High School Students' Understanding of the Scientific Method

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Literature

- The development of a strong understanding of the nature of science is a common goal among countries.[1]

- Raising science literate students has become more important and priority than ever for countries.[2]

- AAAS[3] and NRC[3] have stressed the importance of precollege students' development of understandings of the nature of science and scientific inquiry for years.

- However, research says that school science does not help much to students to develop their scientific literacy.[4]

Alternative Ways!

- In-class science projects or out of classroom work with scientists.[5]

- "working on authentic science research projects facilitates the development of scientific literacy by enhancing students' understandings of science content, the processes and logic of scientific inquiry, and the nature of science"[6]

- Then, it was expected that students who experience the messiness of doing science and seeing its real life connections develop better understandings of the nature of science.

There might be a problem!

- Until recently, researchers and educators assumed use of scientific method as a proper way to involve students in a scientific phenomenon[7]

- However, researchers has started criticizing the teaching of scientific method because they suggested it does not reflect how real science is accomplished[8]
  - It is a linear checklist therefore superficial
  - It is like a verification but science is a creative process

- Overall, the scientific method provides a static set of steps that are more procedural and unable to catch the important parts of the inquiry process of the nature of science including reflection.

However;

- Another group of researchers suggested that the importance of teaching the scientific method cannot be underestimated; especially for younger students.

- It has been placed as a critical component of scientific literacy[10]

- The scientific method is still given as an integral part of myriad science textbooks[11]

- It has been required to be structural frame of "*most science fair projects, as a component of student lab reports, and as the basic structure of research reports, theses, and dissertations*"[12]

Word Association Test (WAT)

- WAT can be used to measure the participant's mental model, verbal memories, thought processes, emotional states and personality[13]

- The basic premise of the word association test is:

- *Stimulus words are presented to the subject (either verbally or in written form) who is asked to respond with the first word or words that come to mind. The resulting word association is thought to mirror the way the words are stored and linked in the mental lexicon[14]*

The Purpose and Research Questions

- *We utilized word association test to map the cognitive structure of scientific methods in both student groups to see if there is any difference that might stem from their I-SWEEEP participation, gender, and geographic area.*

1. To what extent do I-SWEEEP participants' conceptions of scientific methods differ from those who did not participate in I-SWEEEP?

2. To what extent do I-SWEEEP students' conceptions of scientific methods change by their gender?

3. To what extent do I-SWEEEP students' conceptions of scientific methods change by their geographic region?

Method
I-SWEEEP

- I-SWEEEP is an international Science Olympiad with the mission "to spark interest and awareness in our planet's sustainability challenges, help young people grasp the extent of these issues, find workable solutions to these challenges, and accelerate the progress toward a sustainable world by engaging the youth at an early age"

- (1) Energy, (2) Engineering, (3) Environment (Health and Disease Prevention), and (4) Environment (Pollution & Management).

- Winners of the grand award, gold, silver, and bronze medals receive money awards of $1,500, $600, $300, and $150 respectively.

Participants

- The total number of participants in the study was 363 (164 I-SWEEEP participants and 199 control group students.

- Control group students comprised of students from same schools as I-SWEEEP participants come from but they did not participate in I-SWEEEP.

- More than half of the participants (246) were from the United States.
  - Rest: Canada, Germany, Turkey, China and 31 more other countries.

Instruments

- Ten words or phrases were selected as stimulus words to construct the online Word Association Test (WAT).

- The stimulus words were presented in the following order: inquiry, data collection, science fair, writing reports, experiment, project, variable, research, observation, and hypothesis.

- For every word listed on separate pages, students were asked to enter five response words in to the already created five boxes in no more than 2 minutes and move on to the next stimulus word.

Analysis

- First, all the students' responses were coded and grouped.
- To ease the grouping of hundreds of hundreds of categories and speed the calculations and ranking, one of the authors wrote a coding in excel.
- Resulting groups were ranked and numbered and made ready for RC calculation method suggested by Garskof and Houston (1963).
- Later, RC values for both experimental group and control group students' were ranked and used in constructing semantic networks (i.e., knowledge structures) with a cut-off point of 0.50.
- When checking the structures, it should be noted that they are partial semantic networks accounting for the ones greater than 0.50 among 45 RC values.
- Weaker connections among the stimulus words were ignored. For research questions 2 and 3, only I-SWEEEP students were taken as the sample for analysis.

Results
The Effects of Participation in I-SWEEEP Olympiad Competition
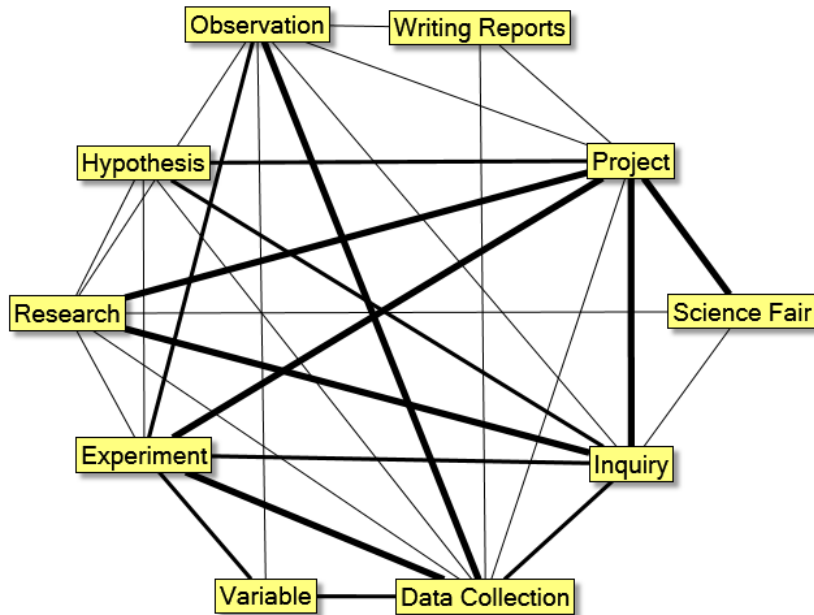

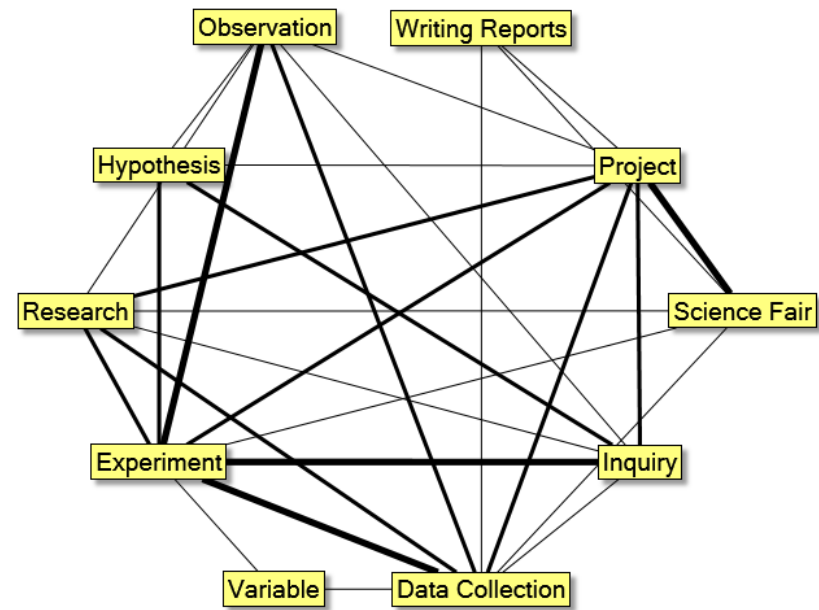*Figure 1*. Semantic network for the I-SWEEEP participants with a 0.50 cut-off point.

Figure 2. Semantic network for the control group students with a 0.50 cut-off point.
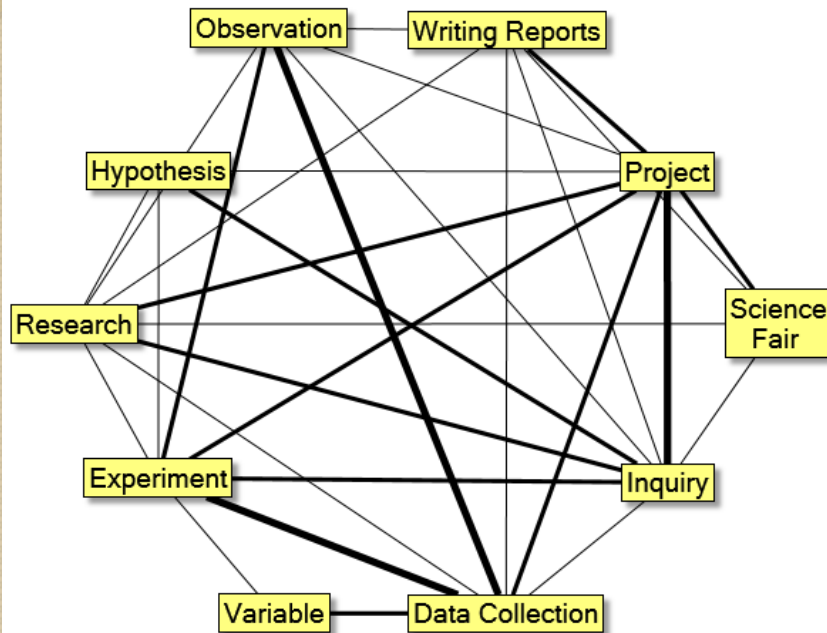
Results
Gender Factor

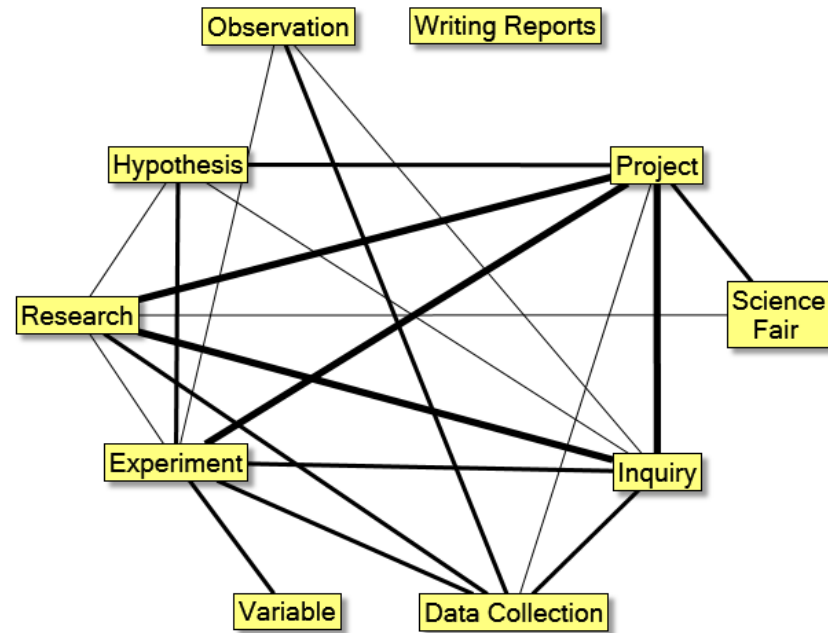*Figure 3.* Semantic network for the "male" I-SWEEEP participants with a 0.50 cut-off point.

Figure 4. Semantic network for the "female" I-SWEEEP participants with a 0.50 cut-off point.
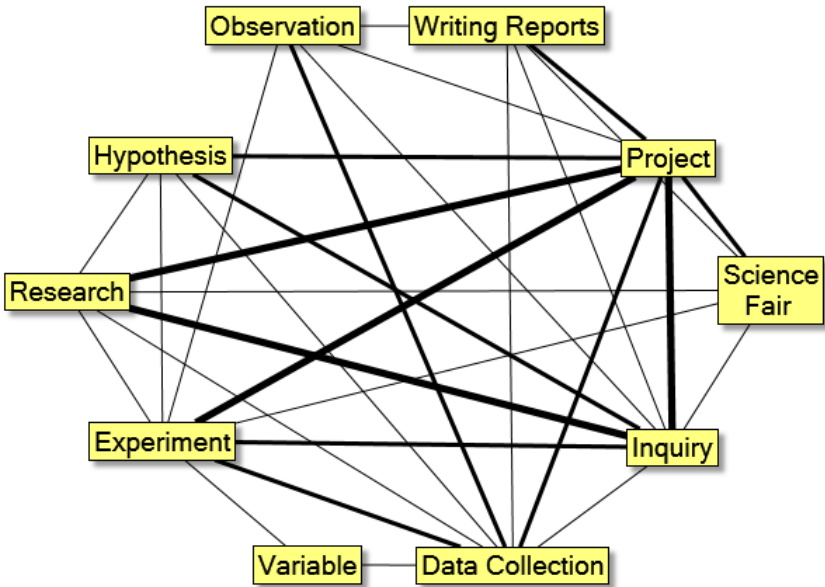
Geographic Region

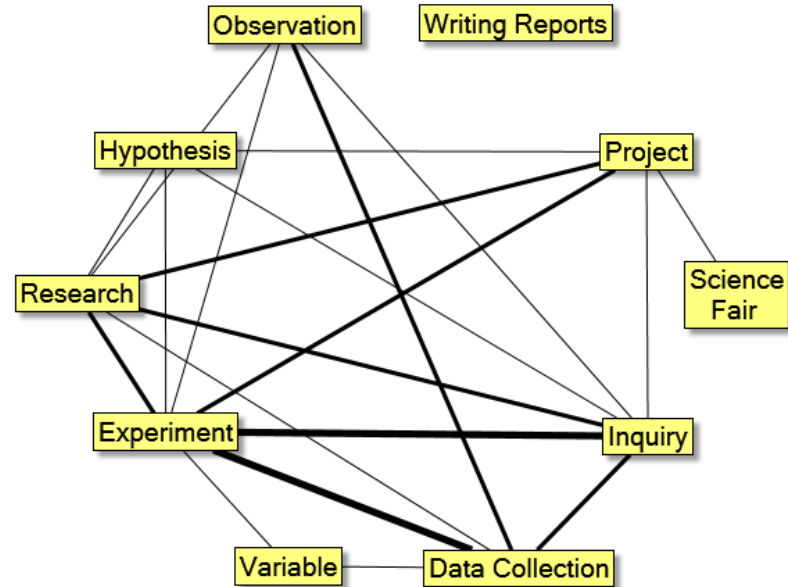*Figure 5.* I-SWEEEP participants from Americas.

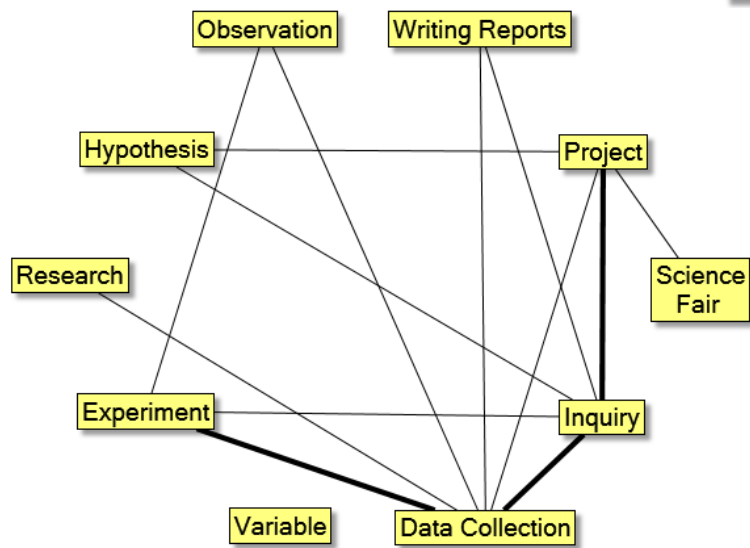*Figure 6.* I-SWEEEP participants from Asia.

Figure 7. I-SWEEEP participants from Eastern Europe.

Discussion

- The I-SWEEEP participants had more sophisticated understanding of scientific method.

- Male I-SWEEEP participants had a much more sophisticated understanding of scientific method with a lot more interconnectedness with other scientific method terms.

- Participants from America—mostly from the United States—had the most sophisticated conception of scientific method with lot of stronger connections among stimulus words.

References

[1]AAAS, 1989; Rutherfor & Ahlgren, 1990

[2]Robeck, 2014; Toulmin & Groome, 2007

[3]AAAS,1989 and National Research Council,1996

[4]Lederman & O'Malley, 1990; Matthews, 1994; Meichtry, 1992

[5]NRC, 1996; Rock &Lauten, 1996, Solomon, 1991

[6] Bell et al., 2002, p. 488

[7]Reiff, Harwood, & Phillipson, 2002

[8]McComas, 1996; Lederman, 1998

[9]Watson & James, 2004

[10]AAAS, 1989; National Science Teachers Association, 1982;   Rutherford & Ahlgren, 1990

[11]Watson, 2004

[12]Watson, 2004, p. 37

[13]Sinopalnikova and Smrz, 2004

14Peppard, 2007, p. 4