Employing Model-Based Reasoning in Socio-Environmental Synthesis

How to Use the EMBeRS Method

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August 7, 2018

INTRODUCTION

The EMBeRS method draws on learning, cognition, organizational and social theories to develop team-based activities designed to facilitate interdisciplinary research and education (Pennington, 2016; Pennington et al., 2016, 2018). EMBeRS activities have been used in research team meetings, graduate training workshops, and formal classes. They are "recipes" that can be modified as desired for a range of contexts. All EMBeRS activities focus on the challenge of integrating deep knowledge across disciplines while also building basic teamwork skills and competencies. Deep knowledge integration has been identified as a key challenge confronted by cross-disciplinary research teams(National Research Council, 2015).

The EMBeRS method aims to invoke co-creative, model-based reasoning between team members. Model-based reasoning theory posits that human's reason by constructing an internal mental model of the situations, events, and processes that they encounter, and that external representations can be used to facilitate construction of these mental models. External representations include the use of analogies, metaphor, visual models, diagrams and/or other representations for abstraction and communication of complex concepts. Such external representations have been studied in a wide variety of disciplines, and have been called boundary objects, material artifacts, and epistemic objects, among other terms. In this document and our activities we refer to these as boundary objects, since that terminology is in widespread usage. Hence, the EMBeRS method is to provide a structured process that facilitates reasoning across perspectives using co-creation of boundary objects.

In addition to model-based reasoning, we draw on a number of other theories from a variety of disciplinary perspectives in the design of EMBeRS activities (Pennington et al., 2018). Specifically, the EMBeRS method includes the following elements:

ATTENTION TO PROCESS

- Problem-based – work on real problems
- Semi-structured, experiential activities
- Participatory – everyone has a turn
- Co-creative – everyone is expected to put forth new ideas
- Cycle individual reflection with group interaction
- Cycle divergent (exploratory) and convergent (synthesis) thinking
- Iteration
- Purposeful reflection on the process

INCORPORATION OF BOUNDARY OBJECTS

- Every activity includes drawing, diagraming, charting, etc.
- These are co-created through the above process

Lightly structured individual and group activity around some kind of visual representation is the key to EMBeRS activities. The facilitator must ensure that participants are contributing, listening to each other, and trying to make sense of how the differing perspectives contribute to a larger picture of the problem. This requires a careful balance between top down structuring and bottom up processes. There should be some guidance and some top down instruction, but the bulk of the time should be dedicated to individual and teamwork designed to organize, represent, and share knowledge within the group, in ways that are conducive to group learning. Achieving the right balance is part art and part practice.

Each activity is designed to last roughly 2.5 to 3 hours, if done in entirety and with a break in the middle. The typical pattern is an introduction to the activity (15 minutes), some kind of individual representation to organize each person's thinking (15-20 minutes), sharing of individual representations (60 minutes), discussion of ideas (15 minutes), co-creation of an integrated boundary object (30-60 minutes), and reflection/debriefing about the activity (15 minutes). Depending on the context an activity can be completed during a half-day workshop or split over several class periods. In some cases, activities are sequenced.

EMBeRS currently has sixteen standard activities in three general segments (Table 1). The activities can be sequenced to achieve the iteration that is required to progressively focus in on an integrated solution. The logical order within each group is indicated, but groups can be combined to achieve different sequencing.

Each activity follows a standard design template (Appendix 1) that separates the description into three parts: epistemic, social, and set, based on a framework developed by EMBeRS participants (Thompson and Gouvea). The epistemic tasks are what participants are going to do. The social description includes any specific instructions they will receive with respect to how they are to interact with each other. The set section describes any materials that are needed for the activity.

These descriptions are then followed by a framework we use to map the activity design to expected participant actions, and to expected learning outcomes (Appendix 1). This enables us to separate two things: 1) whether the actual participant activity matched what was expected and designed for – the "design conjecture"; and 2) kinds of activities that are expected to lead to certain outcomes – the "theoretical conjecture." Our overall theoretical conjecture, as stated above, is based on theories of model-based reasoning and related research that has demonstrated that certain kinds of activity lead to certain outcomes that we desire. The EMBeRS project is not testing theoretical conjectures. Rather, we are drawing on known theoretical conjectures and testing the design of activities based on those.

Table 1. List of activities and their objective by segment. All segments included daily individual and group reflection.

SEGMENT	ACTIVITY NAME	OBJECTIVE
Generic	Share Your Research	Learn participatory process, active listening, divergent,

Teamwork		synthesis, and convergent thinking techniques that will be used in all EMBeRS activities. Learn other participants' research interests.
	Challenges of Interdisciplinary Research	Identify categories of IDR challenges being confronted and compare with categories identified in the literature. Note that perception of challenges depends on experiences.
	Dispositional Characteristics	Increase awareness of differences in interaction styles based on individual behavioral characteristics and motivational drivers. Increase knowledge of self and its influence on interaction with others.
	Toolbox Dialogue	Expose differences in methodologies, epistemologies, and values across disciplines.
Case Study	Stakeholder Analysis	Identify the stakeholders in a problem area and the issues from their perspectives.
	Explore the Problem Space	Map a wide range of concepts relevant to the problem to understand the problem broadly and comprehensively.
	Using Socio-Environmental System Frameworks	Expose students to standard frameworks that have been used to structure socio-environmental problems and map the problem into one framework.
	Systems Thinking 1	Identify measurable properties of entities for which data could be collected.
	Systems Thinking 2	Using Mental Modeler, map the relationships between measurable properties and identify the type and strength of relationships (positively or negatively correlated).
	Systems Thinking 3	Using Mental Modeler explore the impact on the system of increasing or decreasing specific properties.
	Systems Thinking 4	Using the Sustainable Water through Integrated Modeling (SWIM) interface, explore different strategies for intervening in a water system and the tradeoffs in future environment, economic, and social outcomes.
	Mock Solicitation	Design an integrated research approach that could be proposed in response to a solicitation.
Leadership	Designing Interdisciplinary Activities	Review EMBeRS design principles, sources of ideas for participatory activities, and considerations in modifying activities to more effectively enable convergent learning.
	Developing Interdisciplinary Activities	Practice collaboratively developing a new EMBeRS activity.
	Piloting Interdisciplinary Activities	Practice implementing an EMBeRS activity using workshop participants as test subjects.
	Sustainability Course Design	Consideration of knowledge, skills, and attributes needed for convergent research and strategies for incorporating these into a course or program.

CONTRIBUTING DATA

The EMBeRS project is collecting data to assess the effectiveness of the approach. Each activity includes a section describing observations that the facilitator can make, along with a rubric to assist you in assessing the products generated and team functioning. We encourage you to use this for your own benefit, and also to contribute to the project. On the website and in the activity description is a link to an anonymous survey. The survey is comprised of 4 multiple choice questions, 3 comment boxes asking you to describe how you implemented the activity and your assessment of it, 1 rating question, and 1 free text question to provide whatever additional feedback you would like us to receive. The questions are based on instructor observations of the participants as a whole – not on direct data collection from the participants. The survey is subject to University of Texas at El Paso Internal Review Board (IRB) oversight under IRB protocol #781100-2.

REFERENCES

National Research Council, 2015, Enhancing the Effectiveness of Team Science: Committee on the Science of Team Science (N. J. Cooke & M. L. Hilton, Eds.): Washington D.C., The National Academies Press, Board on Behavioral, Cognitive, and Sensory Sciences, Division of Behavioral and Social Sciences and Education, 268 p.

Pennington, D., 2016, A conceptual model for knowledge integration in interdisciplinary teams: orchestrating individual learning and group processes: Journal of Environmental Studies and Sciences, v. 6, p. 300–312, doi: 10.1007/s13412-015-0354-5.

Pennington, D., Bammer, G., Danielson, A., Gosselin, D., Gouvea, J., Habron, G., Hawthorne, D., Parnell, R., Thompson, K., Vincent, S., and Wei, C., 2016, The EMBeRS project: employing model-based reasoning in socio-environmental synthesis: Journal of Environmental Studies and Sciences, v. 6, p. 278–286, doi: 10.1007/s13412-015-0335-8.

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APPENDIX 1. EMBeRS activity template.

Activity Goal:
[Brief description of the overarching goal of this activity. If it is part of a sequence of activities, indicates other activities in the sequence.]

Description:
[Written description of the activity design, summarized in the table below]

- **Epistemic (tasks):** [Description of what the participants will be instructed to do.]

- **Social (rules and roles):** [Special instructions given regarding how the participants should interact]

- **Set (materials):** [Description of any materials and tools provided to the participants]

Post activity: [Description of any follow up conducted with the participants after the activity, such as group reflection on the activity, or group discussion about outcomes.]

<table>
<tr><th colspan="2">DESIGN CONJECTURE</th><th>THEORETICAL CONJECTURE</th></tr>
<tr><td>Epistemic
•</td><td rowspan="3">Expected activity
• [This is a list of the activities that we expect to see, based on the design. Data/observations should be collected based on expected activities. These might include observations about interactions during the activity, or analysis of artifacts produced from the activity.]</td><td rowspan="3">Learning outcomes
•</td></tr>
<tr><td>Social
•</td></tr>
<tr><td>Set
•</td></tr>
</table>

Data collection:
[Description of observations that the facilitator can make, data they can collect, and assessment rubrics for products and team functioning.]