Narrative: Supporting Practice, Integrating Research in Immersive Technologies into Educational Designs (SPIRITED)

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a. Statement of the Interdisciplinary Problem or Area of Investigation

Supporting Practice, Integrating Research in Immersive Technologies into Educational Designs (SPIRITED), proposes an **innovative, interdisciplinary** approach involving faculty researchers from three University of New Mexico Colleges: the College of Education, Department of Teacher Education; The School of Engineering, Department of Computer Science; and the College of Fine Arts, Art, Research, Technology, Science (ARTS) Lab. SPIRITED brings together **complementary, integrated expertise** on **learning, teaching, and technologies** to develop understanding of how immersive technologies might be used to support inquiry teaching and learning.

The study addresses an **important problem**; in schools, science is taught as a fragmented body of concepts and facts, rather than as inquiry process. The forthcoming Next Generation Science Standards seek to change this via a set of dimensions that highlight *Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas* that may deepen understanding (Committee on Conceptual Framework for the New K-12 Science Education Standards & National Research Council, 2012). However, teachers have not been taught in this style, nor have they received professional development to support them in teaching in this style. Although the forthcoming standards represent a significant opportunity to deepen and enrich science teaching and learning in New Mexico, without access to resources to efficiently support such activities, this opportunity is unlikely to be realized. This is further complicated by the diversity presented in the state; despite the being home to the national laboratories, significant science and technology industries, and other DOD/DOE facilities, New Mexico consistently ranks at the bottom of most economic and educational indicators (Economic Research Service USDA, 2011; National Center for Education Statistics & Institute of Education, 2009). While many resources will be deployed via internet, according to the 2009 US Census, 40% of New Mexico residents did not access the internet (United State Census, 2009), compared to nationwide estimates of 31% for the same year. While various factors drive these figures, we see value in pursuing approaches that do not depend solely on internet access, yet still incorporate technology in consequential ways to support deep inquiry learning.

b. Project Goals and Objectives

Our vision for addressing these problems leverages immersive, projected media as a way to reconfigure classroom learning. SPIRITED begins by addressing preliminary questions to support the team's long-term goal of developing affordable, feasible classroom-based immersive projection systems paired with understanding of how the use of such technologies might engage students in the same types of inquiry that professional scientists carry out. If the current study aims of SPIRITED are achieved, **scientific knowledge will be advanced** by developing a first order understanding of how students might learn and participate in scientific inquiry as a result of immersive media, as well as an articulated understanding of ways to design curricula that incorporate immersive media. Broadly, SPIRITED will shed light on how to support teachers to design and implement inquiry lessons in which context is provided and scientific activity structures are provoked using immersive technology; and identify affordances and constraints for using immersive technology to provoke scientific activity structures and provide context for extended inquiry. SPIRITED will focus on **goals** related to teachers as designers and blending inquiry practices with immersive technology to provide context for students to ask their own questions, plan data collection, participate in inquiry, and work with data, provoking scientific activity structures seldom seen in classrooms. Interdisciplinary teacher-designed inquiry lessons developed as part of SPIRITED will address Common Core State Standards and align to the Framework for Next Generation Science Standards. **Project objectives** include identifying affordances and constraints of immersive technologies to provide context for inquiry and provoke scientific activity structures, and shedding light on how blending these might support inquiry practices. To achieve these objectives, SPIRITED will develop technology, codesign projects with teachers, and study implementation and student learning. Building upon recent innovations in interactive and immersive digital environments developed under the auspices of an NSF PFI grant *Consortium for Fulldome and Immersive Technology Development* (Sen, PI, 2009-2012), SPIRITED will extend immersive interactive simulations that allow students to pose questions and analyze data. These objectives will support **subsequent** work, including submission of proposals for extramural funding and peer-reviewed publications and proceedings. Specifically, the proposed project will provide pilot research for a pending NSF Cyberlearning grant submitted December 2011, *Supporting Project-based Practice Integrating Research in Immersive Technologies* (SPPIRIT). SPPIRIT proposes to investigate how immersive experiences might support authentic learning experiences, and reconfigure how students participate, with a focus on extended inquiry practices in secondary settings, and will require significant technological innovations. SPPIRIT will use immersive technologies to allow students to search the galaxy for habitable exoplanets, combining team expertise in scientific inquiry, design of inquiry projects and project-based teaching, computer graphic design, computational modeling, and fabrication. SPIRITED will also support in-progress development of an EPSCoR proposal, *Science Inquiry with Visualizations and Interactive Technologies* (SIVIT), which focuses on using robust-fabricated kits to bring immersive, interactive simulations of field trips with New Mexico EPSCoR-funded scientists to rural schools. To support this innovative, interdisciplinary work, and to advance scientific knowledge, we propose *Supporting Practice, Integrating Research in Immersive Technologies into Educational Designs* (SPIRITED), which places a focus on answering preliminary, related **research questions**:

Q1) How might we support teachers to design and implement inquiry in which context is provided and scientific activity structures are provoked using (immersive) technology?

Q2) In what ways might an immersive experience reconfigure inquiry learning, both before and after the experience?

c. Methods and Approach

Conceptual framework. Professional scientists engage in *designerly* activity as they find problems, pose questions, and plan investigations (Cross, 2001); school inquiry rarely reflects these practices. SPIRITED will explore how design framing and immersive technology might provide opportunities for more authentic inquiry practices. Design has been used previously to support science learning (e.g., Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004; Hmelo, Holton, & Kolodner, 2000), but we view **design as an authentic component of professional STEM practice**. Virtual learning environments enhance learning when they offer a situated experience (Dede, 2009), which is an effective inquiry approach (Rivet & Krajcik, 2008). Although little research has explored the use of immersive projection technologies for learning (Apostolellis & Daradoumis, 2010), studies have found benefits for viewing immersive displays in terms of recall of facts (e.g., Sumners, Reiff, & Weber, 2008). Open questions about the role of immersive environments for learning remain; in particular, Dede (2009) highlights that research is needed on supporting transfer by blending learning across virtual and real settings. One of the affordances of immersive learning environments is the provocation of problem finding and posing activities, (Dunleavy, Dede, & Mitchell, 2009), but this finding is not well understood, suggesting a need for further research.

Design and methods. A design-based approach (Brown, 1992; The Design-Based Research Collective, 2003) will leverage findings for refinements to the inquiry lessons and technology, leading to design guidelines –affordances and constraints—for supporting inquiry practices with immersive technology. An IRB has been approved for human subjects research that covers all research methods involving UNM students. A modification will be submitted to address the research involving secondary students, pending approval of a memorandum of understanding between UNM College of Education and Albuquerque Public Schools. SPIRITED includes four participant types (Table 1), with two primary study goals, tied to the research questions.

Table 1. SPIRITED participants tied to questions

Participant abbreviation -- description (approximate n)	*provides data on:*	*IRB modification?*
D-PBL – designing students enrolled in Dr. Svihla's *Project Based Learning* course, Spring 2012 (n=9) and Fall 2012 (n~10)	Research Q1) design learning	No
D-CC -- design students active in Dr. Kniss's *code camp*, a weekly meeting of students working on designs for the dome; or otherwise supervised by Dr. Kniss to develop immersive media (n~5)	Research Q1) design learning	No
L-UNM – Learners from UNM students enrolled in one of the other courses included in Dr. Svihla's IRB, recruited as volunteers (n~30)	Research Q2) role of immersive media in inquiry learning	No
L-HS – Learners drawn from home school network (recruited via Katina Gamleah, see letter of support), and APS, recruited via PBL teachers (n~30)	Research Q2) role of immersive media in inquiry learning	Yes, pending MOU agreement with APS

In order to answer the research questions, various types of data will be collected and analyzed (Table 2). Most data are qualitative, and intended to document how and what participants learn as they engage in design or inquiry activity. The primary focus is on the participants designing inquiry units incorporating immersive technology, but those designing units incorporating other technologies will serve as comparison cases; additionally, data will be collected to document how computer science students involved in programming design immersive media for educational purposes. Interviews will focus on design process and disciplinary understanding. Artifacts of design process include sketches and notes, drafts, ideation activities, customer needs assessments, and lesson plans. The Design Skills Tests and the Design and Interaction Survey are given as pre/post measures only to the PBL class participants. Versions of these instruments have been used previously (Svihla, 2009, 2010).

Table 2. Data for research questions 1 and 2.

Participant	*D-PBL*	*D-CC*	*L-UNM*	*L-HS*
Interviews	X	X	X	X
Artifacts of design work/process	X	X		
Design skills test	X			
Design and Interaction Survey	X			
Artifacts of inquiry learning			X	X
Assessments (designed by D-PBL)			X	X
Video of interactions			X	X
Modified SUS Measure of Presence			X	X

For the second research question, interviews with will focus on understanding of disciplinary inquiry and experience in the dome. Artifacts of inquiry learning and assessments will be collected, as designed by the D-PBL participants. Videos of interactions before, during, and after the immersive session will be collected to better understand the ways of participating with immersive media. Video records will be collected in accordance with field standards (Derry et al., 2010). A measure of presence—the feeling of being present in a virtual space—will be used in a modified form to apply to the specific contexts under study (Usoh, Catena, Arman, & Slater, 2000). Finally, comparisons will be sought between online versions and immersive versions of the curricula. Because of the exploratory nature of this work, controlled experiments are not warranted by current understanding; rather, we prioritize developing understanding of how immersive media might support inquiry learning.

Analyses. Qualitative analysis, especially interaction analysis (Jordan & Henderson, 1995), will be used for interviews and video records. Artifacts of inquiry learning will be coded using grounded approach (Corbin & Strauss, 1990). Design artifacts will be coded using a mixed approach, beginning with grounded coding, and followed with a design schema (Table 3). Regression modeling may be used, provided sufficient numbers of participants enroll. Triangulation will involve comparing findings for discrepancies and convergence. Iteration will allow evidence-based design decisions to be made while developing a grounded understanding of how immersive media might support inquiry, and what role design might have for teacher learning.

Table 3. Design schema for coding design artifacts

Design Dimension	*Components*
Design occurs under constraints.	Cost – price of the final product; does not include unrealistic resources Regulations—conforms to state/government standards
Design involves form and function. A customer may select a design based on form, even if function is inferior.	Materials—durability, biocompatibility, ethical, feasible to use Style—reflects the style of the designer Ambiguity – no single right answer exists, and many alternatives may suffice
Designs address diverse customer or client needs, some of which may be implicit.	Roles—multiple customers or clients named Needs—multiple needs are considered and evaluated or ranked Implicit/False—Customers may provide misinformation
Design is an iterative process that requires evaluation and optimization across tradeoffs.	Tradeoffs-- Names tradeoffs between variables Improvement—iterative plans to evaluate and improve the design Coevolution—the problem and solution co-evolve during design

d. Innovation

This project demonstrates **innovation** and addresses **emerging issues** in how cutting-edge technologies might support inquiry learning. SPIRITED will answer preliminary questions, providing a way to move forward with innovative technology in classrooms, laying a foundation for the development of affordable, classroom based systems that may checked out to schools around New Mexico. This represents a significant advance both in technology, and in understanding inquiry learning. Our approach is novel, both for studies of learning and research on projection technologies. By adopting a design-based approach, we will contribute novel grounded theory about inquiry learning with immersive media.

e. Resources

SPIRITED leverages existing resources across UNM colleges to contribute to the probability of success. **ARTS Lab Resources.** UNM's Art, Research, Technology & Science Laboratory (ARTS Lab) is a highly equipped 4,000SF new media lab consisting of a motion-controlled sound stage/performance space, a micro-electronics fabrication space, two immersive media spaces, a digital production room for eight people, and two administrative offices. The facility has research-class internet access, 30TB of networked RAID storage, a secure FTP server and professional quality audio and video systems. ARTS Lab has eight professional quality research and production computers (equipped with 8 or more core, 12 or greater GB RAM, Adobe Creative Suite 5, Autodesk Maya, etc.), a SFTP server, 30TB of RAID 5 networked storage, a full compliment of control and input devices (Wiimotes, Wii Balance Boards, Microsoft Kinects, IR and visual cameras, etc.). Software and data developed as part of this project will be stored in a redundant system using both ARTS Lab's storage system and the university's "Dspace Repository," a data archival system administered by UNM's Center for Advanced Research Computing. The ARTS Lab has video cameras, audio recorders, and external microphones that may be used for data collection. Immersive Technology. ARTS Lab's 'gDome,' a 15-ft diameter dome theater system will be a principal asset for this project. The 350SF dome accommodates about 12 people and employs six video projectors tiled together to create a seamless image of about 2000x2000 pixels. The dome is powered by two systems. The second system, developed here as part of an NSF awarded project, uses a single Mac Pro with multiple graphic cards to project the software in development here. The gDome includes surround sound audio via 7 speakers, IR emitters for Wiimote locators, and a series of novel interface devices including active and passive skateboard interfaces ('skate' to move through a digital environment), an armchair interface ('sit and tilt' to control) and others. The Lab has six small projectors for prototyping novel immersive systems, and tools to fabricate systems. The studies will be implemented in the gDome and ARTS Lab Facilities. **College of Education Resources.** Dr. Svihla has software for qualitative analysis (NVivo and Inqscribe) and computers for conducting analyses. The PI's office in the College of Education will secure all educational research data collected under this research project. The PI has three HD video cameras with external microphones and tripods. Access to homeschool students for piloting will be provided by Katina Gamleah, a UNM College of Education graduate student who home schools her daughter. Ms. Gamleah was a student in Dr. Svihla's Spring 2012 course, *Project Based Learning*. Dr. Svihla studies this course under an existing IRB.

f. Future Funding and Dissemination Plan

SPIRITED will help the proposing team attract new external research funding (table 4). The team submitted a proposal to support their interdisciplinary work; however, it is unlikely to be funded on the first submission. Tier 1 funding would provide evidence that would strengthen the proposal for resubmission. The team has an aggressive plan for seeking funding; we address proposals for the next year, with the intent to resubmit as needed. Intramural funding will allow us to be more competitive for extramural funding, to further develop our team, and will provide sufficient data to produce publications and conference proceedings.

Table 4. Plans for extramural funding

Agency and program	*Amount / period*	*Due date*	*Rationale*
NSF Cyberlearning: Transforming Education: Exploratory. submitted 2011	\$405,745 for a 2 year period	12/16 /2011	This program "seeks to integrate advances in technology with advances in what is known about how people learn," making it a good fit. NSF funds projects that will lead to better understanding of "how people learn with technology and how technology can be used productively to help people learn, through individual use and/or through collaborations mediated by technology." Our focus is on learning, teaching, collaboration, and immersive technology.

NSF Early Career (Svihla)	minimum of $400,000 for a five-year period	7/23/ 2012	This program provides support to junior scholars to advance their careers through an integrated research and education plan. Applicants are encouraged to think about "how their research will impact their education goals and, conversely, how their education activities will feed back into their research…[to] pursue research and education activities that cross disciplinary boundaries." This will support continued study of the PBL course leading to understanding the impact learning to design might have on teachers and students.
National Academy of Education/ Spencer Postdoctoral Fellowship (Svihla)	$55,000 for one year, or divided into two	11/1/ 2012	This extremely competitive & prestigious fellowship provides course release funding, allowing the scholar to advance his/her career through research. The NAEd "funds studies that examine the efficacy of curriculum and teaching methods" … but not "the initial development of curriculum or instructional programs"
NSF EPSCoR (RII Track-1), education/outreach	$4 million over 5 years, with educational component a fraction of this	11/4/ 2012	As a team, based on the submission of a white paper and a logic model we have been invited by NMEPSCoR Proposal Steering Committee to continue with the proposal process. With a focus on energy, water, and environment, our proposal addresses the education and outreach components. In this proposal, *Science Inquiry with Visualizations and Interactive Technologies* (SIVIT), we propose to work with EPSCoR scientists to create immersive visualizations and a set of classroom-based kits that both transform the room and allow students to conduct scientific inquiry.
NSF Cyberlearning	$550,000 over 2 to 3 years	12/17 /2012	Based on the acceptance rate (10-12 of the 120 submitted proposals) we will resubmit this proposal, with a stronger interdisciplinary focus, incorporating perspectives on human rights and the arts.

The project deliverables include modifications to immersive media, inquiry units that incorporate immersive media, and publishable research. SPIRITED will disseminate findings to enhance scientific and technological understanding. Findings will be disseminated at conferences, the project website, and through a peer-reviewed publication (Table 5). Broader impacts include supporting a graduate student to develop as a designer of inquiry learning experiences and providing secondary students with a rich inquiry experience.

Table 5. Dissemination plans, including possible publications, presentations, and deliverables.

working title	*venue*	*dates*
Teachers as designers of technology inquiry experiences	Pre-conference workshop for the International Conference of the Learning Sciences 2012	Proposal submitted April 1st; Conference held July 1st-2nd, Sydney
Modified and extended versions of dome programs	Hosted on ARTS Lab and CARC servers	Mid July, 2012
(Title to be decided)	DomeFest 2012	Conference held July 27-28 2012, in Baton Rouge, LA
How being there immersively can reconfigure collaborative inquiry	American Education Research Association Annual Meeting 2013, SIG-Advanced Technologies for Learning	Mid July submission; Conference held April 27 - May 1, 2013, San Francisco
A case for immersive experiences of the abstract	Computer-Supported Collaborative Learning Conference 2013	Mid October submission; Conference held June 15th -19th, 2013
Curriculum and sample student work, aligned to Common Core State Standards and Next Generation Science Standards	Project website, hosted by ARTS Lab	Following refinement based upon implementations, Spring 2013

How being there immersively can reconfigure collaborative inquiry (revised based on AERA submission)	International Journal of Computer-Supported Collaborative Learning	Late Spring, 2013

g. Interdisciplinary Team

This project will bring together investigators from Teacher Education, Computer Science, and the UNM ARTS Lab, solidifying a nascent relationship. The team has been meeting regularly, first to develop a proposal for the NSF Cyberlearning program, SPPIRIT, and they have been drafting a preliminary EPSCoR proposal. Additionally, Dr. Svihla uses Dr. Kniss' classes as a site in her study of design learning. To support symbiotic interdisciplinary work, the team has begun practices to establish and maintain shared understanding across their areas of expertise. The team writes collaboratively via shared Google documents and a DropBox folder. The SPIRITED team includes members with complementary, integrated expertise in design learning in science, teacher education, computer science, instructional technology, and graphics/immersive media design. The members of the team have specialized training and experience related to their expertise, and also related to working on interdisciplinary collaboration. In her previous projects, Dr. Svihla has successfully partnered with engineers, science teachers, health professionals, and technology developers, leading to publications and technology-enhanced curricula. Her expertise in studying teachers designing inquiry, in co-designing technology with teachers, in studying how students learn to design, and her experience as a scientist and teacher will support this work. Dr. Waldschmidt's experience with local schools, her bilingualism, and her enthusiasm for helping teachers learn to use new technologies will provide vital support. Dr. Kniss' experience in programming computer graphics for immersive environments, as well as his deep interest in inquiry practices such as those he employs in his own teaching will provide complementary expertise. Mr. Beining brings experience in project management as well as in using immersive media for public outreach in museums and planetariums. Mr. Strawn contributes technical experience working with immersive media. Dr. Hagerman brings experience writing successful extramural grants. Together, these areas of experience and expertise are synergistic, allowing the team to take on innovative work at the intersection of cutting-edge immersive, interactive technologies and research on strong inquiry methods for teacher practice and student learning. This interdisciplinary partnership creates opportunities to address novel research questions about teaching and learning, and in particular, how technologies might support inquiry learning.

h. Research Timeline

Team activities began Fall 2012. Data collection related to this work began upon IRB approval, March 2012. Activities related to the proposed work are detailed in Figure 1, and in the phases below. See tables 4 and 5 for timing of proposal submissions and dissemination.

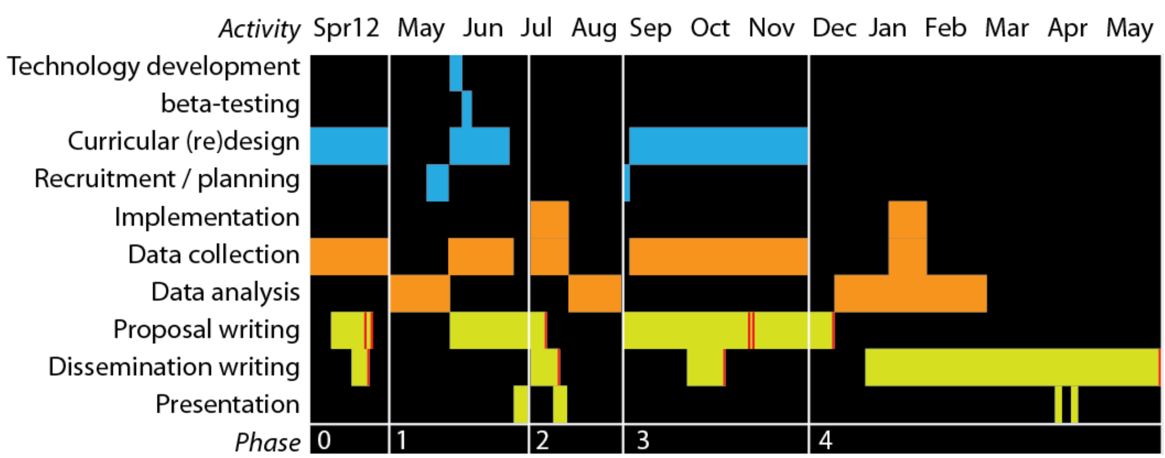

Figure 1. Timeline of activities across project phases.

Phase 0. Pre-project planning and data collection (Spring Semester). In March, students in the Spring 2012 course, *Project Based Instruction*, gave consent to participate in the study (n=9). They completed a pre-test and post-test measuring design skills, they reflected on readings related to design, and they turned in assignments drawn from professional design practice, including a *Voice of the Customer* assignment, as well as artifacts of design work. They completed a performance assessment as a midterm (given 2/29/2012) in which SPIRITED was described and initial design work (ideation) begun. They were given a tour of ARTS Lab (3/28/2012).

Phase 1. Planning and design (mid-May through June). Phase 1 will involve first analyzing data collected in Phase 0 as baseline data for teacher-designed inquiry units. Design work – of the immersive media and inquiry units-- will be documented through interviews and artifacts. Dr. Kniss and his assistant will extend/redesign existing immersive programs in ways that support learning. Dr. Svihla and her assistant will incorporate these into inquiry units, focusing on the nature of science and a physics simulation of particle collisions using the principles of the conservation of energy, the conservation of momentum, and the conservation of angular momentum.

Phase 2. Implementation and analysis (July-August). The second phase will comprise pilot testing of the inquiry lessons with UNM students (secondary students will also be included, pending MOU approval followed by approval of IRB modification). Implementations will be documented through interviews, video records, and artifacts. Dr. Svihla will present initial analysis at a pre-conference session (July 1-2), Teachers as Designers of Technology-Enhanced Learning Materials, for the International Conference of the Learning Sciences.

Phase 3. Design, data collection, and proposal writing (Fall 2012 semester). The third phase will comprise concentrated proposal writing based upon findings from prior phases as well as data collection of design work in the second instantiation of the *Project Based Instruction* course. Refinement of inquiry units developed in Phase 1 will be based upon this evidence as well.

Phase 4. Reimplementation, analysis, and dissemination (Spring 2013 semester). Conference proposals will be revised into a publishable manuscript, incorporating further analysis connecting design processes to designs for learning, and developing understanding of affordances and constraints for integrating immersive technology into inquiry learning. Data collected in phase 3 will be analyzed. The revised versions of units will be implemented with an emphasis on comparisons.

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