Special Session - Cognitive Legos: Helping Your Students Construct Scientifically Accurate Mental Models

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Abstract - **This Interactive Session will provide an active learning environment where participants will:**

- **Discuss mental models and how they can be used to help shape appropriate pedagogy,**
- **Engage in discipline-based discussions about the mental models engineering students use to explain certain scientific concepts, and**
- **Brainstorm ideas about instruction that helps students construct scientifically accurate mental models of the concepts we discuss in the session.**

The session will expand upon the successful Interactive Sessions at Frontiers in Education 2003 ("Why are Some Science and Engineering Concepts So Difficult to Learn? Identifying, Assessing, and 'Repairing' Student Misunderstanding of Important Concepts") and 2004 ("Concept-based Engineering Education: Designing Instruction to Facilitate Student Understanding of Difficult Concepts in Science and Engineering"). However, participants do not need to have attended those sessions to benefit from this one.

Index terms – Constructivism, difficult concepts, interactive session, mental models, misconceptions

INTRODUCTION

This session follows the successful Interactive Sessions at FIE 03 ("Why are Some Science and Engineering Concepts So Difficult to Learn? Identifying, Assessing, and 'Repairing' Student Misunderstanding of Important Concepts"") and FIE 04 ("Concept-based Engineering Education: Designing Instruction to Facilitate Student Understanding of Difficult Concepts in Science and Engineering").

The proposed session takes the logical next step, and discusses the mental models students create to explain scientific concepts, and where those models can break down. As we did in our FIE 04 session, workshop participants will engage in collaborative analysis of research results – this time looking at transcripts of student explanations of scientific concepts.

This session will provide a collaborative learning environment where participants will:

- Discuss mental models and how they can be used to help shape appropriate pedagogy,
- Engage in discipline-based discussions about the mental models engineering students use to explain certain scientific concepts, and
- Brainstorm ideas about instruction that helps students construct scientifically accurate mental models of the concepts we discuss in the session.

SESSION TOPICS AND TIMELINE

Participants will be assigned to teams based on their discipline (e.g. mechanical engineering, chemical engineering, electrical engineering) and will work in these teams throughout the workshop. We have used this format in prior interactive sessions and found that it provides the opportunity for participants to hold rich and fruitful discipline-based discussions with colleagues at other institutions.

The session will address three questions:

(1) What is a mental model? (30 minutes)
The cognitive psychology literature will be used to define the term "mental model."
We will explore reasons why it is useful for instructors to know what mental models their students hold.

(2) What mental models do students construct to explain certain difficult scientific concepts? (60 minutes)
Here we will use our own research data to provide examples of mental models. Participants will be given excerpts from transcripts* of interviews where engineering students answer questions about certain scientific concepts. From these transcripts, participants will speculate about the mental model that underlies these explanations. [*In order to protect confidentiality, students' names and other identifiers will be removed from the transcripts.

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Transcripts will be collected at the end of the session and destroyed.]

(3) How can we design instructional environments to help students construct accurate models of these scientific concepts? (30 minutes)

Participants will take what they have learned from the previous exercise (analysis of transcripts) and discuss the types of activities and approaches they can use to help students construct scientifically accurate mental models.)

EXPECTED OUTCOMES (LEARNING OBJECTIVES)

- Participants will be able to describe a mental model and explain why it is useful for instructors to know about their students' mental models.
- Participants will practice analysis of student transcripts.
- Participants will develop ideas about how to design instruction that helps students construct mental models of scientific concepts that are scientifically accurate.

RELATED PEER-REVIEWED PAPERS BY SESSION PRESENTERS

Precursors to this work have been presented by the authors at FIE 2002 [1] 2003 [2, 3], and 2004 [4] and at ASEE 2003 [5] , 2004 [6], and 2005 [7]. The references for these works are listed below.

[1] Evans, D.L., Midkiff, C., Miller, R., Morgan, J., Krause, S., Martin, J., Notarus, M., Rancour, D., & Wage, K. (November, 2002). Tools for assessing conceptual understanding in the engineering sciences. *Proceedings of the Frontiers in Education conference, Boston, MA.*

[2] Evans, D.L., Gray, G.L., Krause, S., Martin, J., Midkiff, C., Notaros, B.M., Pavelich, M., Rancour, D., Reed-Rhoads, T., Steif, P., Streveler, R., Wage, K., (November, 2003). *Progress on concept inventory assessment tools.* Proceedings of the Frontiers in Education conference, Boulder, CO.

[3] Streveler, R. A., Nelson, M.A., Olds, B.M., & Miller, R.L. (November, 2003). *Why are some science and engineering concepts so difficult to learn? Identifying, assessing, and "repairing" student misunderstanding of important concepts.* Special Session at the Frontiers in Education conference, Boulder, CO.

[4] Miller, R.L., Streveler, R.A., Olds, B. M., & Nelson, M. A. (2004, October). *Concept-based engineering education: Designing instruction to facilitate student understanding of difficult concepts in science and engineering*. Interactive session at the Frontiers in Education Conference, Savannah, GA.

[5] Streveler, R.A., Olds, B.M., Miller, R. L. & Nelson, M.A. (June, 2003). Using a Delphi Study to identify the most difficult concepts for students to master in thermal and transport science. *Proceedings of the Annual Conference of the American Society for Engineering Education, Nashville, TN.*

[6] Olds, B.M., Streveler, R.A., Miller, R.L., & Nelson, M.A. (June, 2004). Preliminary results from the development of a concept inventory in thermal and transport science. *Annual Conference of the American Society for Engineering Education, Salt Lake City, UT.*

[7] Miller, R.L., Streveler, R.A., Olds, B.M., Nelson, M.A., & Giest, M. R. (June, 2005). Concept Inventories Meet Cognitive Psychology: Using Beta Testing as a Mechanism for Identifying Engineering Student Misconceptions *Proceedings of the Annual Conference of the American Society for Engineering Education, Portland,OR.*.

ACKNOWLEDGMENT

We wish to thank the National Science Foundation for funding *Developing an Outcomes Assessment Instrument for Identifying Engineering Student Misconceptions in Thermal and Transport Sciences* (DUE - 0127806) and *Center for the Advancement of Engineering Education* (ESI-0227558).

Thanks also to our extended research team, most notably Mary A. Nelson, Monica R. Geist, Candace Ammerman, and Ravel Ammerman, as well as to all our research partners in the Center for the Advancement of Engineering Education team.