A Design Approach to Understanding the Activity of Learners in Interdisciplinary Settings: Environment and Diversity

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Abstract: The aim of this paper is to describe the design approach developed to analyze the design and consequent activity of learners engaged in an undergraduate environmental science course. The course was taught using the EMBeRS method that emphasizes generation of external representations of mental models to build shared understanding of socio-environmental systems (Pennington et al., 2015). The design approach adopted combined expertise in (1) design research (from Sandoval, 2014) and (2) design for learning (from Carvalho & Goodyear, 2014). Taking a systems view of the design, activity, and learning outcomes, this paper describes the linkages between these and extracts the design conjectures of the instructor and the theoretical conjectures implicit in the EMBeRS approach. In collaboration with the instructor, the use of this approach: identified disconnects between design and theoretical conjectures; linked these disconnects to specific design considerations so that; recommendations for areas of redesign and parallel research were made.

Keywords: design, interdisciplinary problem solving, collaboration, environmental science

Introduction and background

In environmental science, finding ways to engage in productive interdisciplinary collaborative research is essential to finding solutions to real world problems, such as climate change. A synthesis approach to research focuses on the integration of perspectives to create a shared model of a given system, as a negotiated boundary object, to represent and mediate conversations about the phenomenon in study. In synthesis research, interdisciplinary teams come together to refine existing data, ideas, theories or methods, from many sources, and across multiple fields (NCEAS, 2014; Kemp & Boynton, 2011). A synthesis approach is necessary when an individual perspective cannot answer questions, but the integration of knowledge and perspectives across disciplines into a shared model has been identified as one of the key challenges to the success of this method of research (Roy et al., 2013). In 2013, a number of programs were funded to investigate the design of undergraduate and postgraduate programs around socio-environmental synthesis skills. This paper focuses on one of these projects: Employing Model-Based Reasoning in Socio-Environmental Synthesis (EMBeRS). The EMBeRS approach (Pennington et al., 2015) combines model-based reasoning with an emphasis on the creation of, and conversation around, boundary negotiating objects (Lee, 2007; Pennington 2010). Model-based reasoning is a feature of scientific thinking (e.g. Nersessian 2002) that science educators have been striving to support in science learners (e.g. Jacobson & Wilensky, 2006; Lehrer and Shauble, 2006; 2000; Raghavan & Glaser, 1995). The EMBeRS project elaborates on this approach for use in interdisciplinary contexts. Specifically, the approach allows disciplinary experts to share aspects of their internal mental models by collaborating to generate and refine external representations of complex systems. During this process, it is expected that experts will uncover and reconcile discrepancies in their understandings of a system and over time develop a more comprehensive synthetic understanding of a complex problem (a shared problem model).

In parallel to developing the EMBeRS approach (for a full description see Pennington et al., 2015), members of the project team also developed an approach to design for, and analyze, the resultant learning. Our aim was to describe the organization of collaborative interdisciplinary learning environments in terms of the design, the activity of learners and instructors, and the outcomes of learning so that we could articulate and test conjectures about learning to do synthesis research. In this paper we present an example of an analysis of a lesson from an undergraduate environmental science course designed using the EMBeRS approach.

Methods

We take a systems approach to analyzing learning that allows us to propose conjectures about the mechanisms underlying commonly reported measures of effectiveness, such as learning gains. Understanding the relationships between the components in a system of learning helps us to better predict whether a successful design is repeatable or transferable. We can ask whether the observed success is linked mechanistically to intentionally designed aspects of the program, or whether it emerged from as yet unconsidered features of the program or participants (learners or instructors). We draw on recent work in design for learning (Carvalho & Goodyear, 2014) and design-based research (Sandoval, 2014) to map learning systems in a way that centralizes the activity of the learner – where the mechanisms of learning unfold. Drawing on the work of Carvalho & Goodyear (2014) we map learning environments by accounting for (1) the designed elements, including tasks (epistemic), role and rules of interactions (social) and digital and physical learning environment and tools (set); (2) learner activity (observable learner behavior); and (3) the learning outcomes (measurable changes over time). We will then illustrate how to analyze such systems adapting conjecture mapping (Sandoval, 2014) to draw out and evaluate the (1) design conjectures that link designed elements of a learning environment to the desired activity of learners (conjectures about how the design will be enacted); and (2) theoretical conjectures that link the activity taking place in a learning environment with anticipated learning outcomes (conjectures about how people learn).

This paper focuses on an exercise designed as part of an undergraduate, first year seminar course called *Everybody's Environment*. The course included 16 students with an expressed interest in a range of majors. We describe the design of the EMBeRS exercise, as well as the observations made of learner activity, particularly in relation to assessing the ability of students to engage in the core objectives of the EMBeRS approach (broadening of individual perspectives mediated by boundary negotiating objects in a collaborative setting).

Findings

The students engaged in a sequence of activities to explore different understandings and conceptualizations of the term *environment.* The instructor intended to use this exercise to prepare students to adopt the EMBeRS approach to address a more complex problem later in the course. As outlined in the EMBeRS approach (Pennington et al., 2015), students were expected to have the opportunity to a) identify their own view (perspective) of *environment*; b) listen to and understand other students' perspectives; c) share their own and others' perspectives (written and oral); d) collaboratively construct a representation of their shared understanding; and e) apply this to another problem. Students engaged in a sequence of tasks over three days:

Task 1 required students to identify one resource that represented their view on *environment* and provide a reason for their choice. The responses were submitted online, and brought to class. In Task 2 students were placed in dyads to describe their resource, changing partners several times over 20 minutes, until all students had interacted with each other. Students individually reflected on a guiding question about what they had learned about others' representations of the environment, and these were presented to the class. Students were then divided into groups of three based on proximity and given ten minutes to identify commonalities and differences in their resources, followed by another individual written reflection about their learning. Finally, the whole class discussed the individual reflections, which were recorded on the board by the instructor. Task 3 was completed asynchronously. Students were asked as individuals to identify one resource (visual, symbolic) that represented their small group's view on environment and provide a written description as well as a reason for choosing the resource, submitted online and face-to-face in the following class. In Task 4 the resource and explanation from Task 3 were shared in class with the same groups of three as the first day, and the students were asked to write a guided reflection as individuals. In the same groups of three, students were asked to generate a mind map of shared understandings and perspectives of the environment, which were photographed and shared with the class. One of the groups utilized computer software to generate their concept map, while the remainder drew their maps on notebook paper.

The design of the exercise is outlined in Figure 1 below. The *epistemic* elements of the design were a series of subtasks that elicited external representations as well as explanations and reflections of perspectives about the definition of *the environment*. Repetition around the key skills (creation of artefacts, discussion, reflection) was used to train students in the cyclical nature of the EMBeRS approach. The *set* design supported the creation and sharing of artefacts, explanations, and reflections, and allowed these to be accessible by the instructor and learners as needed during the subtasks. The *social* design included a series of individual, dyad, small group, and whole class discussions, aligned carefully with the epistemic elements. Beyond this, however, the social activity of the learners was unscripted; there was no scaffolding of the collaboration in terms of roles in the groups or rules to follow.

The observable learner activity was characterized in terms of the same three constructs: epistemic, social and set. The key epistemic aspect of learner activity was identifiable changes in perspectives about the environment, most obviously identified in the written reflections and descriptions of the artefacts. It was anticipated that learners would use the tools available, physical and digital, to aid them in communicating their perspective to the group and the instructor. It was also anticipated that the social interactions, and the rules and roles that emerged during the structured collaboration would help learners to shift perspectives, as per the

EMBeRS approach. The projected learning outcomes revolved around preparing learners with the skills required to adopt this approach later in the semester, including collaboration, artifact creation, and writing.

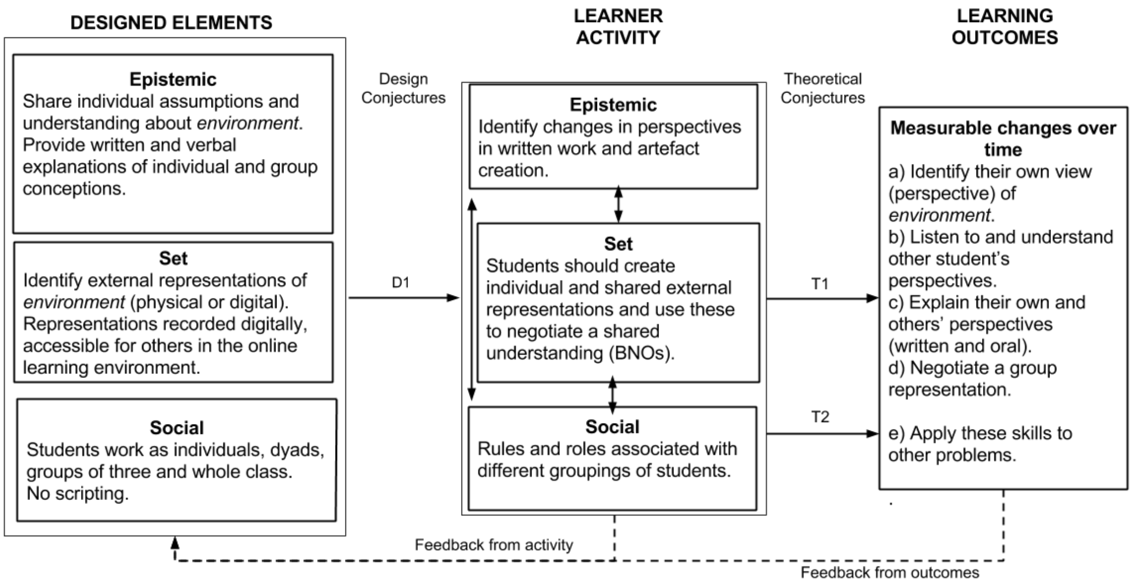

Figure 1: Representation of the key design elements considered in *Everybody's Environment.*

Discussion and conclusion

Our analysis allows us to explicitly draw out the conjectures embedded in the design of this lesson. The primary design conjecture (D1) was that the design elements would work together to generate discourse and activity in which students would share and negotiate their perspectives. It was assumed that the construction and refinement of representations would mediate this process, allowing students to record and reference their ideas. The instructor also assumed that a range of understandings of *environment* would exist among the students. The design purposefully encouraged a range of modalities to present these understandings, including written and verbal, interpersonal, intrapersonal, as well as visual and spatial. Most of the resources identified by the learners were digital (including photos and music), however some were physical resources (including a book and a terrarium). There were two theoretical conjectures identified. The first (T1) linked this intended activity (iterative, collaborative externalization and negotiation of perspectives) to shifts in individual students' perspectives about *environment*. The second (T2) was that participation in this exercise would prepare learners to participate in further model-based reasoning in groups later in the semester.

With these conjectures articulated we were able to identify evidence in the observed learning activity and learning outcomes. The instructor observed various levels of sharing, description, inquiry and collaboration, and noted discrepancies between the collaboration in real-time, and written explanations submitted. What was not clear without recordings of the collaborative tasks was the role that the different social groups had in the generation of artefacts or shifts in perspectives. Further investigation is needed before support can be given to the design conjecture. A shift in perspectives was observed by the instructor in the written and oral descriptions (related to T1), most noticeably in recognizing that not all students identified nature as environment, but identified themselves or their neighborhood or some other physical space as environment. Students did articulate their own and others' perspectives, and participated in generating shared representations. Further analysis needs to be done of the artefacts produced to understand how the interaction of different types of learner activity supported this. To test T2, the instructor applied the same design to the discussion of another term (diversity), rather than an environmental case study. Student comments included feedback that the exercise was not academic enough, as it provided no grounding in the literature in terms of defining or conceptualizing the concept of *environment*.

In the following, we consider the feedback from the three aspects of the activity of learners, and the learning outcomes. The *epistemic* design seems to have been successful, at least in terms of anecdotal reporting of participation in the task. Further research could investigate the reflections and artefacts for evidence of perspective change, particularly to understand how this interacts with the other design elements. The design of the *set* was complex with online, digital and physical artefacts created and shared by individuals and in groups. Future research should address the interaction between this heterogeneous learning environment and the role of the boundary negotiating objects in the shared understanding of the key term. The design of the *social* groupings was complicated (individual, dyads, small groups and whole class), further investigation is needed of the rules and roles that emerge in further iterations in order to ensure that timely support is given to groups as necessary, or to reconsider the complexity of the groupings. The feedback from students implies that they lacked motivation to apply these skills to the negotiation of a second key term. This may be linked to the epistemic design. In synthesis research, experts come together around a pressing environmental problem that they want to solve. In the classroom task, students were engaged in defining a term (an initial step towards solving a problem) without the context of the bigger problem that this would help them to solve. Changing the focus of the exercise to an authentic environmental issue, around which differences in worldviews or mental models exist, warrants further investigation.

By combining the approaches that foreground both design-based research and design for learning, the key considerations of the instructor as well as learning sciences researchers can be included, and in so doing, provide a more informed design of a complex task. Given the roll out of the EMBeRS approach in multiple institutions (Pennington et al., 2015), a systematic way of assessing the variations of the design as well as the resulting activity and learning outcomes support their comparison across learning environments. As the results are further refined, design guidelines can be developed to support the successful implementation of EMBeRS.

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