class-wide Alerts

Triggers when any subskill falls below the limit for enough students. The limit and percentage of students required to trigger an alert is set in the settings, and defaulted to "50% of students falling below 60% performance"

If there are no class-wide alerts, this section should not be visible (no header, etc)

New "Alert Time" label

Added to help clarify what the time displayed is. This should be tested for usability, and may need iteration



The screenshot shows a sidebar with 'Students', 'Alerts', and 'Settings'. The main content area is divided into two sections: 'Class-wide Alerts' and 'Recent Student Alerts'. The 'Class-wide Alerts' section shows a blue alert for '> 50% of students struggling Collecting Data' with an 'Alert Time' of '1 min'. The 'Recent Student Alerts' section lists individual students with their current activity and alert time. A detailed view of a 'Hypothesizing Alert' for John Marcone is shown, including a progress bar, a 'Mark as Resolved' button, and a table of variables.

About this lab	
Phase Change amount of ice vs melting point	
Independent Variables	Dependent Variables
Container Size	Melting Time
Amount of Ice	Melting Point
Amount of Heat	Boiling Time
	Boiling Point

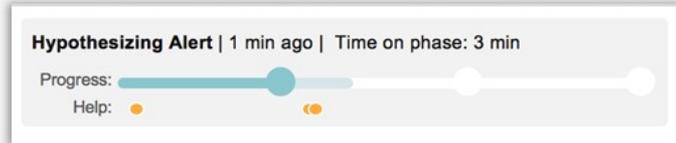
Today's Performance		
Hypothesizing	Collecting Data	Analyzing
12%	86%	56%

Today's Alerts	
Phase Change amount of ice vs melting point	
13:24	Hypothesizing: Identifying IV Struggling to understand what an independent variable is
13:12	Hypothesizing: Identifying DV Struggling to understand what a dependent variable is
Phase Change container size vs boiling time	
13:24	Hypothesizing: Identifying IV Struggling to understand what an independent variable is

Alerts are generated in real-time, as your students work in Inq-ITS. If an alert is resolved it will disappear from this list after 5 minutes.

Updated Header

- Added "time on phase" which should reflect the amount of time the student has been working on the phase in question
- Added Progress Bar, showing where a student is in the activity set
- Added help indicator dots, show how much help the students received and when.



The close-up shows the header 'Hypothesizing Alert | 1 min ago | Time on phase: 3 min'. Below it is a progress bar with a blue circle indicating the current phase. To the right of the progress bar are three orange dots representing help received.

-  Shows completed phases within an activity
-  Indicates a completed activity
-  Indicates the current phase
-  Student received help from rex (dots spaced by phase)
-  Student received help from rex twice that phase
-  Student received help from rex 3 times that phase (etc...)

Slow Progress Alerts

If a student spend too much time on one phase, the teacher is alerted. This limit is set in settings.

Study 3: Testing Inq-Blotter

RQ1) Are real-time alerts for inquiry practices associated with student improvement?

RQ2) Does the pattern of teacher support provided to students differ in relation to performance on practices?

Methods

- Participants:
 - 2 middle school teachers
 - 211 middle school students
- Procedure:
 - Students completed three Inq-ITS lab activities
 - Teachers used Inq-Blotter as students completed Inq-ITS labs
 - *Audio data of interactions were recorded*
 - *Inq-ITS triangulates all teacher blotter data with all students' Inq-ITS data + voice recording (for research)*

Measures: Inq-ITS and Inq-Blotter Log Data

- Students' competencies were scored using our assessment algorithms for each practice *
- Log data from Inq-Blotter was examined in terms of:
 - *alerts that appeared for the teacher*
 - *the student alerts accessed by the teacher*
 - *the content of alerts*
 - *timestamps*
- $N = 35$ recordings were captured and transcribe
- Teacher turns were coded by two raters for types of supports provided
 - *i.e., science practices v. content, evaluative, etc.*

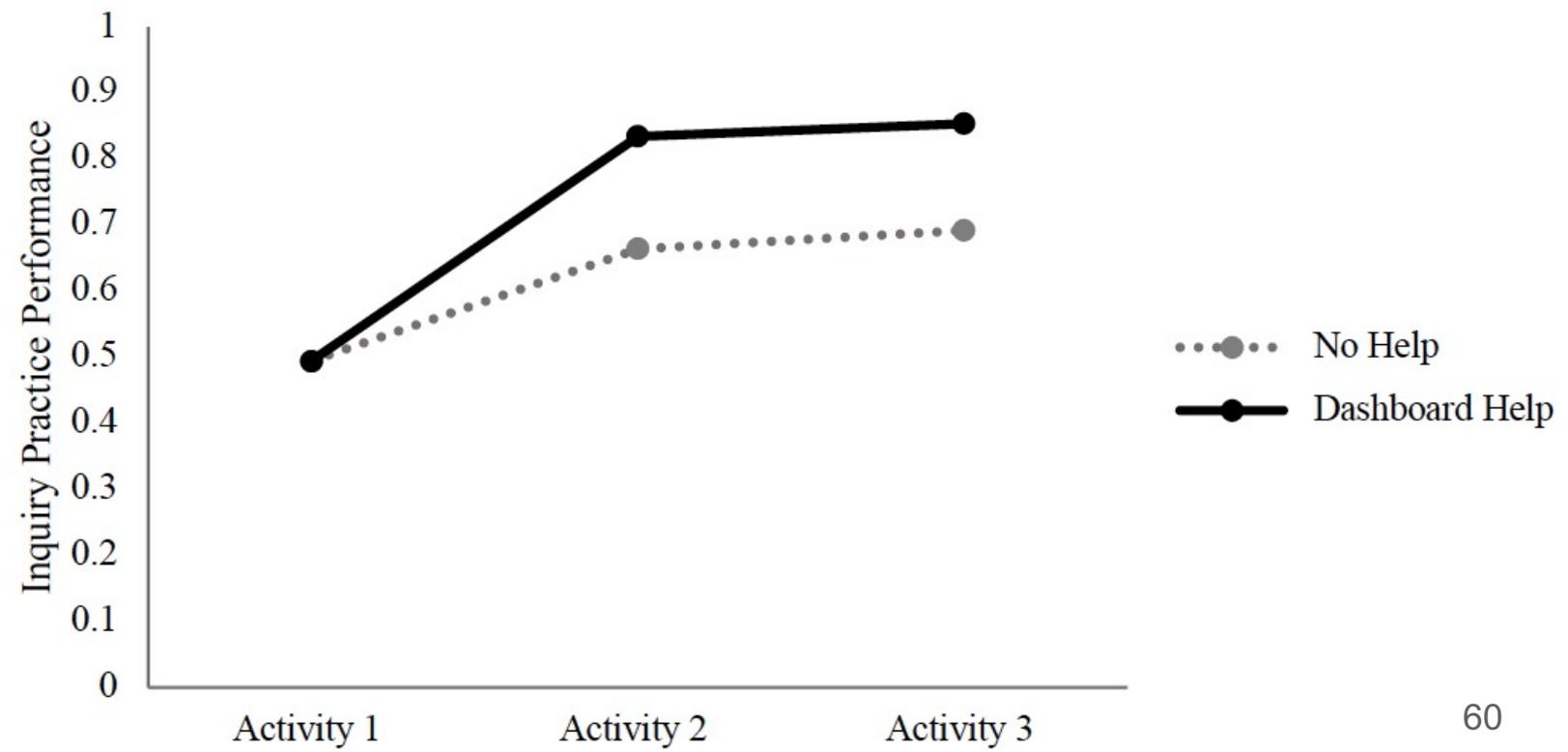
Analyses: RQ1

RQ1) Are real-time alerts for inquiry practices associated with student improvement*?

- Triangulated log data from Inq-ITS and Inq-Blotter
 - *Identified students who were helped (n = 35 students) and matched students who were **not** helped (n = 35 students)*
- A Mixed Model Analysis of Variance (MM ANOVA) was used to compare student performance across activities between conditions
 - *i.e., help versus no help*

Results: RQ1

- The MM ANOVA revealed that students helped based on an alert had marginally significantly greater improvement across activities on the practice on which they were helped
 - i.e., interaction effect, $F(2, 136) = 2.60, p = 0.078$



Analyses: RQ2

RQ2) Does the pattern of teacher support provided to students differ in relation to performance on practices?

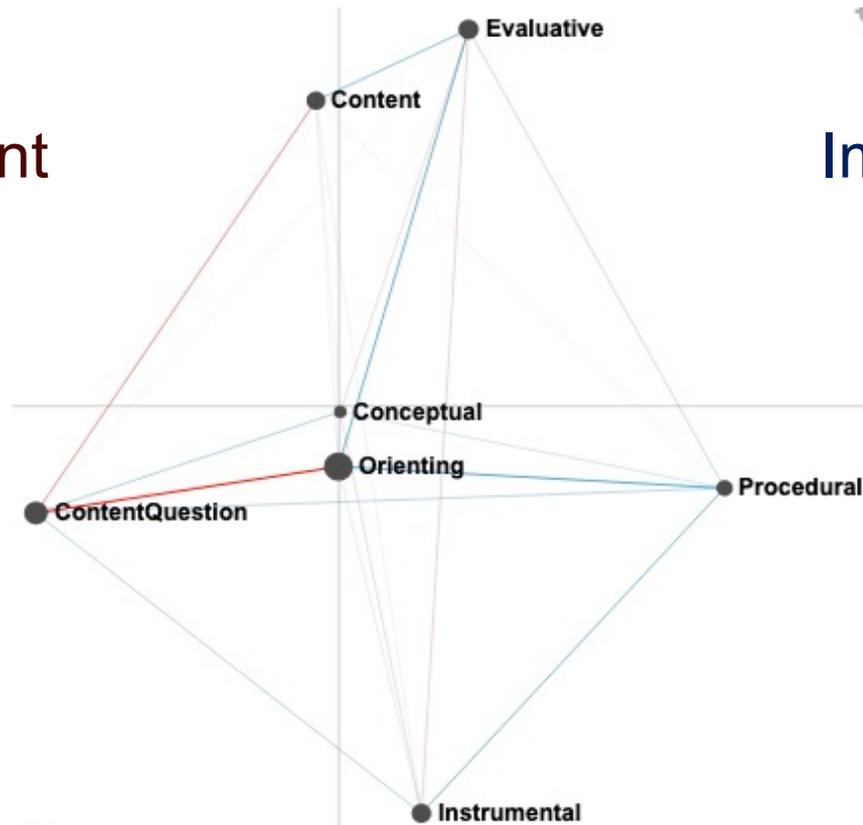
- Triangulated log data with coded audio transcripts
- Compared patterns in support when helped students improved or did not improve on their next activity using ENA

Results: RQ2 (continued)

- Students who did *not* improve received combinations of lower-level/content supports more frequently

No Improvement

Improvement

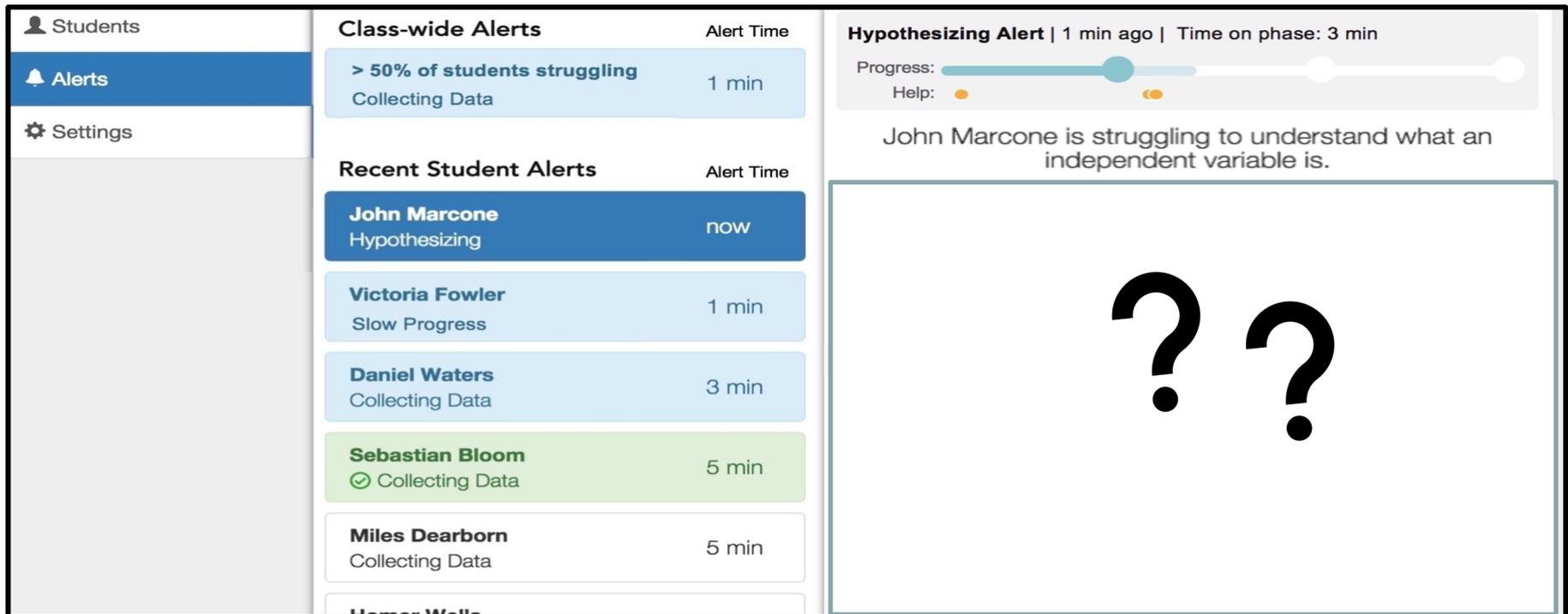


Results: RQ2

- ENA revealed the pattern of support associated with improvement was significantly different, $t(34) = 2.45, p = .04$
- *Those who showed improvement received more high level support, i.e. procedural & conceptual support.*
- *Those who did not improve received combinations of lower-level & content support.*
- These findings have important implications for designing *alerts to promote explicit practice support*
 - *Prior studies indicate potential of providing teachers with example prompts to guide interactions (e.g., Morris & Chi, 2010)*

Supporting Teachers with TIPS

- Since Study 3 showed that discourse support of specific types can lead to student improvement, we added TIPS (Teacher Inquiry Practice Supports) to our alerting dashboard
- These were mined from our previous study.



The dashboard is divided into three main sections:

- Left Sidebar:** Contains navigation options: 'Students', 'Alerts' (selected), and 'Settings'.
- Class-wide Alerts:** A table showing alerts for the entire class.

Alert	Alert Time
> 50% of students struggling Collecting Data	1 min
- Recent Student Alerts:** A list of individual student alerts.

Student Name	Alert	Alert Time
John Marcone	Hypothesizing	now
Victoria Fowler	Slow Progress	1 min
Daniel Waters	Collecting Data	3 min
Sebastian Bloom	Collecting Data	5 min
Miles Dearborn	Collecting Data	5 min
- Alert Detail View:** A detailed view of the 'Hypothesizing Alert' for John Marcone, received 1 minute ago. It shows a progress bar and a help icon. Below the progress bar, the text reads: 'John Marcone is struggling to understand what an independent variable is.' Below this text, two large black question marks are displayed.

TIPS Development

- Teacher Inquiry Practice Supports – prompts for teachers to support the student's inquiry practices
 - *TIPS are sent directly to the teacher within alerts in Inq-Blotter*

TIPS were added to Inq-Blotter; Development included

Obtained 219 teacher-spoken segments from recorded conversations with the 2 middle school teachers from Study 2

Used segments that had previously been coded for four categories of support (i.e., orienting, conceptual, instrumental, procedural)

Filtered segments for which students improved on the practice after receiving support from the teacher

Constructed TIPS for each category of support based on filtered teacher segments

Embedded TIPS into the Inq-Blotter system

 Students

 Alerts

 Settings

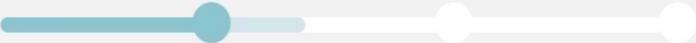
Class-wide Alerts

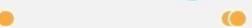
	Alert Time
> 50% of students struggling Collecting Data	1 min

Recent Student Alerts

	Alert Time
John Marcone Hypothesizing	now
Victoria Fowler Slow Progress	1 min
Daniel Waters Collecting Data	3 min
Sebastian Bloom ✔ Collecting Data	5 min
Miles Dearborn Collecting Data	5 min

Hypothesizing Alert | 1 min ago | Time on phase: 3 min

Progress: 

Help: 

John Marcone is struggling to understand what an independent variable is.

[✔ Mark as Resolved](#)

TIPS

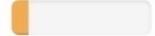
[Press for TIPS \(Teacher Inquiry Practice Supports\)](#)

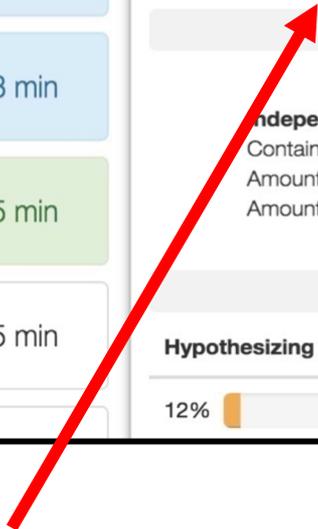
About this lab

Phase Change | amount of ice vs melting point

Independent Variables	Dependent Variables
Container Size	Melting Time
Amount of Ice	Melting Point
Amount of Heat	Boiling Time
	Boiling Point

Today's Performance

Hypothesizing	Collecting Data	Analyzing
12% 	86% 	56% 



Students

Alerts

Settings

Class-wide Alerts

Alert Time

> 50% of students struggling
Collecting Data 1 min

Recent Student Alerts

Alert Time

John Marcone
Hypothesizing now

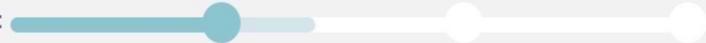
Victoria Fowler
Slow Progress 1 min

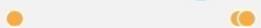
Daniel Waters
Collecting Data 3 min

Sebastian Bloom
Collecting Data 5 min

Miles Dearborn
Collecting Data 5 min

Hypothesizing Alert | 1 min ago | Time on phase: 3 min

Progress: 

Help: 

John Marcone is struggling to understand what an independent variable is.

[Mark as Resolved](#)

TIPS



“What’s your independent variable?”

[Click here to minimize](#)

About this lab

Phase Change | amount of ice vs melting point

Independent Variables	Dependent Variables
Container Size	Melting Time
Amount of Ice	Melting Point

Students

Alerts

Settings

Class-wide Alerts

Alert Time

> 50% of students struggling
Collecting Data 1 min

Recent Student Alerts

Alert Time

John Marcone
Hypothesizing now

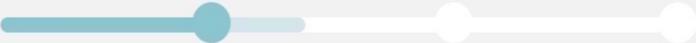
Victoria Fowler
Slow Progress 1 min

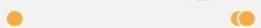
Daniel Waters
Collecting Data 3 min

Sebastian Bloom
Collecting Data 5 min

Miles Dearborn
Collecting Data 5 min

Hypothesizing Alert | 1 min ago | Time on phase: 3 min

Progress: 

Help: 

John Marcone is struggling to understand what an independent variable is.

[Mark as Resolved](#)

TIPS

Orienting Support → **Conceptual Support** → Procedural Support → Instrumental Support

“Remember, an independent variable is the thing that you want to *change*.”

[Click here to minimize](#)

About this lab

Phase Change | amount of ice vs melting point

Independent Variables	Dependent Variables
Container Size	Melting Time
Amount of Ice	Melting Point

Students

Alerts

Settings

Class-wide Alerts

Alert Time

> 50% of students struggling
Collecting Data 1 min

Recent Student Alerts

Alert Time

John Marcone
Hypothesizing now

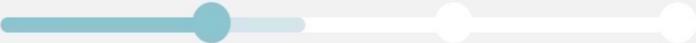
Victoria Fowler
Slow Progress 1 min

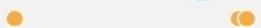
Daniel Waters
Collecting Data 3 min

Sebastian Bloom
Collecting Data 5 min

Miles Dearborn
Collecting Data 5 min

Hypothesizing Alert | 1 min ago | Time on phase: 3 min

Progress: 

Help: 

John Marcone is struggling to understand what an independent variable is.

[Mark as Resolved](#)

TIPS

Orienting Support → Conceptual Support → **Procedural Support** → Instrumental Support

“For the independent variable, select which variable you are going to change in your investigation.”

[Click here to minimize](#)

About this lab

Phase Change | amount of ice vs melting point

Independent Variables	Dependent Variables
Container Size	Melting Time
Amount of Ice	Melting Point

- Students
- Alerts**
- Settings

Class-wide Alerts

Alert Time

> 50% of students struggling
Collecting Data 1 min

Recent Student Alerts

Alert Time

John Marcone
Hypothesizing now

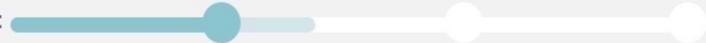
Victoria Fowler
Slow Progress 1 min

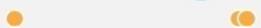
Daniel Waters
Collecting Data 3 min

Sebastian Bloom
Collecting Data 5 min

Miles Dearborn
Collecting Data 5 min

Hypothesizing Alert | 1 min ago | Time on phase: 3 min

Progress: 

Help: 

John Marcone is struggling to understand what an independent variable is.

[Mark as Resolved](#)

TIPS

Orienting Support → Conceptual Support → Procedural Support → **Instrumental Support**

“Your independent variable should be the amount of ice because this is what you are going to change.”

[Click here to minimize](#)

About this lab

Phase Change | amount of ice vs melting point

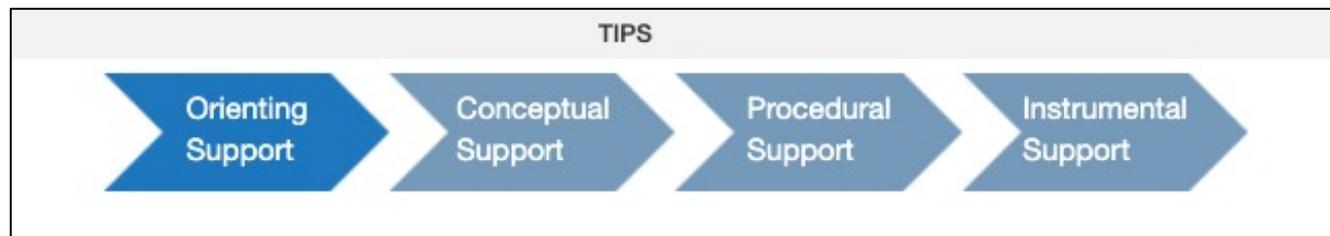
Independent Variables	Dependent Variables
Container Size	Melting Time
Amount of Ice	Melting Point

Methods

- Participants:
 - 4 teachers from different schools
 - 2 Remote (Fully Online, Synchronous)
 - 1 In-Person/Traditional
 - 1 Hybrid
- Procedure:
 - Teachers used **Inq-Blotter with TIPS** as students completed Inq-ITS labs; Clickstream data of the types of alerts and supports that teacher selected and timestamps; Audio recordings
 - Teachers were interviewed about their experiences

Teacher Interviews – Theme 1

- TIPS helped teachers differentiate levels of support
 - *“In general, it was **helpful to remind me to not jump straight to giving kids the answer.** I had a few kids surprise me. They figured things out on their own using the TIPS more often than I thought they would.”*
 - *“I talk to my kids all the time, but it made it easier to identify like **a laser what I needed to talk to them about.**”*

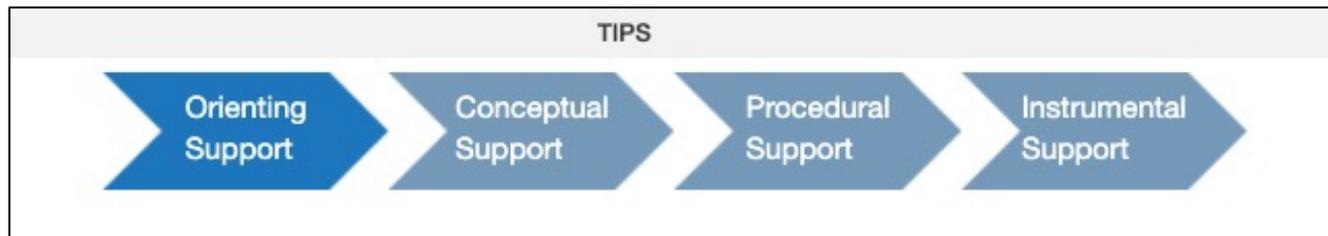


Teacher Interviews– Theme 1, cont'd

- TIPS helped teachers differentiate levels of support
- Teacher quotes:
 - *“I use conceptual TIPS to **students who are more skilled** at science to prompt them to think at the next level. For example, if they have changed too many variables at once, I say “How will you know what caused the change in your dependent variable?”*
 - *“I typically use instrumental-type hints for students who are in Special Ed or on IEPs. For example, I might say, change only one variable at a time, then I ask them to explain to me why this permits them to know how the change in the independent variable lead to changes in the dependent variable.”*

Teacher Interviews– Theme 2

- TIPS helped teachers with timeliness
 - "The **TIPS saved me time** to clarify what is going on...I was able to make my way around the room to more students. When you add [that] up...it really saves me time."
 - "[TIPS] helped me with **starting that communication with the students**. How much did that decrease the amount of time? Probably 1-2 minutes. I get those TIPS, and that's what I would send the kids online."



Discussion

- These preliminary results suggest that adding TIPS to the alerting dashboard helps inform teachers' instruction of inquiry practices, as expected by NGSS.
- Our early findings also suggest the TIPS allows teachers to:
 - *help more students,*
 - *help them more efficiently,*
 - *give them precisely the help they need (Sao Pedro et al, 2019)*
- Important to NGSS instruction, TIPS gives teachers powerful data and actionable TIPS to differentiate help to students who have different needs with science inquiry.
- On-going analyses will look at log data to determine how students' performances changed as a result of teachers using TIPS in their instruction (Adair et al., ICLS, 2022)

Overall Implications for Assessment & Instruction

- This approach, based on the assessment triangle and Evidence Centered Design & data mining, can inform the design of future *scalable* assessments for science inquiry practices (Mislevy et al, 2012; Mislevy, Yan, Gobert & Sao Pedro, 2020), important to rigorous performance assessment & instruction.

Inq-ITS Teams

@ RU

Mike Brigham, Software Engineer
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Mariel O'Brien, Doctoral Student
Jeremy Lee, Doctoral Student
Jessica Owens, Doctoral Student
Ellie Segan, Doctoral Student

Haiying Li, Former Post Doc
Victor Brusca, Former Developer
Rachel Dickler, Former Ph.D.
Student

@ Apprendis

Michael Sao Pedro, CTO
Cam Betts, Managing Director
Jason Kleban, Software Engineer

Brett Craig & Kaitlyn Cuff, & Parker
Shannon, Partnerships
Denise Sao Pedro, Project Success



- Thank you!
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