A qualitative analysis of Concept Maps through the Research Experiences for Undergraduates (REU) programs

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Motivation

The primary goal of existing assessments of undergraduate research experiences (e.g., SURE and URSSA) is to measure students' broad learning progress and assess outcomes of research experiences prioritized by funding agencies. However, to measure more detailed outcomes of the undergraduate research programs, especially related to conceptual understanding and structure of scientific knowledge, these self-assessment tools may be insufficient. We use concept maps, a knowledge elicitation method, for assessing mentees' and mentors' knowledge structures during Research Experience for Undergraduates (REU) programs. Concept maps reflect and assess students' learning and understanding, while also encouraging them to use meaningful knowledge and develop relationships between the concepts.

Research Questions

RQ1: What **types of knowledge** are represented in mentees' research project concept maps?
RQ2: How did mentees and their mentors **organize their knowledge** around their research projects?
RQ3: What **differences** exist between mentors' and mentees' concept maps?

Methods

Population

Reached out to 64 physics REU programs

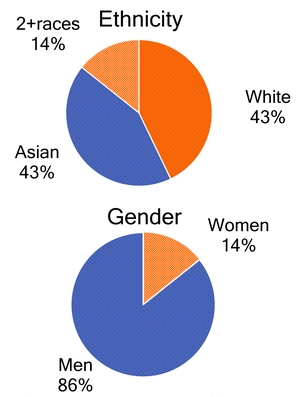
- Hosted remote REU program, N=8
- Canceled, N=18
- No response, N=38

7 paired mentor-mentees from six REU programs

Concept maps

- Methods to elicit mentors' and mentees' knowledge of their REU project
- Data was gathered through semi-structured interviews with mentees and paired mentors
- Concept maps were created in a Google Slides presentation

Mentee's characteristics (N=7)



The sample of mentors was all men.

RQ 1: Categorizing knowledge types

Learning physics and thinking like a physicist requires learning its concepts, terms, and the relational structure between these pieces of knowledge. In order to move forward on the path from novice to expert, undergraduate students are required to develop their understanding and knowledge to achieve an accurate scientific mental model. The participants' maps illustrated the various ideas in their research projects, which divided into two types of knowledge: Conceptual and Procedural.

Conceptual knowledge (CK)

- **Fields**: Large areas of science such as "Optics" and "Cosmology"
- **Topics**: Knowledge about specific concepts in their project
- **Quantities**: Measurable physical property such as "Entropy"

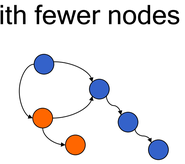
Procedural knowledge (PK)

- **Explicit**: Procedural actions were involved in observation, calculation, and simulation
- **Implicit**: Imply particular actions as part of a outcome procedure

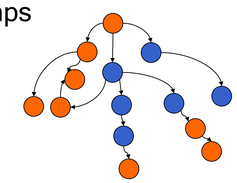
Comparisons between mentors' and mentees' maps

- **Mentees used more procedural knowledge** than conceptual knowledge (PK=64% and CK=32%).
- **Mentors used more conceptual knowledge** with fewer nodes in their maps (PK= 40% and CK=57%).

● Conceptual knowledge
● Procedural knowledge



A sample of a mentor's map

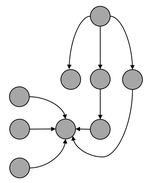


A sample of a mentee's map

RQ 2 and 3: Structural analysis of the maps

Concept maps are represented by meaningful relationships between elements of knowledge (circles) in the form of propositions that are linked with directional arrows.

- Mostly participants used a **hierarchical format, structured as a combination of a set of knowledge.** Some participants **combined the hierarchical form with a network of knowledge**.



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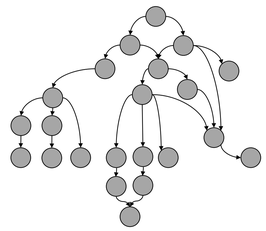
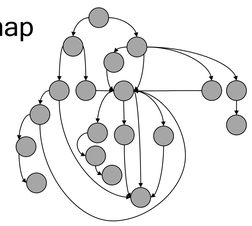


A sample of a mentee's map

Connectivity or Scale

- **Mentees' maps had high connectivity** expressed by a more significant number of links and nodes.



A sample of a mentee's map

- **Maps from mentors and mentees differ in terms of scale, language**, and how these affect the types of explanations provided by them. (e.g. mentors were focused on how their projects fit within a larger scientific endeavor, while the mentees saw their projects from the vantage point of a person carrying out the detailed steps in a project.)

- **Mentees used more time to develop their maps** compared to mentors.

Implications

- **Mentors' maps were smaller but more significant** in using more comprehensive conceptual knowledge and connecting their maps to the broader scientific context
- **Mentors and mentees differed in their ways of organizing and displaying their knowledge**.
- As an assessment tool, concept maps allow us to document mentors' and mentees' knowledge representation, including conceptual and procedural ways they were thinking and talking about their project.