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Designing the EMBeRS Summer School: Connecting Stakeholders in Learning, Teaching and Research

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Abstract: In this paper, we describe our research investigating design, teaching and learning aspects of the EMBeRS Summer School. In 2016, thirteen graduate Environmental Science students participated in a ten-day Summer School to learn about interdisciplinary approaches to researching socio-environmental systems. Using the Employing Model-Based Reasoning in Socio-Environmental Synthesis (EMBeRS) approach, students learned about wicked problems, team composition, systems thinking and modelling, stakeholder management, and communication. They applied this approach to their own research, as well as to a case study, in order to, ultimately, further the EMBeRS approach in their own institutions. Learning sciences researchers, environmental science instructors and learners collaborated in design, teaching, and learning during the 2016 Summer School in order to co-create and co-configure the tasks, social arrangements, and tools for learning, teaching and design. This paper identifies four examples of connections between the stakeholders (researchers, instructors and learners), the tools that facilitated the connection, and the implications for learning, teaching and design.

Keywords: interdisciplinary problem-solving, collaboration, learning, design

1. Introduction and Background

Learning, teaching, and design for learning have been conceptualised in terms of complex networks of learners, instructors, designers, and researchers, integrating physical and digital spaces (Howard & Thompson, 2016; Jacobson & Wilensky, 2006). To understand the relationships between design, teaching and learning, strong connections must be made between researchers and practitioners. This paper presents the application of a design-inquiry framework to analyse the Employing Model-Based Reasoning in Socio-Environmental Synthesis (EMBeRS) Summer School. It involved stakeholders in design, teaching and learning, and all contributed to the co-creation and co-configuration of the tasks, social arrangements, and tools for learning. Four examples of connections are presented: between researchers and instructors; instructors and learners; researchers and learners; and researchers, learners and instructors. The tools that facilitated each of these connections are discussed, and the implications for learning, teaching and design.

Synthesis, the act of integrating knowledge, data, methods, and perspectives in pursuit of a more comprehensive understanding, across disciplinary and professional boundaries is at the heart of addressing important socio-environmental issues. Many environmental science programs are functionally multidisciplinary and struggle to synthesize knowledge across disciplines (Vincent et al., 2015). Researchers, designers, instructors, and learners require guidance on how to more effectively accomplish their interdisciplinary goals, yet there is little evidence-based advice to be given beyond ensuring quality communication (O'Rourke et al., 2013). Methods for sharing knowledge in groups have previously been provided for group settings in professional fields (Brown, Lindgaard & Biddle, 2011), but little has been explicitly developed for interdisciplinary teams of scientists (Pennington, 2011). In such teams, this knowledge is complex, must be conveyed to team members with basic training in that field, and needs to be connected to achieve research outcomes that are truly synergistic.

Core to the development of EMBeRS was understanding the design of several common techniques of problem-solving and adapting elements of each to a socio-scientific context. Idea generation must be conducted in a way that ensures each idea is explained and all members of the group understand (Pennington, 2011). Time must be purposefully allocated for team members to try to make connections with their own research and generate novel, synergistic models of the problem (Fiore & Schooler, 2004; Pennington et al., 2016). Building on research from experiential learning theory (Kolb, 1984) and creativity (Brophy, 1998), three features of successful synthesis were identified: the ability to externalize one's own disciplinary knowledge; promotion of active listening and individual reflection; and iterating between divergent and convergent thinking activities.

Model-based reasoning (MBR) is based on the concept that when faced with a problem-solving task, humans reason by constructing an internal mental model of the situations, events, and processes that comprise the problem, and that external representations can be used to facilitate construction of a mental model (Nersessian, 2009). MBR provides a cognitive explanation for boundary objects (Star & Griesemer, 1989) as key components that link across expert perspectives (Pennington, 2010). Pennington et al. (2016) identified the key stages of interdisciplinary problem-solving for socio-environmental synthesis as: (1) identifying an appropriate research question; (2) agreeing on a shared vocabulary; (3) co-creating boundary negotiating objects; and (4) deploying tools for visualizing and combining data, with the aim of (5) producing a new, connected model of understanding. The product of this negotiation is a model of the system under inquiry. Individual scientists contribute data to the model, building on their initial conclusions and further discussing the relationships between this model and other connected research.

Understanding the relationships between the components in a system of learning and design helps us to better understand why a design is successful, repeatable or transferable. We draw on the Activity Centred Analysis and Design (ACAD) framework (Carvalho & Goodyear, 2014) to map learning systems and design so that the activity of the learner is placed at the centre of the design. Research on the implementation of the EMBeRS approach with undergraduate students (Thompson et al., 2016) demonstrated the importance of considering the connections between the design, implementation and outcomes in order to inform redesign. We combined key concepts from design based research (Sandoval, 2014) and the ACAD framework to: organize multiple analytic techniques applied to complex datasets; allow tasks to be compared across learning settings; and connect design and theoretical assumptions with specific design decisions. (Figure 1). The *designed learning environment* encompasses multiple components of the learning environment: the digital and physical learning environments, tools, resources, as well as the tasks and social arrangements. *Learner activity* refers to the observable aspects of learner behaviour: their social interactions, how they approach and work through tasks, and how they communicate in talk and through the generation of written or computer-generated representations. The activity of the instructor is also important. *Learning outcomes* refer to measurable changes in learners over time.

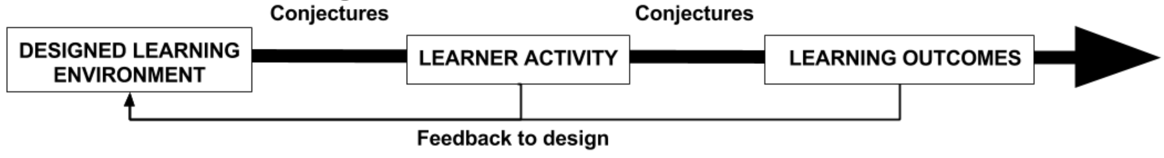


Figure 1. The combined design approach

Much of the recent discussion about multimodal data for learning (MMDL) has been reported in the context of multimodal learning analytics. In multimodal learning analytics, multiple types of data such as speech, text, handwriting, sketches, action and gesture, affective states, neurophysiological markers, and eye gaze (Blikstein & Worsley, 2016) are used to collect data about learner activity.

Research discusses how these data types can be connected, such as Thompson et al. (2013), and the importance of considering multiple dimensions of learner data to gain a more holistic understanding of learning activity (Blikstein & Worsley, 2016). Essential to considering MMDL is a way to organise, connect, and make decisions based on the results of analyses. Thompson et al. (2013) argue that the selection of data can be related to the ACAD framework.

2. Methods

The team implemented training activities during a two-week Summer School for PhD students, in July 2016, at the University of Texas at El Paso. The stakeholders included: seven instructors from the EMBeRS team (backgrounds in geological sciences, earth sciences, environmental science); guest instructors (specializing in systems thinking, stakeholder management); five researchers (backgrounds in science education, learning sciences, linguistics, learning analytics); and thirteen graduate students (six males, seven females). Graduate students were selected based on their disciplinary background (including environmental science and engineering; archaeology; bioengineering; urban management; ecosystem science and sustainability; agriculture and biological engineering; agricultural economics; water science and management; water resources), letter of recommendation from their advisor, the stage of their PhD, and their interest in interdisciplinary science.

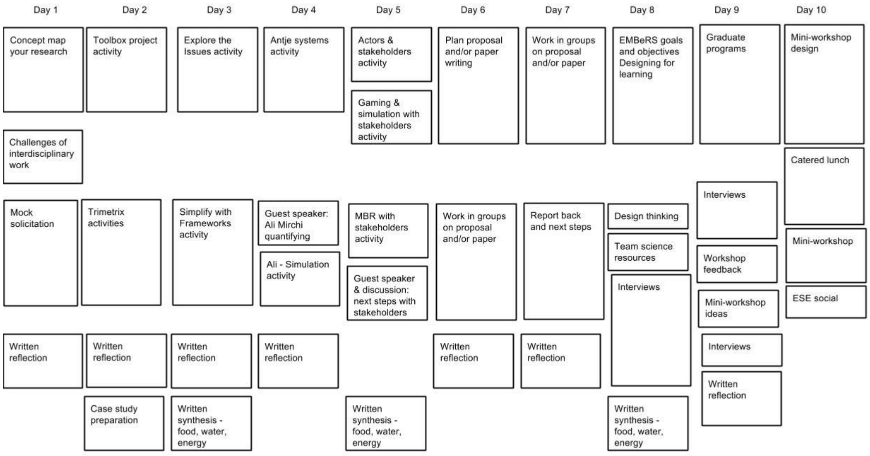
The Summer School guided participants through lightly structured activities that employed the key phases of interdisciplinary problem-solving. At the end of each day, the group had explicit time for reflection on these activities, using the ACAD framework to guide student understanding of design choices, learner activity and learning outcomes, and each night they were asked to engage in individual reflections about their learning. In addition to the collaborative, discursive synthesis tasks, students were also given an individual, written synthesis task.

Participants were asked to complete an initial ***survey*** about their disciplinary background, educational experience and other background information. ***Design documents*** were prepared by members of the team, and their implementation recorded as the Summer School progressed. Audio recordings were collected, transcribed, and the ***discourse*** coded (using automated learning analytic techniques developed by team members) for convergence around ideas and language, and disciplinary knowledge. Video recordings were collected and the ***artefacts*** analyzed to identify the tools used. ***Interviews*** were conducted after the Summer School in order to obtain the participants' perspectives on their gains in understanding and abilities and to evaluate the effectiveness of the different activities included in the school. Participants were asked to discuss what they learned, which activities were most helpful, how they intended to use their new knowledge and skills, and how the Summer School could be improved.

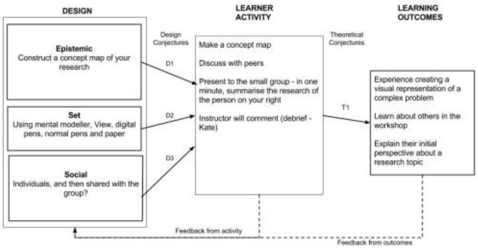
3. Results

The design of the Summer School and individual tasks was carried out by instructors and researchers over many months. The final design of the workshop was agreed upon, and transferred to a shared visual representation (Figure 2). Visualising the design of the Summer School allowed instructors to identify links could be made between individual tasks (e.g. *Challenges of interdisciplinary work* and *Mock solicitation*, Day 1), and repetition (e.g. *Written reflections*) and to manage tasks to be completed in students' own time (e.g. *Written reflections*, *Written synthesis*). For researchers, visualizing the complexity of the design of the Summer School helped to guide the research questions and data collection, and ensure that appropriate data was collected to answer key research questions.

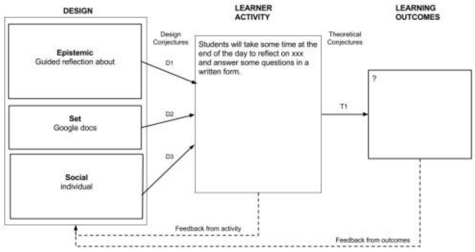
As can be seen in Figure 2, on most days there was a morning session (e.g. *Toolbox project*, Day 2), an afternoon session (e.g. *Simplify with frameworks*, Day 3), and tasks to be completed during the evenings (e.g. *Written synthesis*, Days 3, 5 and 8). Some tasks were repeated (e.g. *Written reflection* each evening) and others involved guest presenters (e.g. *Simulation activity*, Day 4). Each activity was also mapped using the combined design framework (Figure 1), identifying elements of the epistemic, social and set design and the design and learning conjectures. Figures 2b and 2c shows the design of two of the tasks designed for Day 1. The combined design framework provided an important link between researchers and instructors. The framework was used as a tool to prompt discussion and negotiation of meaning around key terms. After each discussion, researchers better understood the design and learning intentions of the instructors. Instructors were able to articulate the assumptions that they made about learning and teaching, and conduct design of the tasks that ensured that epistemic, social and set elements were considered. Every task was visualized using the framework, which provided researchers with detailed representations of designed tasks that can be compared in future analyses.



(a) Summer School, 2016 design



(b) Concept map your research



(c) Written reflection

Figure 2. Design of the Summer School, 2016

Students were given multiple opportunities to practise the EMBeRS approach. Important features of the approach include active listening, and respect for different disciplinary approaches to solving problems. A strong culture of trust and a rhythm of communication developed between the instructors and the students. Multiple students wrote about trust particularly in their reflective tasks:

> *The culture that has been established by the group was intentionally designed by the organizers of this workshop, and is one that creates a high level of trust, knowledge sharing, and respect. I believe that respect is at the center of the cultural values... The high level of trust can only be established in a safe space for talking and sharing your knowledge, where every member is supported, rather than judged. (Samantha, Day 4 reflection)*

This was most apparent during the tasks led by guest instructors, when it became obvious that the emergent practices of the group had not been communicated. This experience connected the instructors and learners in an unanticipated way.

> *The culture that the group developed by using the EMBeRS model to communicate our ideas and bring them into a common space was readily apparent today when we introduced other members … to the group dynamic via Skype. Because these people weren't present in the room, and had not experienced the culture… communication with them during question and answer period was more strained. ... In other words, the trust that we developed during the previous days of the workshop had not yet developed. (Sandy, Day 4 reflection)*

Following this reflection, time was devoted to articulating the co-constructed group practices and the Summer School culture explicitly. Briefing of subsequent guests included introductions, a slower pace, and the provision of time for connections to be made in the co-creation of a shared model of understanding. It was empowering for the students to articulate and encourage these practices.

Researchers connected with learners in ways separated from the instructors. This was done through interviews at the end of the Summer School, and also tasks that students were asked to complete in the evenings (written reflections and synthesis tasks). During the interviews, most participants reported that they: learned skills to participate in and lead interdisciplinary/transdisciplinary teams (77%); gained an enhanced understanding of interdisciplinary/transdisciplinary research processes (69%); gained understanding of multiple perspectives/disciplines (62%), and learned to integrate disciplinary knowledge and methods using interdisciplinary modeling tools (54%). In a post-program survey asking participants to rate the effectiveness of each activity, almost all rated all the activities as of very high or high value. In addition to the written reflections, on three evenings, students were asked to write a synthesis of three articles, which had a shared theme (the water-food-energy nexus), each from a different disciplinary perspective. The students were first asked to draft a synthesis on Day 3 of the workshop, with opportunities on days 5 and 8 to redraft. While the interdisciplinary synthesis practices that were developed through discussion and co-creation of artefacts during the Summer School are important for an environmental scientist, the skills to synthesise and communicate different disciplinary knowledge in writing are also essential. The learners had the opportunity to engage in this practice, and to observe how their ability to connect disciplinary knowledge developed as they learned the group skills in parallel. The researchers analysed these syntheses with respect to their inclusion of topics or themes from the sources, intra- and inter-textual synthesis, evaluation, and sourcing (which articles were explicitly referred to). This analysis was conducted across all available drafts, to better understand the evolution of the synthesis over time. Across the texts produced, clear differences could be identified between students and over time, with students varying in the number of sub-topics or idea units expressed, the sourcing of these from the three documents, and their evaluation towards a particular conclusion.

The ACAD framework was used to guide group reflection at the end of each day. Students were asked to identify learning outcomes, and researchers suggested additional outcomes as relevant. Students then identified their activity, and the researcher outlined the design. The intention was for students to understand the purpose of the tasks they had participated in, for them to ask questions, and for them to make connections between what they were doing and what they were learning. For example, the overarching aim of all the tasks designed for Day 1 (Figure 2) was for students to gain experience in enacting the EMBeRS approach to solving problems. Learning outcomes were identified, including abilities to simplify thoughts about own research, communicate with non-experts, learn about different ways of representing, [develop] social capital, [identify] social implications, see interactions between research, and [realise] different programs experience with representatives. Only a subset of these identified learning outcomes aligned with those of the instructors. The guided reflection was beneficial for both instructors and students. For students, it scaffolded the connection of tasks within a day, or between days, with the overall learning goals. The process also allowed the instructors to reflect on whether the design and learning intentions of each day were met, and to make adjustments to the design of the tasks on subsequent days to ensure that any misalignment was corrected.

4. Discussion and Conclusions: Implications for design, research and learning

Many changes were made for the 2017 Summer School based on the analysis presented above. Two main changes reflect the importance of designing for the co-creation of an environment for learning in which instructors, researchers, and learners can connect, trust and build a collaborative culture as well as models of understanding. The timing of the Summer School was chosen to ensure that more of the instructors could be present in person, and the ‘share your research’ task on the first day was extended to ensure that all students have the opportunity to work together. This tests the design conjecture: *more time will enable the culture to be co-created and co-configured*. The ultimate aim of the research is to generate new insights into effective synthesis practices. These insights will enable synthesis decision-makers (by which we mean research team leaders, learners, instructors, and program designers) to make informed decisions about designing and engaging in synthesis activities. The multimodal dataset captured the activity of learners, over time, as participants learned to identify and represent their own disciplinary knowledge; collaborate in an interdisciplinary team; and allow a shared problem model to emerge. Further analysis of the dataset is focused on identifying evidence of disciplinary knowledge, interdisciplinary knowledge (the shared 'language'), and collaboration, and relating these to the design of tasks and instructional practices.

Given the complexity of the design of the EMBeRS Summer School, there were numerous learning objectives related to individual tasks, as well as the Summer School overall. One of the implications of using the ACAD framework is the importance of observing the co-creation and co-configuration of learning. Learners were given access to the design intentions every day (through the guided reflections), and developed relationships with the researchers and the instructors. They became important stakeholders in their own learning, and had significant power in that relationship. A follow-up survey has revealed that many of the participants have applied what they learned during the Summer School to planning the next stages of their dissertation with their advisors. They have also been using elements of the approach in professional settings including the design of workshops, presentations, and other interdisciplinary research. The tools used (the ACAD framework) as well as the social relationships (with researchers and instructors), and the development of a shared culture, were as important as the designed tasks in enabling these students to co-create and co-configure their learning.

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