# Investigating Cognitive Correlates of Science Achievement

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## Background

**Why Science Achievement?**

- STEM (Science, Technology, Engineering, and Mathematics) is valued as one of the most important and fast-growing areas in education. Thus, educators are obliged to know more about the predictors of science achievement and its learning mechanisms.
- In Hong Kong, such research is still scarce apart from understanding the effect of medium of instruction on secondary school students' achievement (Yip, Tsang, Cheung, 2003).

**Candidate predictors of Science Achievement**

- Epistemic beliefs (Conley et al., 2004)
  - Epistemic cognition is defined as the cognition related to knowledge and knowing.
  - Children's epistemological understanding could be related to their inquiry skills. (Kuhn, 2011; Kuhn, 2001).
  - Children with lower achievement in Science have less sophisticated epistemic beliefs, compared to their higher-achieving counterparts (Conley et al., 2004).
- Relational reasoning (Murphy, Firetto, & Greene, 2016)
  - RR has proposed to be related to acquiring scientific thinking (Dumas, 2017; Gentner et al., 2016) and understanding extreme scales in science (Resnick, Davatzes, Newcombe, Shipley, 2016).

## Research Question

- To what extent do relational reasoning and epistemic beliefs in Science predict science achievement?

## Methods

- **Participants**: One hundred and sixty S.3-4 students (95 male, mean age = 15.39 years old, SD = .67 years old) were recruited from local schools of various bandings.
- **Measures:**
  - *Science Achievement.* Seventeen released items from the Programme for International Student Assessment (PISA) were used as proxy for science achievement. Cronbach's alpha: .50
    - Sample: As a meteoroid approaches Earth and its atmosphere, it speeds up. Why does this happen?
  - *Relational Reasoning.* The test of relational reasoning (Alexander, Dumas, Grossnickle, List, & Firetto, 2016) was used. It consisted the four types of relational reasoning skills (i.e., analogy, anomaly, antinomies, and antitheses). Cronbach's alpha: .75

Sample item: Analogy
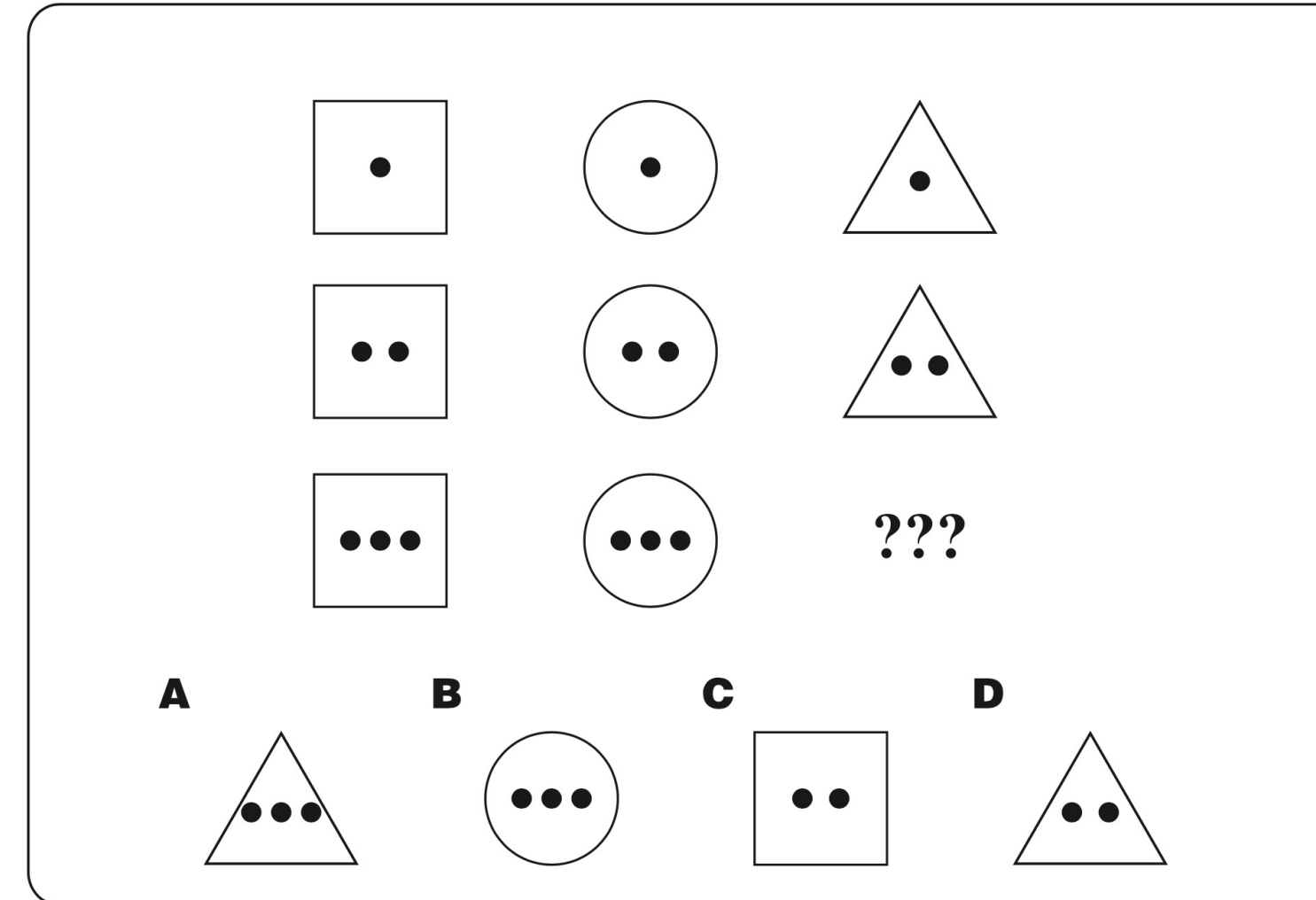


  - *Epistemic Beliefs.* EBSQ (Conley et al., 2004) was used. There were 26 items in 5-point Likert scale, measuring four dimensions of epistemic beliefs: Source, Certainty, Development, and Justification of knowledge in Science. Cronbach's alpha: .84
    - Sample (source): Only scientists know for sure what is true in science.
  - *Verbal Working Memory.* Backward Syllable Recall task was used to assess verbal working memory. The test stopped when error was made on both trials of the same level. Cronbach's alpha: .78
  - *Non-verbal Intelligence.* The abbreviated form of the Raven's standard progressive matrices (Bilker et al., 2012) was used to measure participants' nonverbal intelligence. Cronbach's alpha: .63
- **Procedure:**
  - Participants were invited to complete a series of tasks related to science and cognitive skills online via Zoom or MS Teams. The testing session lasted about 2 hours 30 minutes.
  - Data were collected from July to October, 2020.

## Results

### 1. Using Relational Reasoning to predict Science Achievement

| | Block 1 / Step 1 | | | | | Block 2 / Step 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | B | SE | β | t | p | B | SE | β | t | p |
| (Intercept) | 10.39 | 3.74 | | 2.78 | .01 | 8.86 | 3.75 | | 2.37 | .02 |
| Age | -.31 | .24 | -.10 | -1.32 | .19 | -.26 | .24 | -.08 | -1.09 | .28 |
| NVIQ | .27 | .07 | .32 | 4.14 | <.001 | .19 | .07 | .23 | 2.71 | .01 |
| Verbal WM | .07 | .06 | .10 | 1.23 | .22 | .08 | .06 | .11 | 1.40 | .17 |
| Relational Reasoning | | | | | | .07 | .03 | .20 | 2.34 | **.02** |
| $R^2$ | .14 | | | | | .17 | | | | |
| $\Delta R^2$ | .14 | | | | | .03 | | | | |

- Relational reasoning (RR) significantly predicted science achievement, after controlling for age, NVIQ, and verbal working memory.
- RR explained 3% unique variance in science achievement.

### 2. Using Epistemic beliefs to predict Science Achievement

| | Block 1 / Step 1 | | | | | Block 2 / Step 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | B | SE | β | t | p | B | SE | β | t | p |
| (Intercept) | 10.39 | 3.74 | | 2.78 | .01 | 4.49 | 3.84 | | 1.17 | .24 |
| Age | -.31 | .24 | -.10 | -1.32 | .19 | -.22 | .22 | -.07 | -.98 | .33 |
| NVIQ | .27 | .07 | .32 | 4.14 | <.001 | .20 | .06 | .24 | 3.19 | <.001 |
| Verbal WM | .07 | .06 | .10 | 1.23 | .22 | .05 | .05 | .07 | 1.00 | .32 |
| EBSQ (Source) | | | | | | .68 | .22 | .26 | 3.04 | **<.001** |
| EBSQ (Certainty) | | | | | | -.50 | .31 | -.14 | -1.64 | .10 |
| EBSQ (Development) | | | | | | .26 | .36 | .08 | .71 | .48 |
| EBSQ (Justification) | | | | | | .88 | .38 | .24 | 2.31 | **.02** |
| $R^2$ | .14 | | | | | .26 | | | | |
| $\Delta R^2$ | .14 | | | | | .13 | | | | |

- Among the four dimensions of epistemic beliefs, only source and justification of knowledge significantly predicted science achievement, after controlling for age, NVIQ, and verbal working memory.
- Together they explained 13% unique variance in science achievement.

## Discussion

- Our results found that relational reasoning and epistemic beliefs significantly predicted science achievement.
- One limitation of the study is the reliability of the science achievement measure as only released items of PISA were used.
- Further studies should use a more reliable science achievement measure (E.g., TIMSS 2019) and explore how the two dimensions of epistemic beliefs in Science correlated with learning behaviours.