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InQ-ITS™
Real Time Science Assessment & Tutoring

Automated Analyses of Students' Difficulties with Explanations in Science Inquiry

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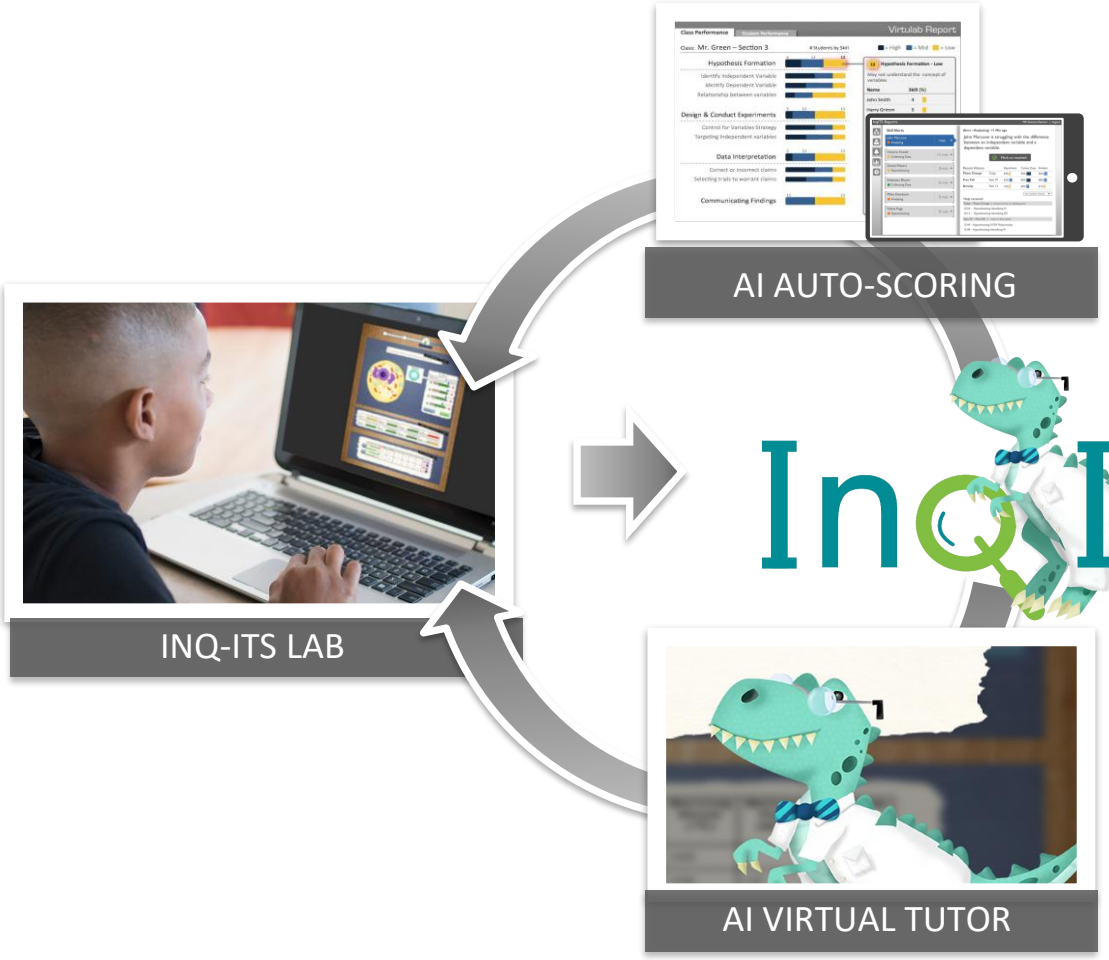
Inquiry Intelligent Tutoring System (Inq-ITS)



For Teachers:
Actionable alerts via teacher dashboard

For Students:
Real-time feedback just when it is needed

Gobert, Sao Pedro, Baker, & Betts,
US Patents 9373082, 9564057, 10186168;
See inqits.com/research for papers

Next Generation Science Standards (NGSS)

(NGSS, 2013; NRC, 2012)

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Claim - Evidence - Reasoning Framework

(McNeill & Krajcik, 2011)

Inq-ITS Claim, Evidence, and Reasoning Rubric

Claim	Evidence	Reasoning
A statement or conclusion that answers the original question (hypothesis).	*Appropriate and sufficient scientific data to support the claim.*	*A scientific principle that connects the evidence to the claim. It shows why the data counts as evidence by using appropriate and sufficient scientific principles.*
Example: *In my hypothesis I stated that if I changed the amount of liquid so that it increases, the density of the liquid would stay the same. My data supported my hypothesis.* *IV: The amount of liquid* *DV: The density of the liquid* *IV(R): so that it increases* *DV(R): would stay the same*	***Example:*** *My data clearly shows that as the liquid increased from 250 ml to 500 ml then to 1000 ml, the liquid's density stayed the same at 1.*	***Example:*** *The reason that my evidence supports my claim is because the density of a liquid does not change just by adding more liquid. Water always has a density of 1 whether it is in a little cup or in a giant lake. You can't change its density unless you change the liquid itself, like when fresh water becomes salt water in estuaries.*

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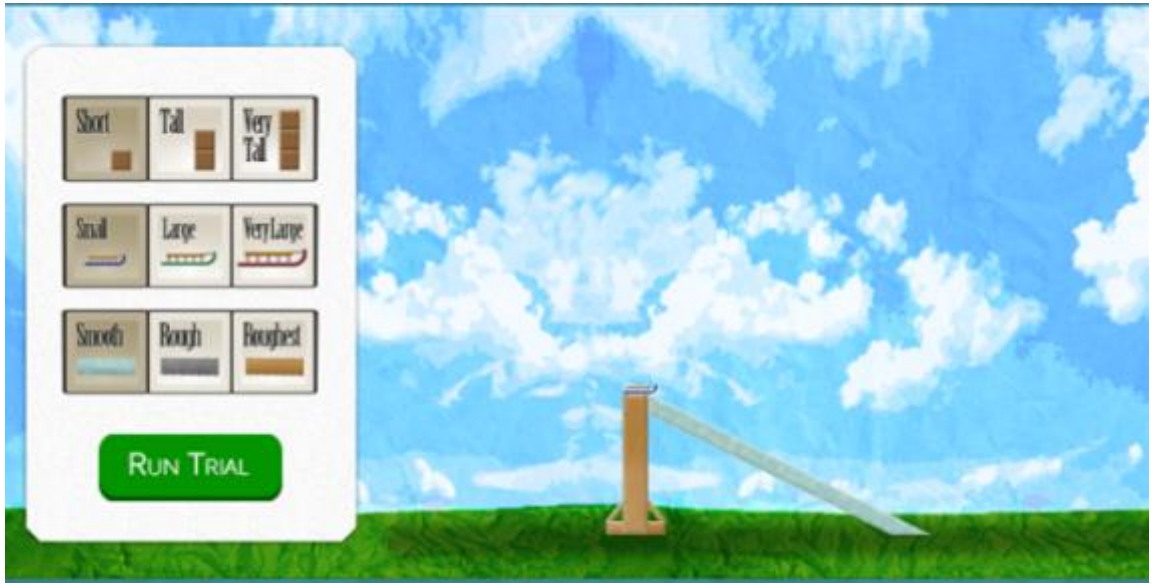
Research Questions

1. Which sub-components of the Claim-Evidence-Reasoning process did students struggle with the most?

2. Were difficulties consistent across the two driving questions?



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Study Overview

Participants

- 76 eighth-grade students from four science classes taught by one teacher in the Northeastern United States

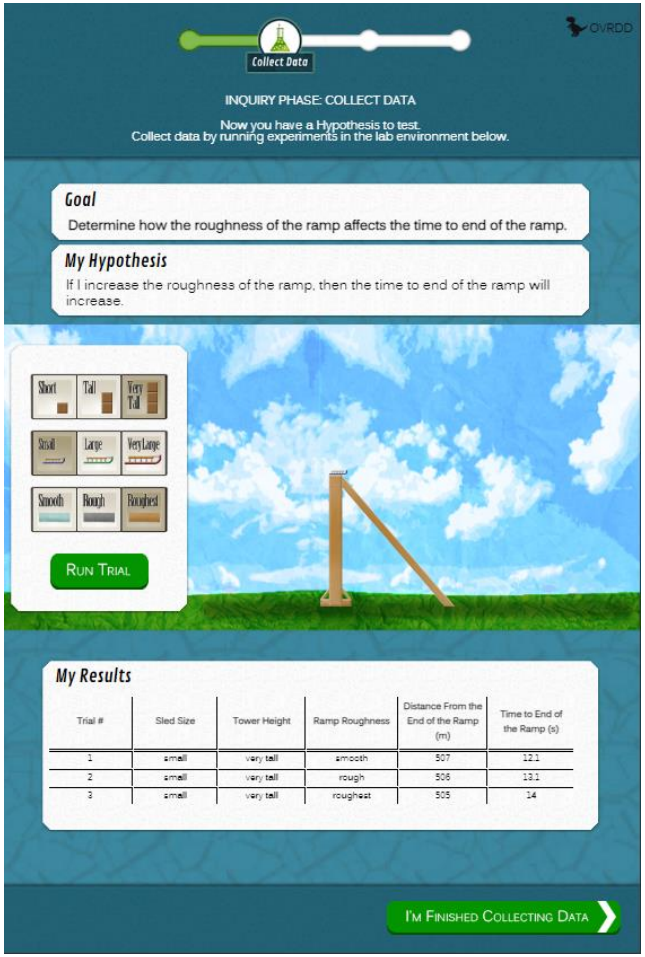
Materials

- Inq-ITS online intelligent tutoring system (Gobert et al., 2023)

- One Forces & Motion Virtual Lab was used as a formative assessment in which students answered two different driving questions:

  1. How does **ramp roughness** affect **time** to the end of the ramp?

  2. How does **sled size** affect **distance** traveled from the end of the ramp?



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Scored with Automated NLP Algorithms

- Scores for each C-E-R component are automatically calculated as a sum of their sub-components

C-E-R	Sub-Component	Description	Possible Point Values
Claim	Claim IV	Did the student state the target independent variable (IV)	No Credit: 0, Max Credit: 1
	Claim IVR	Did the student say how they changed the independent variable (i.e., the independent variable relationship; IVR)?	No Credit: 0; Partial Credit: 0.5, 0.8; Max Credit: 1
	Claim DV	Did the student state the target dependent variable (DV)?	No Credit: 0, Max Credit: 1
	Claim DVR	Did the student say how the dependent variable changed in the experiment (i.e., the dependent variable relationship; DVR)?	No Credit: 0; Partial Credit: 0.5, 0.8; Max Credit: 2
Evidence	Sufficient	Did the student state data for at least two trials (i.e., a sufficient amount of data)?	No Credit: 0; Partial Credit: 0.5, 1; Max Credit: 2
	Appropriate IVR	Did the student state the appropriate data for the independent variable?	No Credit: 0; Partial Credit: 0.5, 0.8; Max Credit: 1
	Appropriate DVR	Did the student state the appropriate data for the dependent variable?	No Credit: 0; Partial Credit: 0.5, 0.8; Max Credit: 1
Reasoning	Connection	Did the student state how the claim relates to the evidence?	No Credit: 0; Partial Credit: 0.5, 0.8; Max Credit: 1
	DV/DVR	Did the student state the dependent variable and/or say how the dependent variable changed?	No Credit: 0, Partial Credit: 0.5. Max Credit: 1
	IV/IVR	Did the student state the independent variable and/or say how they changed the independent variable?	No Credit: 0, Partial Credit: 0.5, Max Credit: 1
	Theory	Did the student explain the scientific principle behind the phenomena?	No Credit: 0, Max Credit: 1

(Li et al., 2017)

Focus on Reasoning

- Using the C-E-R sums from the automated scoring, we analyzed students' performance across the two driving questions to see which sub-components students struggled with most frequently
- Three paired samples t-tests showed:
  - Claim and Evidence did *not* have a statistically significant change between the two trials
  - Reasoning *did* have a significant change between the two trials
    - The students' scores **decreased significantly** from Driving Question 1 to Driving Question 2
    - DQ1 M = 3.49, SD = 1.37 to DQ2 M = 2.96, SD = 1.75; t(75) = 2.68, p = .009
- Previous research shows that students often demonstrate difficulties with incorporating scientific theories and principles into their reasoning across science domains both in Inq-ITS (Adair et al., 2023) and elsewhere (McNeill et al., 2006)

C-E-R	Sub-Component	Description
Reasoning	Connection	State how the claim relates to the evidence
	DV/DVR	State the dependent variable and/or say how the dependent variable changed
	IV/IVR	State the independent variable and/or say how they changed the independent variable
	Theory	Explain the scientific principle behind the phenomena

Fine-Grained Hand Scoring

1. Students were grouped based on the overall **change in their score** for **Reasoning**
2. Their scores were assessed for **correctness** and **frequency** to determine their outcome

Reasoning Sub-Component	Overall Change in Reasoning	Correct Both Times	Partially Correct Both Times	Incorrect Both Times
Connection	Increased	9	2	1
	No Change	15	0	2
	Decreased	6	1	6
DV/DVR	Increased	8	0	2
	No Change	17	0	3
	Decreased	12	2	4
IV/IVR	Increased	7	3	1
	No Change	17	0	3
	Decreased	8	0	6
Theory	Increased	1	0	9
	No Change	0	0	20
	Decreased	2	0	30

Fine-Grained Hand Scoring

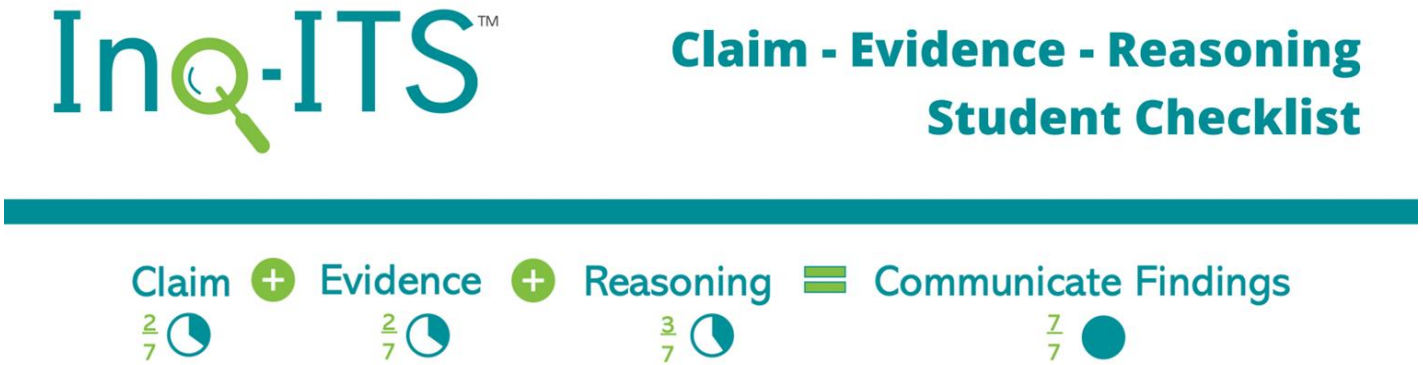
1. Students were grouped based on the overall **change in their score** for **Reasoning**
2. Their scores were assessed for **correctness** and **frequency** to determine their outcome
3. Their scores were assessed based on whether they **increased** or **decreased**

Reasoning Sub-Component	Overall Change in Reasoning	Correct Both Times	Partially Correct Both Times	**Increased from DQ1 to DQ2**	**Decreased from DQ1 to DQ2**	Incorrect Both Times
Connection	Increased	9	2	**4**	**2**	1
	No Change	15	0	**2**	**2**	2
	Decreased	6	1	**7**	**17**	6
DV/DVR	Increased	8	0	**7**	**1**	2
	No Change	17				3
	Decreased	12				4
IV/IVR	Increased	7				1
	No Change	17				3
	Decreased	8				6
Theory	Increased	1				9
	No Change	0				20
	Decreased	2				30

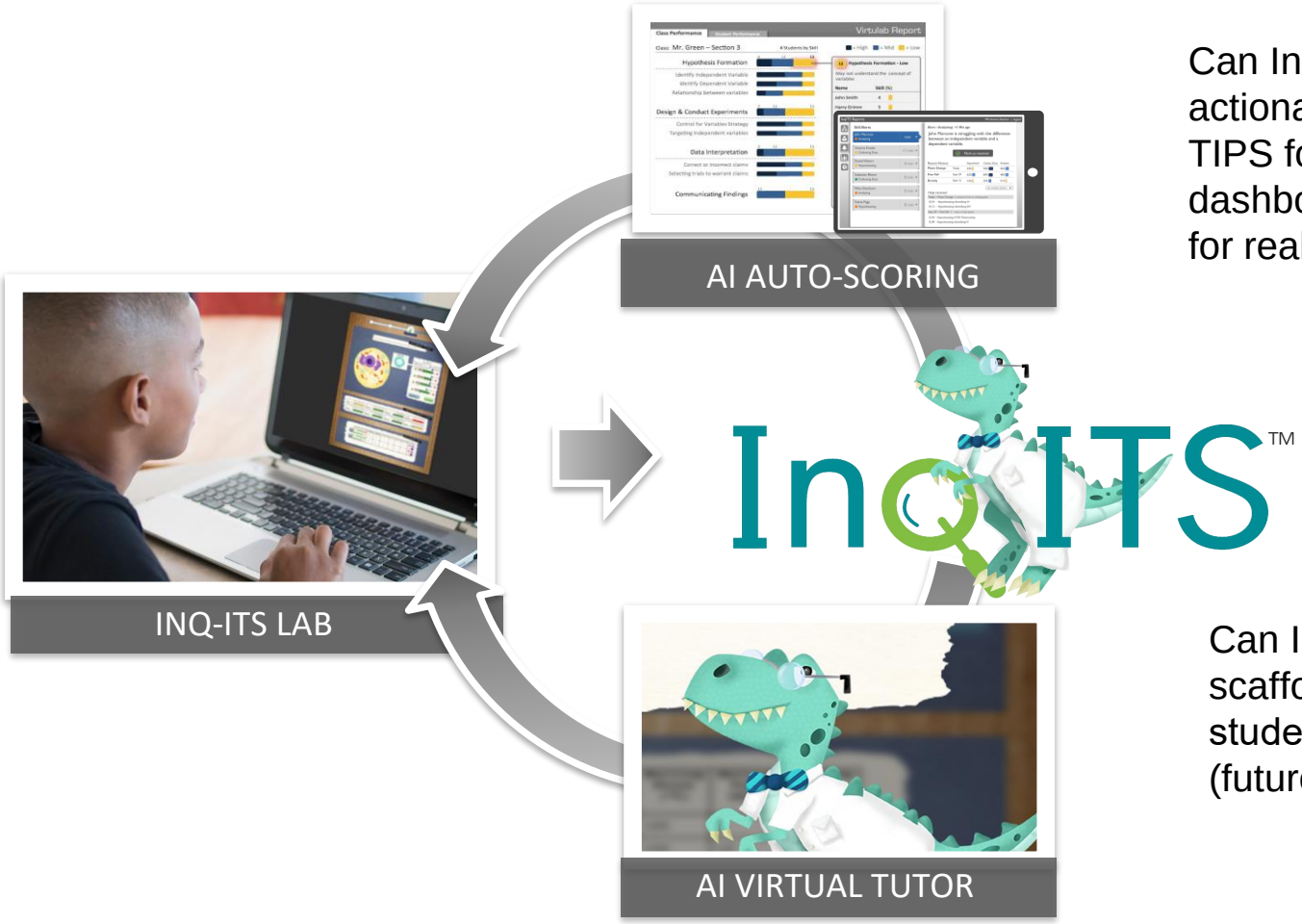
77.6% incorrect both times

Discussion

- C-E-R and their respective sub-components are difficult for students, as evidenced by our fine-grained NLP scoring
- The *Theory* subcomponent is particularly difficult because students must explain the scientific principle behind the phenomena
- Looking at the two driving questions:
  1. How does **ramp roughness** affect **time** to the end of the ramp?
     - Students likely have prior knowledge of *roughness* making the task a bit easier
  2. How does **sled size** affect **distance** traveled from the end of the ramp?
     - Requires more content knowledge, which may have been why the scores decreased



Implications for Future Work



Can Inform detailed, actionable alerts and TIPS for teachers on our dashboard, Inq-Blotter, for real time instruction

Can Inform our fine-grained scaffolds so Rex can target students' specific difficulties (future work)

Thank you!

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