

Scientific explanation



UiO : Department of Teacher Education and School Research
University of Oslo

Leveraging log data to examine students' progression in constructing scientific explanation

Nani Teig and Fredrik Jensen

University of Oslo, Norway

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Background

- The role of explanations in science: *what we know, why it happens, and how we know* (Rocksén, 2016).
- The role of explanations in science education:
 - understand science content
 - understand the nature of science
 - promote critical thinking and scientific literacy (Duschl & Osborne, 2002; McNeill & Krajcik, 2011).
- Scientific explanation plays an integral role in science education reforms around the world.

CLAIM

A conjecture, conclusion, principle, explanation, or question that address a specific phenomena

Fits with ...

Supports...

EVIDENCE

Measurement, observation, or data from other studies that have been collected and analysed

Justified with ...

Explains...

REASONING

Statements that explain *why* the evidence supports the claim and *why* the evidence should count as support for the claim

Scientific explanation

Phenomenon

Question about the natural world

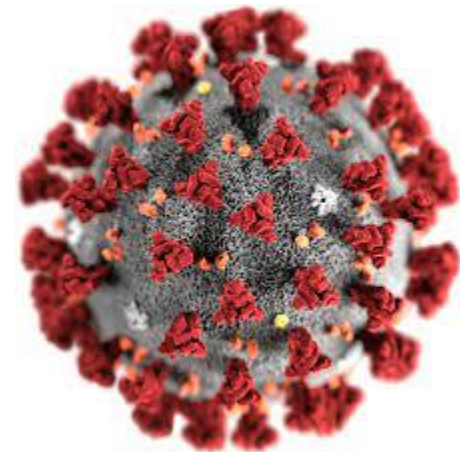
CLAIM

Handwashing with soap is an effective tool to prevent the spread of coronavirus

Scientific explanation

Phenomenon

Handwashing



CLAIM

Handwashing with soap is an effective tool to prevent the spread of coronavirus

Fits with ...

Supports...

EVIDENCE

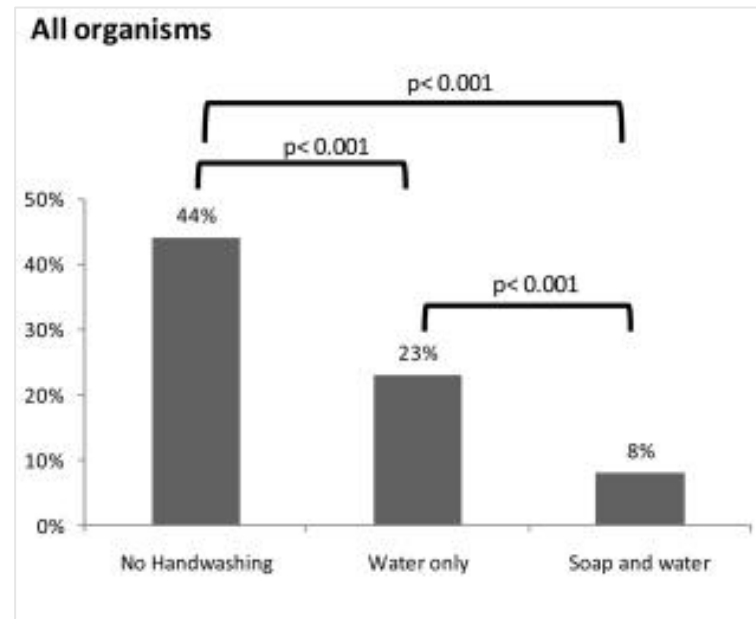
Data from observation, experiment, or existing studies

Justified with ...

Explains...

REASONING

Germs including coronavirus can spread through contact. Handwashing with soap destroy the chemical bonds and remove germs from hands.




Scientific explanation in ILSAs

IEA
TIMSS
2019

The pictures below show a shadow at three different times of the day.

9 a.m. 12 noon 5 p.m.



Explain why the shadows changed.

The shadows changed because the sun changed position in the sky



Research question

How do students construct scientific explanation using simulated investigation?

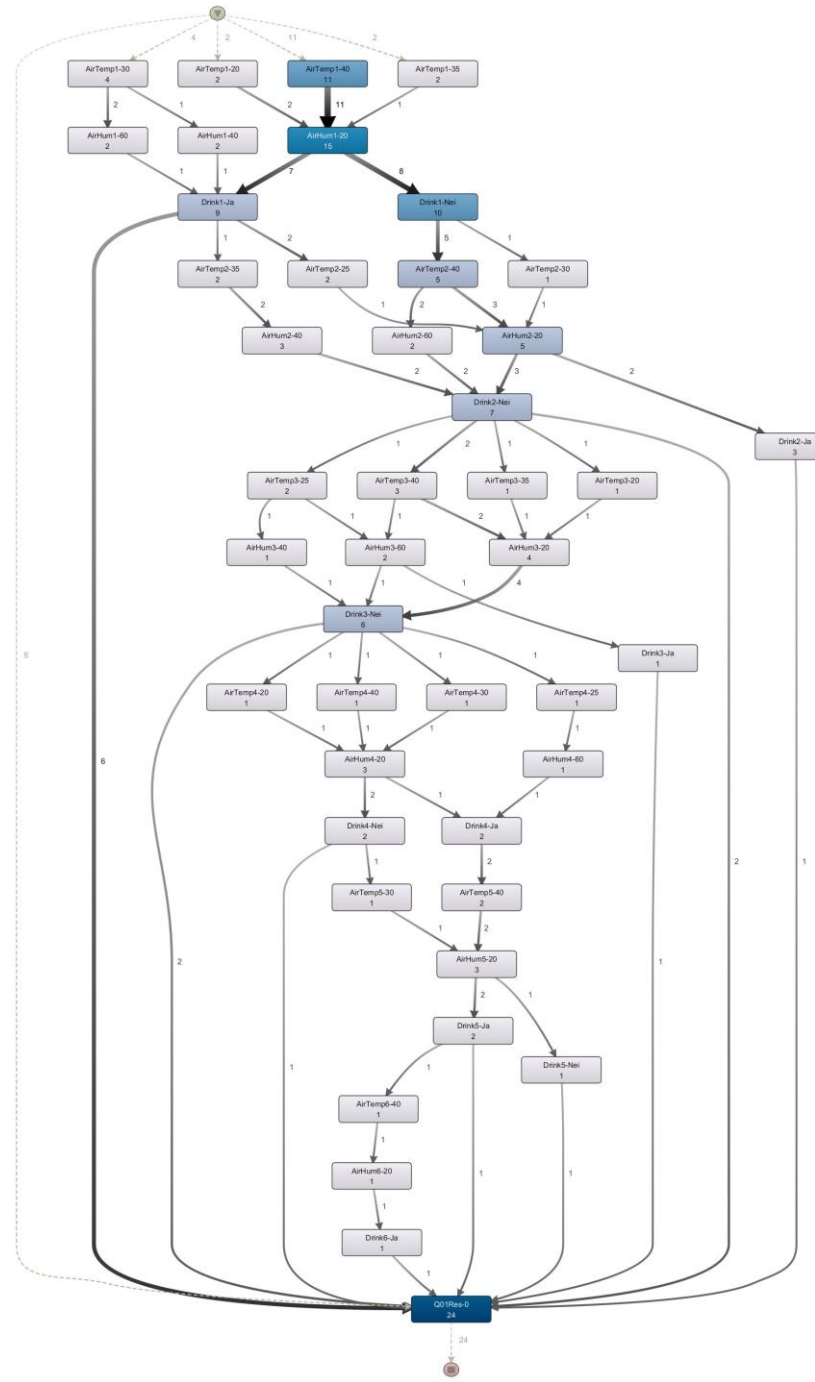


Data

- PISA 2015 field trial data from Norway
- The Running in Hot Weather unit (five interactive tasks): <https://bit.ly/PISA-science>
- $N=81$ students (39 girls and 42 boys)

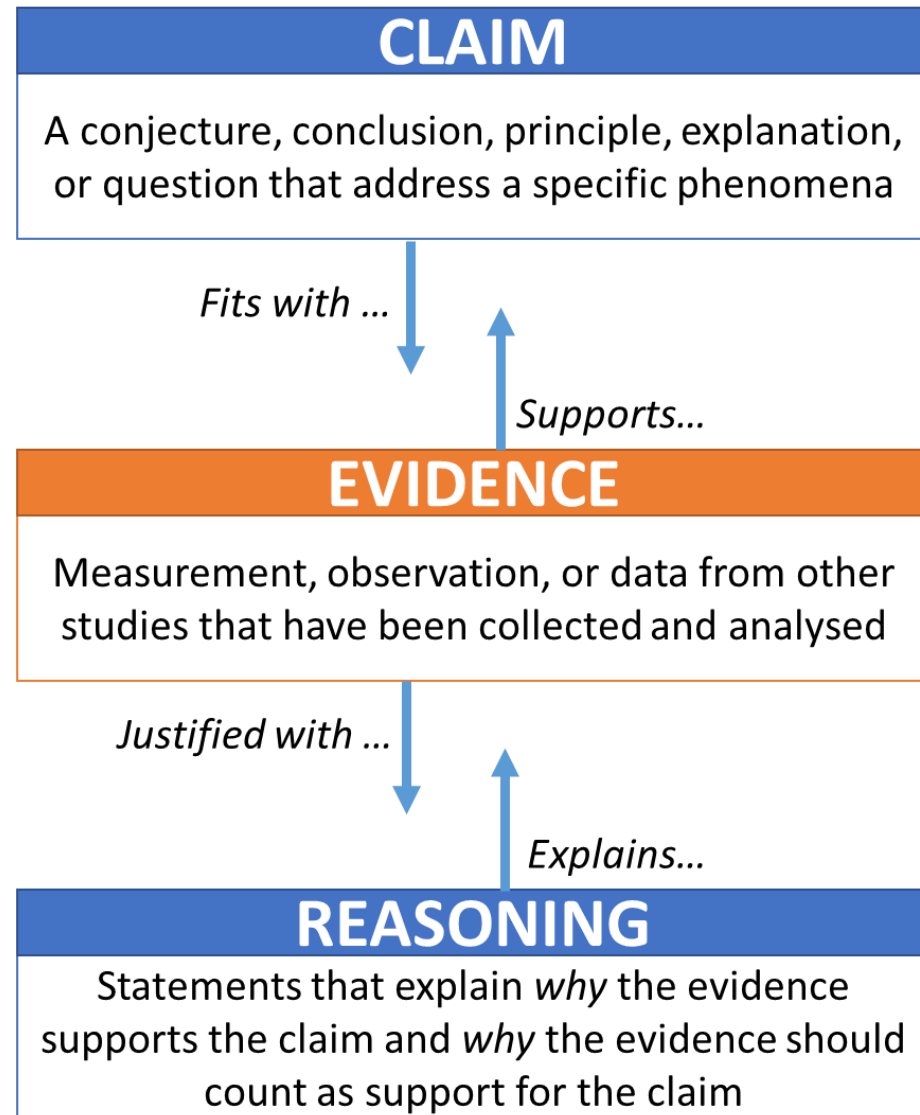
Methods

- Students' log file data
- XML files → CSV file → CER variables
- Process mining (Disco) → to analyse students' sequence of actions to generate evidence in simulated investigation.
- Behavioural indicators



Findings

Mapping students' pattern of performance in constructing scientific explanation into a theoretical framework



Scientific explanation (SE) framework

Yao, Guo, & Neumann (2016); McNeill & Krajcik (2011)

Components	Basic	Moderate	Complex
Claim	Affirming and describing the phenomenon. [The phenomenon is clear; it has single variable or has a few variables, but their relationship is simple; the changing pattern is conforming to everyday experience.]	Abstracting and representing the phenomenon. [The phenomenon needs processing from real context. It has several variables, and their relationship is complex; the changing pattern may not conform to everyday experience.]	
Evidence	Searching data in a small data set. Data set is limited to appropriate data	Searching data in a big data set. Data set includes both appropriate/inappropriate data/non-related data set	Defining the data set.
	Data set is ready for directly processing	Data is collected by directly observation, measurement, etc.	Data is collected by indirectly observation, measurement, etc.
Reasoning			
<i>Domain general</i>	Making basic logical connection between idea, data, and phenomenon, though generalization, induction, or simple causal reasoning.	Developing a causal chain or clarifying the mechanism that connecting phenomenon, evidence, and theory, though scientific reasoning including isolation and control of variables, correlational reasoning, probabilistic reasoning, etc.	Designing a unification model that connecting phenomenon, evidence, and theory, though scientific reasoning including but not limited to isolation and control of variables, combinatorial reasoning, probabilistic reasoning, hypothetical-deductive reasoning, etc.
<i>Domain specific</i>	Applying scientific ideas, law-like sentences, etc. under the scaffold from teacher or instructional materials.	Using the key variable as the clue for independently selecting scientific concepts, laws, theories, and principles.	Independently selecting the scientific concepts, laws, theories, and principles by systematically analysing the context.

Stage 1: Basic SE

Claim

Identify the phenomenon that needs explaining

Evidence (not scored)

- Searching data in a small data set.
- Data set is limited to appropriate data

Reasoning

Making basic logical connection between phenomena and data

PISA 2015

Running in Hot Weather

Question 1 / 6

► How to Run the Simulation

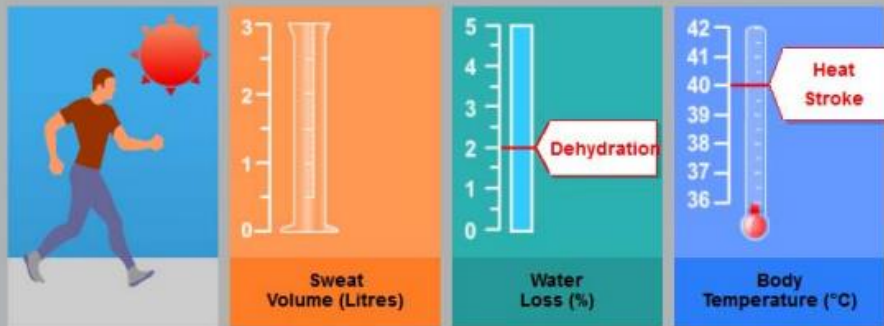
Run the simulation to collect data based on the information below. Select from the drop-down menus to answer the question.

A runner runs for one hour on a hot, dry day (air temperature 40°C, air humidity of 20%). The runner does not drink any water.

What health danger does the runner encounter by running under these conditions?

The health danger that the runner encounters is .

This is shown by the of the runner after a one-hour run.



Sweat Volume (Litres) gauge: 0 to 3, needle at 3. Dehydration label at 2.

Water Loss (%) gauge: 0 to 5, needle at 2. Dehydration label at 2.

Body Temperature (°C) gauge: 36 to 42, needle at 40. Heat Stroke label at 40.

Air Temperature (°C) slider: 20, 25, 30, 35, 40. Value: 40.

Air Humidity (%) slider: 20, 40, 60. Value: 20.

Drinking Water: Yes No

Run

Air Temperature (°C)	Air Humidity (%)	Drinking Water	Sweat Volume (Litres)	Water Loss (%)	Body Temperature (°C)

Stage 1: Basic SE

Claim

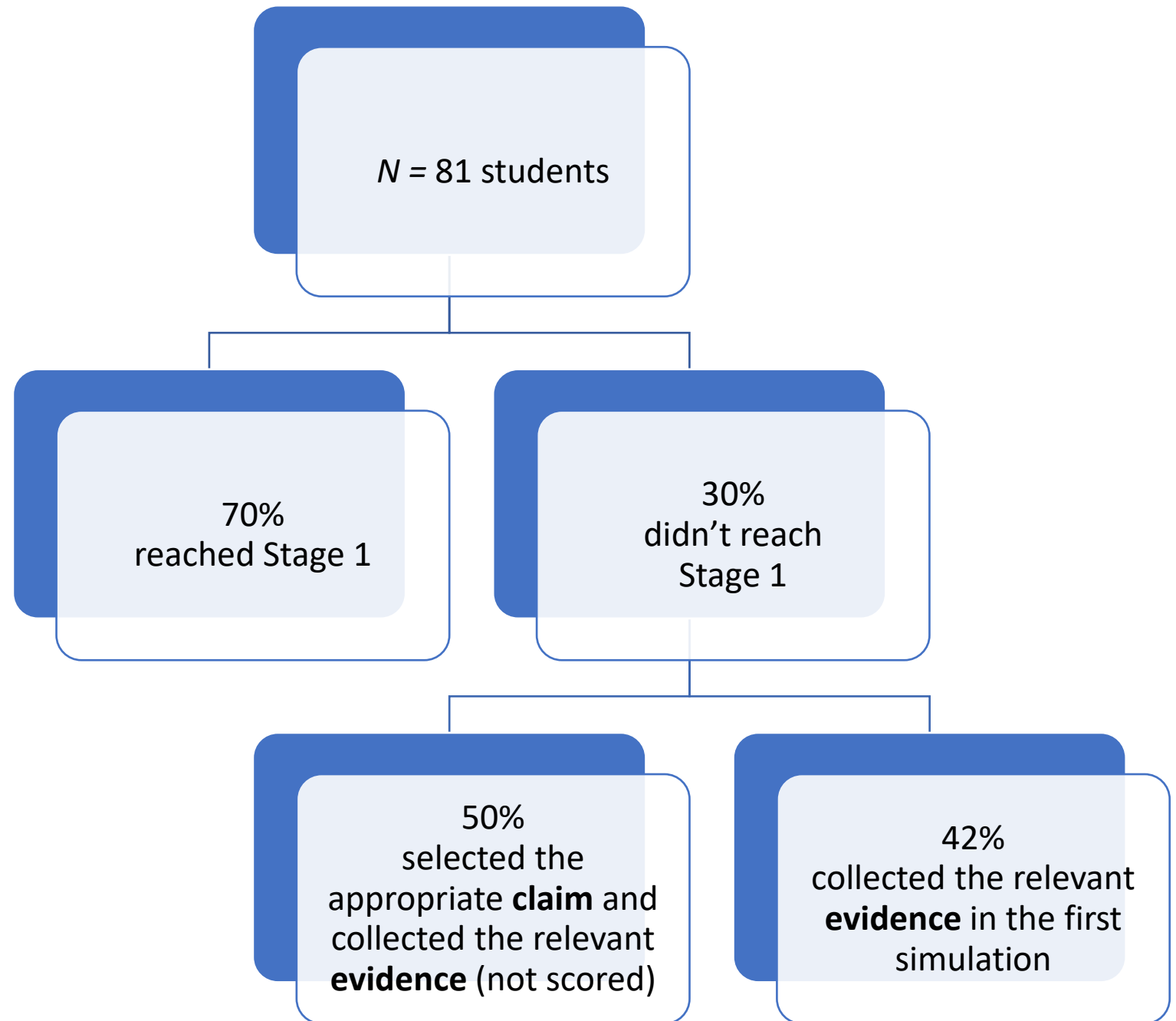
Identify and describe the phenomenon that needs explaining

Evidence (not scored)

- Searching data in a small data set.
- Data set is limited to appropriate data

Reasoning

Making basic logical connection between phenomena and data



Stage 2: Moderate SE

Claim

Identify and describing the phenomenon

Evidence

- Searching data in a small data set.
- Data set is limited to appropriate data

Reasoning

- Using basic scientific reasoning (appropriate isolation and control of variables)
- Developing a causal chain that links phenomenon and data

PISA 2015

Running in Hot Weather

Question 4 / 6

▶ How to Run the Simulation

Run the simulation to collect data based on the information below. Click on a choice, select data in the table, and then type an explanation to answer the question.

Based on the simulation, when the air humidity is 40%, what is the highest air temperature at which a person can run for one hour without getting heat stroke?

20°C
 25°C
 30°C
 35°C
 40°C

★ Select two rows of data in the table to support your answer.

Explain how this data supports your answer.

Air Temperature (°C)	Air Humidity (%)	Drinking Water	Sweat Volume (Litres)	Water Loss (%)	Body Temperature (°C)

The simulation interface includes a runner icon, a red sun, and four gauges: Sweat Volume (Litres) from 0 to 3, Water Loss (%) from 0 to 5 with a 'Dehydration' label at 2, and Body Temperature (°C) from 36 to 42 with a 'Heat Stroke' label at 40. Below the gauges are sliders for Air Temperature (°C) from 20 to 40, Air Humidity (%) from 20 to 60, and a 'Drinking Water' checkbox (Yes/No). A 'Run' button is also present.

Stage 2: Moderate SE

Claim

Identify and describing the phenomenon

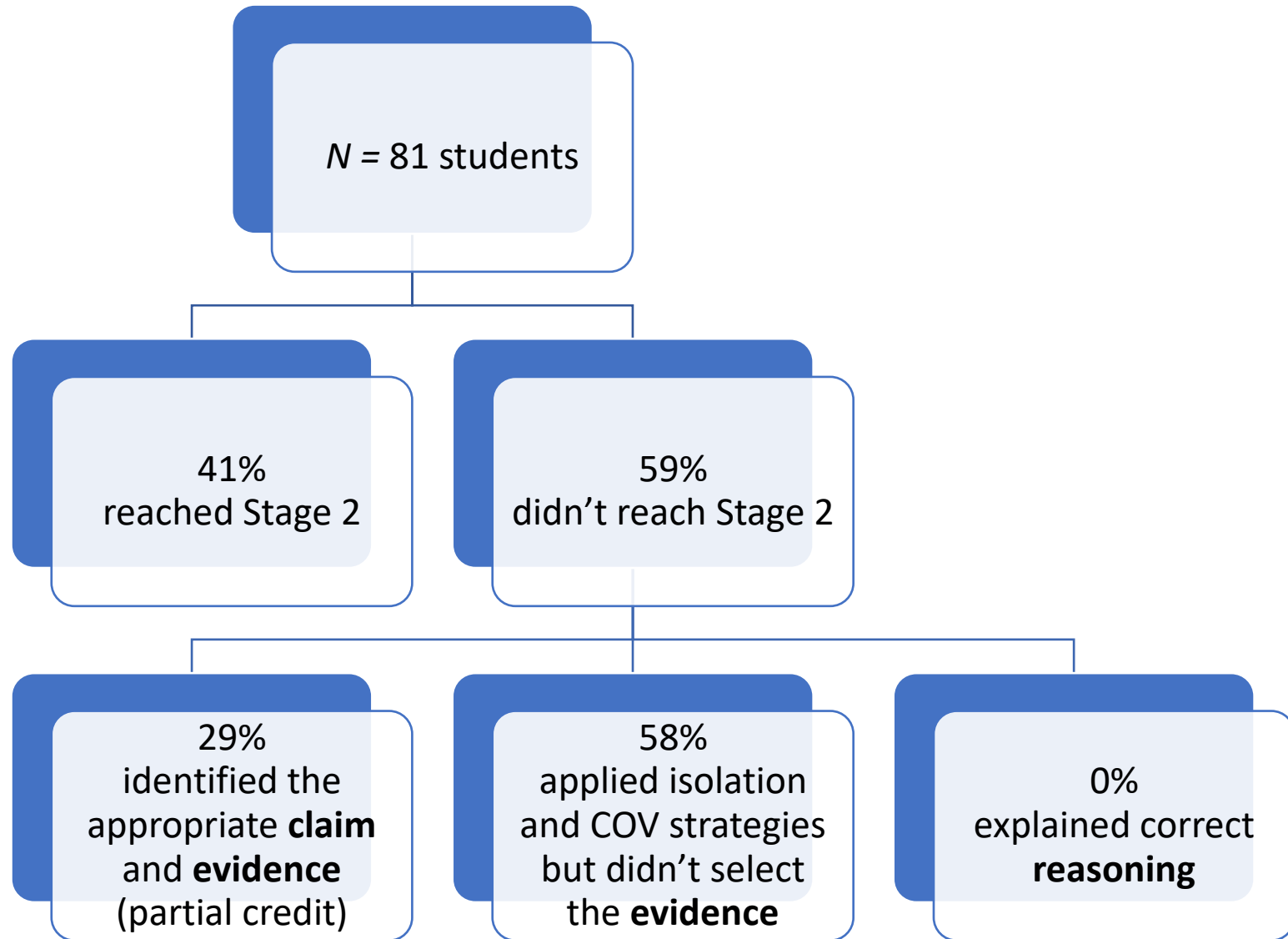
Evidence

- Searching data in a small data set.
- Data set is limited to appropriate data

Reasoning

Applying domain general reasoning (appropriate isolation and control of variables)

Developing a causal chain that links phenomenon and data



Stage 3: Complex SE

Claim

Abstracting and representing the phenomenon.

Evidence

- Searching data in a small data set.
- Data set is limited to appropriate data
- Data set includes both appropriate/inappropriate data/non-related data set

Reasoning

- Using basic scientific reasoning (appropriate isolation and control of variables)
- Developing a causal chain that links phenomenon and data
- Using the key variable as the clue for independently selecting scientific concepts, laws, theories, and principles.

Unit 623 Running in Hot Weather Released Item #3

PISA 2015

Running in Hot Weather
Question 3 / 6

► **How to Run the Simulation**

Run the simulation to collect data based on the information below. Click on a choice, select data in the table, and then type an explanation to answer the question.

When the air humidity is 60%, what is the effect of an increase in air temperature on sweat volume after a one-hour run?

Sweat volume increases
 Sweat volume decreases

★ Select two rows of data in the table to support your answer.

What is the biological reason for this effect?

Air Temperature (°C) 20 25 30 35 40
 Air Humidity (%) 20 40 60
 Drinking Water Yes No

Air Temperature (°C)	Air Humidity (%)	Drinking Water	Sweat Volume (Litres)	Water Loss (%)	Body Temperature (°C)

Run

Stage 3: Complex SE

Claim

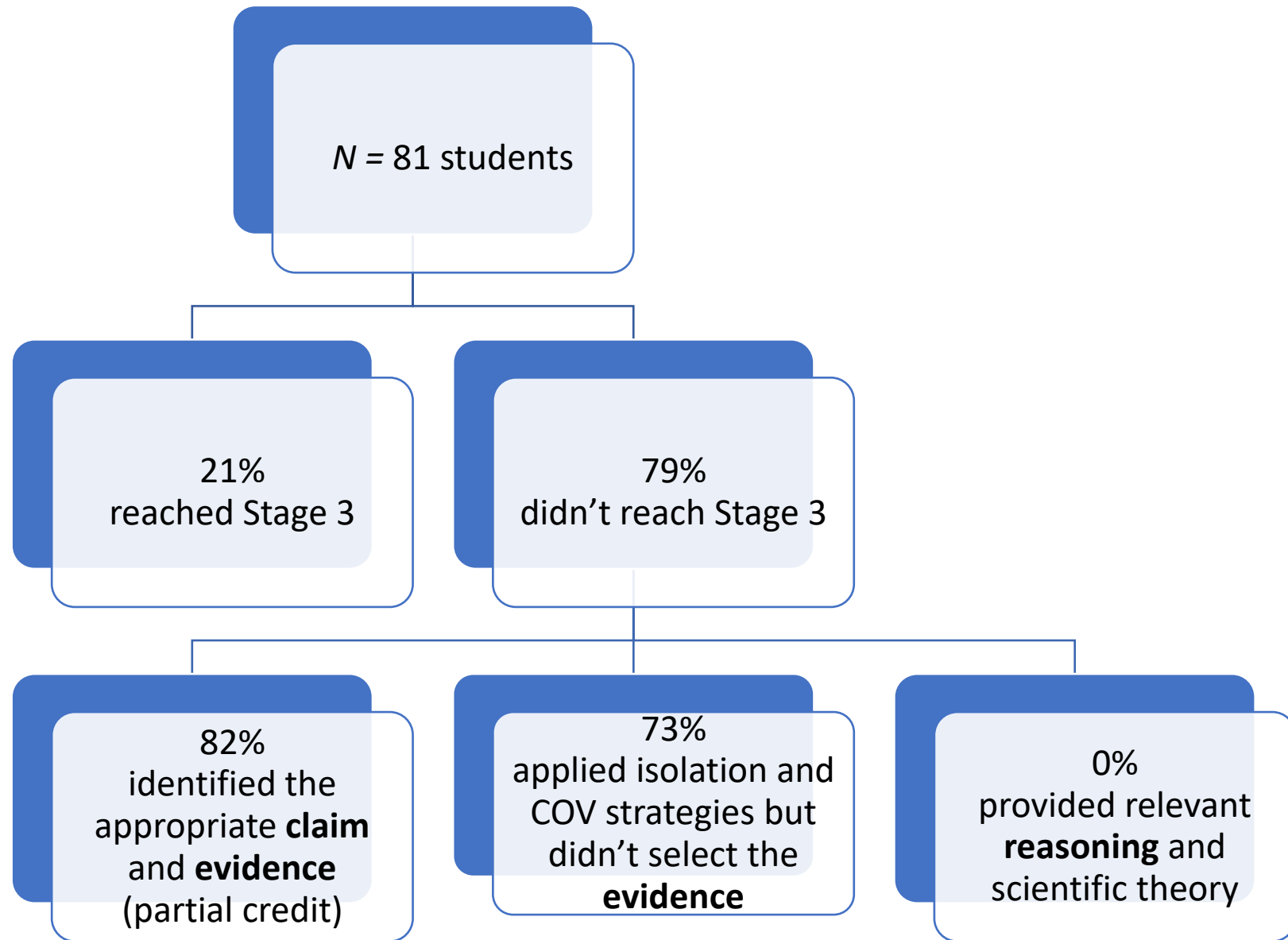
Abstracting and representing the phenomenon.

Evidence

- Searching data in a small data set.
- Data set is limited to appropriate data
- Data set includes both appropriate/inappropriate data/non-related data set

Reasoning

- Using basic scientific reasoning (appropriate isolation and control of variables)
- Developing a causal chain that links phenomenon and data
- Independently selecting the scientific concepts, laws, theories, and principles by systematically analysing the context.



Higher number of trials, time before the first action, and time-on-task

Discussion

- Challenges in constructing scientific explanation:
 - Using appropriate and sufficient evidence
 - Providing reasoning that links the evidence and claim
 - Applying scientific theories, concepts, laws, and principles
- Norwegian students had fewer opportunities to engage in inquiry-based activities compared to other countries (PISA 2015, TIMSS 2019).
- The potential of log file data in examining students' scientific explanation.