EXPLORING JUNIOR SECONDARY STUDENTS' KNOWLEDGE-BASED REASONING IN THE CONTEXT OF ENGINEERING DESIGN

Chee-Siang Tan, Yu-An Chen, Su-Chi Fang[a]

Contact Author: Su-Chi Fang (fangsuchi33@ntnu.edu.tw)

[a]Graduate Institute of Science Education, National Taiwan Normal University, Taipei, Taiwan

THEME:

Engaging students in STEM education

BACKGROUND AND AIMS

STEM education has garnered extensive attention worldwide in the past decades. Engineering design is promoted as one dominant approach for STEM education because it can serve as a catalyst bringing all the four disciplines on a shared learning platform and create rich opportunities to apply disciplinary knowledge and inquiry.

Previous research has shown that during engineering activities, students are inclined to focus on the making aspects, instead of drawing on relevant disciplinary knowledge to make design decisions (Vattam & Kolodner, 2008). Various innovative instructional designs were developed to facilitate teaching and learning, but only a few dug into how and to what extent students apply disciplinary knowledge to make design decisions. This study explores the nature of students' knowledge-based reasoning in the context of an engineering design.

METHODOLOGY OR PROCESS(ES) UNDERTAKEN

The research team developed an engineering design-based paper-and pencil assessment on the topic of mini-wire-controlled cars, including eight test items. 285 seventh-graders participated in this study. The scoring rubrics were developed based on the students' responses and in reference to Zeineddin & Abd-El-Khalick (2010).

RESULTS AND CONCLUSIONS

Our preliminary findings indicate that only a few students were able to perform high-quality knowledge-based reasoning. Students' restricted reasoning might be due to their poor communication skills, limited scientific knowledge, and limited reasoning about data analysis. For instance, students might misunderstand/misuse scientific terms or use informal scientific terms, like "electric power". Instead of using fundamental statistical concepts such as mean and outliers, students created their own criteria to select the fastest car from given data. Moreover, researchers encountered challenges in examining students' reasoning. Often, students' responses were incomplete sentences or composed of everyday language. It is difficult for researchers, who share no common language with them, to verify their thinking and meaning. However, students' naïve responses prompted researchers' reflections on a better design of engineering-based assessment.

REFERENCES

Vattam, S. S., & Kolodner, J. L. (2008). On foundations of technological support for addressing challenges facing design-based science learning. *Pragmatics and Cognition*, *16*(2), 406-437.

2022. J. Bobis & C. Preston (Eds.), Proceedings of the 7th International STEM in Education Conference (STEM 2022), University of Sydney, Sydney, Australia, November 23-26. University of Sydney.

Zeineddin, A., & Abd-El-Khalick, F. (2010). Scientific reasoning and epistemological commitments: Coordination of theory and evidence among college science students. *Journal of Research in Science Teaching*, *47*(9), 1064-1093.

Exploring Junior Secondary Students' Knowledge-based Reasoning In The Context Of Engineering Design

Chee-Siang Tan, Yu-An Chen, Su-Chi Fang

Graduate Institute of Science Education, National Taiwan Normal University, Taiwan.

STEM 2022

7th International STEM in Education Conference

Introduction

STEM education has garnered extensive attention worldwide in the past decades. Engineering design (ED) is promoted as one dominant approach for STEM education. Previous research has shown that during ED activities, students are inclined to focus on the making aspects, instead of drawing on relevant disciplinary knowledge to make design decisions (Vattam & Kolodner, 2008). Various instructional designs were developed to facilitate teaching and learning, but only a few dug into how and to what extent students apply disciplinary knowledge to make design decisions.

This study developed an ED-based assessment to examine students' knowledge-based reasoning before and after an ED course: mini-wire-controlled cars. While examining students' performance, the research team also explored the characteristics of students' knowledge-based reasoning in the ED context and discussed the challenges to develop ED-based assessments.

Research Questions

1. How do students perform knowledge-based reasoning before and after an ED course?
2. What are the characteristics shown in students' knowledge-based reasoning regarding each dimension of engineering design?
3. What challenges do researchers encounter when developing ED-based assessments?

Methods

Participants

285 seventh graders taught by the same technology teacher in one public junior high school were recruited in the study. The school is located in Northern Taiwan. The technology teacher has two-year teaching experience, and he taught the ED course: mini-wire-controlled cars for the first time.

The ED course: mini-wire-controlled cars

This course required students to design and make a mini-wire-controlled car (Fig.1) in groups and complete a challenge: a tortuous and narrow car route, see Fig. 2, where the car was required to pass the route as fast as possible. Two motors, wires, a thin plank, and copper nails were given, and students could select appropriate wheels for their cars.

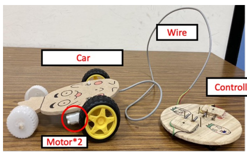

Figure1: mini-wire-controlled cars

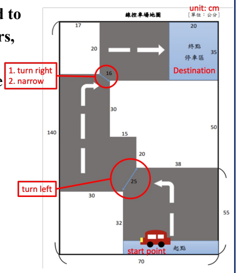

Fig2. The map of the car and obstacles in

The ED-based assessment

The research team developed an ED-based assessment on the topic of mini-wire-controlled cars based on the four phases involved in ED, see Table 1.

Table 1. ED phases and subdimensions

ED phases	Sub-dimensions	ED phases	Sub-dimensions
Identify the problems	Identify the problems	Implement plans, models, and prototypes	Solve technical problems
	Set goals		Troubleshoot
Develop plans	Weight the pros and cons of the plan	Evaluate and Test	Analyze data
	Identify the best solution		Test results

Eight items, corresponding to each sub-dimension, were developed in the assessment. Students spent 40 minutes to complete the assessment before and after the ED course. Taking "weight the pros and cons of the plan" as an example, students were required to explain the pros and cons of a four-motor-driven car compared to a two-motor-driven car.

Data analysis

An preliminary scoring rubrics was developed. Two raters scored one-third of the pre-test independently. The discrepancies were discussed and rubrics were modified accordingly. The same raters scored another one-third of the pre-test, and the inter-rater reliability reached 95%. The two raters then scored the rest of the pre- and post-tests.

Results and Discussion

Students' performance before and after ED course

A paired-sample t-test was conducted to examine students' scientific reasoning before and after ED course. The results show that the post-test total score ($M=5.90$, $SD=2.96$) is significantly higher than the pre-test score ($M=5.29$, $SD=2.80$); $t=-3.78$, $p<0.001$.

Each dimension of ED phases was also examined. The analysis showed that students performed significantly better on "test result" and "solve technical problems" and "troubleshoot".

According to classroom observation, the teacher focused his teaching on the completion of the car. Only certain dimensions of ED phase were emphasized. Thus, students were not given enough time to discuss and think their making processes throughout the whole ED course.

Characteristics of students' responses in the engineering-design-based assessment

Our findings indicate that high-quality knowledge-based reasoning was hardly seen in the students' responses. The analysis of students' responses suggests that students' restricted reasoning might be due to their poor communication skills, limited scientific knowledge, and limited reasoning about data analysis.

- Responses are often oversimplified.
  For example, when students were asked to identify the problems they may encounter on a given car racing track, many used short terms, such as "stuck", or "hit an obstacle" instead of complete sentences. Also, they did not provide reasons to explain "why and how".
- The use of informal scientific terms.
  Some students used informal terms such as "electric power" in their responses. This might be due to that the 7th-graders have not learned the topic Electricity formally in science.
- Students' responses were based on their own experiences.
  For example, item 1-2 requires students to list and explain the essential functions for a car to win the race. Students used some technical terms in the racing realm such as drifting, horsepower, and suspension, or in the toy realm such as mini 4WD.

Challenges to design context-based STEM assessment

- The wording of the test item needs to be precise and straightforward.
  Several alternative interpretations were made by students as they responded to some items. For example, we asked students to design an experiment to test cars, and select on that can run the fastest and at a steady speed. Several students took the word "steady" as the car needs to run straight, not deviate from a straight line.
- The selection of the topic for ED-based assessments should not be too complex.
  Students learn science knowledge from textbooks, and most of which were written in an ideal and simplified context. STEM deals with real-world, complex problems, for example, friction in real-work works in a more complex way than that in the textbooks. Thus, how to select a topic for ED-based assessments needs careful consideration.