PROJECT DESCRIPTION

Learning to See, Seeing to Learn: A Sociotechnical System Supporting Taxonomic Identification Activities in Volunteer-Based Water Quality Biomonitoring is an **Innovations in Development** proposal to further develop and study a cyber-enhanced informal learning environment to support observational practices and classification skills in a citizen science context. In particular, we focus on the taxonomic ID bottleneck that hampers the acquisition of high-caliber biotic data needed for volunteer-based water quality monitoring efforts. We propose through a design-based research process to develop an innovative open educational resource, the Macroinvertebrate Identification Training Environment (MidTE) that makes the task of learning to identify macroinvertebrate easier and more engaging by developing a new kind of tool for guiding scientific observation and inquiry. This project builds on our high-resolution digital image collection of aquatic macroinvertebrates <www.macroinvertebrates.org>[1] that we will expand and reimagine with a co-developed set of learning supports that aim to increase public participation in monitoring the health freshwater resources. Our goal is to foster volunteer engagement, confidence, and accuracy in freshwater insect identification tasks by scaffolding observational practices and identification skills, thereby increasing the reliability and value of citizen-generated data for scientific research, conservation, and environmental decision-making.

Leading this three year interdisciplinary design research and development effort is the University of Pittsburgh Center for Learning in Out-of-School Environments (UPCLOSE) in close partnership with Carnegie Museum of Natural History (CMNH), Stroud Water Research Center, Clemson University (CU), and Carnegie Mellon University's (CMU) CREATE Lab and School of Design. We will collaborate in an iterative participatory design process with five regional volunteer biomonitoring organizations: Maryland DNR's *Stream Waders* program, Trout Unlimited's *Cold Water Conservation Corp*, Nature Abound's *Senior Environmental Corp*, Nine Mile Run Watershed Association's *Urban Ecostewards* and Dickinson College's *ALLARM* program*.* Through these partnerships we reach a diverse set of volunteers including rural populations, older adults and urban youth, and the trainers who support them.

A. Project Rationale

Taxonomy—the study of the diversity of life on earth—is one of the oldest forms of scientific practice. Systematically observing, classifying and naming organisms based on morphological features and evolutionary relationships is fundamental to many branches of science and their everyday application. Conservationists, ecologists, biologists, regulators, policymakers, citizen scientists and many others rely heavily on taxonomic information to monitor, manage, conserve, use and protect our biodiversity. But we face a critical worldwide shortage of high-quality taxonomic data, large gaps in taxonomic knowledge, and a dearth of trained taxonomists, curators and experts in biotic identification and classification. Known as the taxonomic impediment, the lack of taxonomic expertise, training, and certification has been recognized by state and federal agencies, as well as within the scientific community, leading to repeated calls for increased funding of research and training (Carvalho et al., 2005; Cotterill & Foissner (2010); Ang et al., 2013). Taxonomic bottlenecks stymie many citizen science and volunteer biomonitoring programs, which struggle to train observers for full participation in scientific research. In an era of tight funding, public participation in science is an increasingly vital resource for research, conservation, and regulatory programs that aim to monitor changes in populations, communities and ecosystems with broad spatial and temporal reach (Shirk et al., 2012; Dickinson et al., 2010)

Our project focuses on volunteer water quality monitoring programs where trained participants assess the conditions of their local streams, lakes, estuaries, wetlands and ground water resources. Since the 1990's there has been a steady increase in volunteer water monitoring activity in the US and worldwide. As of 2014, there are 1720 groups across the USA conducting volunteer water quality monitoring and

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[1] View the online collection with a HTML5 compatible browser (Chrome/Firefox) on PC or tablet devices. Click labels for **Order** & **Family Overview Pages** <http://macroinvertebrates.org/ - /ephemeroptera> <http://macroinvertebrates.org/#/ephemeroptera/heptageniidae>. Click images directly to explore the zoomable **Taxa Pages** with annotated diagnostic characters, in some cases with dorsal/ventral/lateral views selectable: e.g. <http://macroinvertebrates.org/ - /plecoptera/capniidae/allocapnia/lateral>.

associated activities.[2] A 2005 legislative report by The Center for Rural Pennsylvania revealed that, in Pennsylvania alone, there are more than 580 community-based watershed groups collecting water quality data, in addition to the state and federal agencies, private consulting firms and professional scientific organizations who regularly assess water quality for research and regulation purposes. With this trend, there is a critical need for more certified science professionals, educators, and a trained citizenry of amateur experts to meet the increasing public interest and demand for physical, chemical, and biological water quality monitoring—especially as government budgets for this work are shrinking (Pearson et al., 2011; Conrad & Daoust, 2008).

Biological monitoring—biomonitoring—is one of the most reliable, and widely accepted methods for measuring water quality and stream health over time (USGS, 1995; USEPA, 1997). High-quality biodiversity data that quantify species composition and richness are especially critical for effective ecological assessment of freshwater ecosystems. Effective biomonitoring requires regular sampling of underwater insect populations in set locations, ideally over the full geographic extent of a watershed. Productively involving volunteers in site sampling and species identification tasks increases the range and capacity of research programs to broadly monitor conditions broadly. However, the data quality issues endemic to scientific research such as sampling error and bias, poor data management, misidentification, and variable observer quality become more complex with the public's involvement in the research endeavor (Dickenson et al., 2010; Conrad & Hilchey, 2011).

In particular, water quality biomonitoring research programs require reliable species identification, at least to family or genus, to make accurate assessments. While the challenge of training lay observers to reliably identify benthic macroinvertebrates reliably is well documented in the literature (Penrose & Call, 1995; Engle et al., 2002; Nerbonne et al., 2003; Stribling et. al., 2008; Vetter, 2014), studies show that, with appropriate support, volunteer water quality ratings based on family level analysis metrics are consistent overall with expert findings to genus (Fore et al., 2001; O'Leary et al., 2004). In one study that directly examined the challenge of macroinvertebrate identification, Nerbonne and her colleagues looked at volunteers' abilities to correctly sort and ID macroinvertebrates using a family-level identification tool (Nerbonne & Vondracek, 2008). Their research indicated frequent "failures to see" as a primary cause of misidentification in volunteers. This work highlights the challenges of training students and volunteers to observe and identify, especially with existing learning resources.

Our project responds directly to these findings, exploring further why novices fail to see discriminating features, and then build on our research to develop socio-technical supports and training to help overcome the challenge of learning skilled observational practices, and ultimately to increase the number of well-trained volunteers who can participate in biomonitoring activities.

Learning to Observe Scientifically

Even in a highly technological age, observation remains a fundamental practice of science, especially in fields where deep looking is a core means of finding questions, generating data, and constructing evidence. Scientific observation is a highly refined and practiced form of attention that requires particular ways of coordinating the mind and eye. It draws on distinct forms of reasoning and relies on specialized tools and systematic techniques of description and representation in order to build accepted bodies of evidence (Norris 1985, Lynch, 1985). It is also a highly social practice, requiring organized communities of inquirers collaborating through time and space (Daston, 2008). The term observation itself has faceted meanings. Observation can mean visual perception, an empirical form of evidence, a technique with specific ways of recording and representing insights, or a community of practice endowed with particular conventions and standards for participation (Daston & Lunbeck, 2011). Each of these aspects of scientific observation is part of learning to see with a trained eye. But engaging and supporting powerful forms of visual observation is tricky and requires explicit educational scaffolding and mediation in both virtual and place-based learning environments (Stevens & Hall, 1998; Eberbach & Crowley, 2009; Phipps & Rowe, 2010; Zimmerman et al., 2013). Observation is a core competency in many fields of scientific inquiry, and central to developing the kind of entomological expertise that we seek to foster.

Tools for Guiding Vision

The guiding tool on which taxonomy rests is the dichotomous key, a decision tree with a succession of

[2] http://acwi.gov/monitoring/vm/programs.html

paired choices. In the late 18th century, the great French naturalist Lamarck realized the power of ordered binary statements as a means to teach botanical observation and classification skills. Despite its invention over 200 years ago, the taxonomic key remains remarkably unchanged as a cognitive tool and visual aid for learning to identify organisms. Illustrated pathway keys, which lead users though contrasting sets of character state choices to a single end point, remain the primary tool that students and scientists alike use to identify unknown organisms (Walter & Winterton, 2007). Despite their widespread use as an observational guide and diagnostic aid, pathway keys are difficult to use and do little to prevent learners from making wrong turns, or to provide ways to recover from error or overcome blind leads. Computer-based, interactive, and multiple-entry keys address some of these issues, but several problems remain Couplet comparisons commonly use specialized language, name difficult-to-recognize features, and often provide only black and white drawings of diagnostic features that can be difficult to see in actual specimens. Other kinds of ID tools include field guides, flashcards, and online keys that may include color photographs or illustrations of ideal types with one or two key characteristic "field marks" called out; in each a representational tradeoff is being made between photographic verisimilitude and illustrated emphasis (Law and Lynch, 1988). Most online tools are a direct translation of the static key into a tabular or hyperlinked format, with imagery that does not exceed screen resolution. These various forms of scientific inscription can be difficult to interpret for students and participants in training, especially given variability in the size, color, and form of field collected specimens found at different locations and lifecycle stages. The "gold standard" is a reference collection of actual voucher specimens, but these verified resources are usually available only to professionals in natural history museums and research organizations. Our project seeks to unlock these collections and expertise.

Our project seeks to develop an innovative cognitive tool for observation that augments existing taxonomic keys and guides by combining the overview qualities of a synoptic reference collection with the visual fidelity of high-resolution images, and supplemented annotations of diagnostic characters marked and linked to multimedia overlays that help guide perception and understanding. In the scientific field, great strides are being made to produce high quality digital reference collections for the research community; Sepsident, AntWeb, and iDigBio are good examples. However, as of yet, these impressive projects have not been optimized for informal science learning and training environments that support public participation in research. Our work will serve as an exemplar of a broader impacts goal for large-scale digitization projects, with a needed, innovative approach to education and public engagement (Newman et al, 2011; Ang et al., 2013). Our product also will serve as an example end point for taxa pages in online biodiversity reference projects, like the Encyclopedia of Life and Tree of Life.

Creating Rich Observational Environments with Gigapixel Technology

At the heart of the proposed MidTE system is networked gigapixel image technology. This is an emerging class of explorable interactive media, where high-resolution images viewed in zoomable, visual environments enable users to move seamlessly from full panoramic views to deep close-ups, often comprising billions of pixels (Albers, 2014). These dynamic multiscalar image viewers are most familiar in online mapping and geospatial browsing applications such as *Bing Maps* and *Google Earth,* but the information these viewers organize can extend well beyond maps to include large composite photographic images, and even computationally rendered data visualizations and time-series imagery (Nichols et al, 2013). The zoomable image interfaces that gigapixel viewers employ offer a spatial way to display and organize large amounts of information dynamically in a single interface using scroll, pan, and deep zoom controls and gestures (Bederson, 2011). Users can embed text, images, graphics, audio, and video at different locations and zoom levels within an image, creating localized sites for annotation, comment, and conversation (Luan et al, 2008). Compared to earlier forms of interactive media, multi-resolution image platforms afford deeper navigational agency and observational control in a shared visual space (De Rijcke & Beaulieu, 2011). Our CMU CREATE Lab partner has been at the forefront of this technical innovation and its transfer to an innovative medium for science communication and learning with projects funded by Google and private foundations, including Explorables, GigaPan and Fine Outreach for Science (Sargent & Nourbakhsh, 2010; Frankel, 2010).

Prior NSF Work

Our project builds upon a prior 2012 NSF ISE grant where UPCLOSE, CMNH, and CMU initially explored the affordances of gigapixel technology for scientific communication and informal learning [NSF/DRL

#1114476-*Gigapixel Cyberinfrastructure For Participatory Science Learning*]. The emerging technology platform we advanced included software and hardware innovations for creating, annotating, and dynamically viewing extreme resolution gigapixel imagery online. Our exploratory work to date suggests that these richly detailed interactive visual environments offer a powerful tool for scaffolding scientific observation and engaging learners in productive forms of disciplinary talk, perceptual reasoning and interpretation (Louw et al., 2014).

Our first demonstration project, *Stories in the Rock,* drew on a Public Understanding of Science approach to learning interactions in a museum setting (McCallie et al., 2009). We focused on engaging museum visitors in observing and interpreting richly figured ancient petroglyph sites in Saudi Arabia, the subject of active curatorial research that is difficult to communicate to public audiences using traditional museum exhibit approaches (Louw & Crowley, 2013). Summative evaluation results showed that the explorable image platform was intuitive across a broad range of age and visitor configurations (parent-child, adults, individual, school age), had unusually long dwell times for a museum interactive, and was generally compelling and enjoyed by the public (Sanford, 2014). The explorable image platform also supported rich kinds of interpretive talk around what visitors were observing—analysis of videotaped interactions indicated that visitors used annotated features and evidence from the image itself to reason and make meaning. Such results made us confident that we had developed an engaging, usable platform that supported disciplinary ways of noticing and reasoning about complex visual evidence (Louw et al., 2013). [Supplementary Documents: *Prior Work Evaluation Findings].*

We presented the *Stories in the Rock* viewer design process and evaluation findings at the 2014 American Educational Research Association annual conference, as well as the National Association for Research in Science Teaching, and Museums and the Web (Ansari et al., 2013). The application and impact of this work has supported several new project implementations, including the British Museum's 2012 *The Horse: From Arabia to Ascot* installation, the Museum of the White Mountains 2013 *Beyond Granite* exhibition, and the Heinz History Center's online/onsite archeological interpretation of Meadowcroft Rock Shelter, the earliest known site of human habitation in North America.

Our second demonstration project, most directly related to the current proposal, focused on applications of gigapixel technology for public participation in scientific research. One of our goals was to connect and leverage the expertise and collections of a natural history museum in ways that engaged and supported regional citizen science and environmental education programs. With a specialized GigaMacro photography rig, CMNH staff refined camera-ready specimen preservation techniques and perfected imaging protocols needed to create ultrahigh resolution images of insect type specimens across multiple views as required for diagnosis. The project team used open document/data sharing tools (Google Docs/Fusion Tables) as a content management system for order-, family-, genus-level annotations, and as a data entry tool for inputting taxa characteristics (feeding guilds, pollution tolerance values, distribution and habitat information). We developed a custom tool for pinpointing annotations in the x, y, z image space. To ensure accurate depiction of diagnostic character traits and the supporting overlay annotation media and copy, we consulted with Dr. John Morse, a renowned aquatic macroinvertebrate entomologist to review the online site and content (Morse continues as a collaborator in the current proposal.)

We engaged a graduate-level design student from CMU School of Design in an independent study for course credit to assist in front-end design research, prototyping and usability studies and to develop the visual and interaction design treatments, and prototype mockups. Through this prior work, the core project team established workflow processes, customized tools, and developed trusted working relationships that will support the future expansion of the system in this proposed project.

This past summer we evaluated the www.macroinvertebrates.org digital teaching collection using an embedded assessment approach with 21 high-school aged youth participating in "Creek Camp," a week-long environmental science summer program. Evaluation results demonstrate that youth were more correct in their insect identifications to family and genus when they used the digital teaching collection than when compared to other identification resources (Family-level Dichotomous Key (condition 1) and EPT Family Flashcards (condition 2). The findings also indicated that students using the digital teaching collection were significantly more confident in the accuracy of their identifications than when using the dichotomous key. In focus group sessions, the participating youth reported that they liked the detailed images (52%), the ease and efficiency of use (29%), and the way in which the insects were organized for viewing within the online interface (29%). Creek Camp educators acknowledged that the small size of collected specimens often made facilitating youths' insect ID work challenging. However, they felt that the technology's ability to zoom closely onto specific features of an organism helped to support observations. Furthermore, educators appreciated that the digital teaching collection provided engaging family- and genus-level information that helped them to go more in-depth than they usually could in a typical lesson.

We are presenting the macroinvertebrate digital teaching collection and our findings to the scientific community at the upcoming Entomological Society of America annual conference, and the Entomological Collections Network meeting, as well as at the 2015 Citizen Science conference. This demonstration project has also been shortlisted for the International 2015 Interaction Design Award.

Theoretical Approach and Design Conjectures

Our prior NSF-funded work validated our proof-of-concept, and laid the technical, design and scientific foundations upon which we now propose to build a full scale cyberinfrastructure platform to serve as an entomological reference collection of aquatic macroinvertebrate images and associated training environment for use in volunteer water quality monitoring research. We rely on collaborative design methods to involve key participants, stakeholders, and technical developers at critical phases throughout the design research and development process. Central to our design process is a human-centered approach that productively involves end-users from the inception of the project to ensure that design solutions respond directly to the needs and culture of a community (Sanders, 2008, DiSalvo et al., 2012), an approach increasingly being adopted in educational research (DiSalvo & DiSalvo, 2014).

Design based research in the learning sciences is a methodological approach to generating knowledge and evidence-based design principles that can be iteratively tested and refined through the development of a learning environment (DBRC, 2003; Kelly, Lesh & Beck, 2008). Critiques of DBR emphasize the lack methodical rigor, unclear standards of evidence and the need for defensible explanatory mechanisms that connect observed learning outcomes to specific features of a design (Pea, 2004; Dede, 2004). To address these methodological concerns, we draw on a "conjecture mapping" framework to make explicit the learning theories and evolving design conjectures that guide a design-based research program (Sandoval, 2004, 2014). Conjecture mapping draws links between the designed embodiment of an instructional idea to its enacted use by learners via a "mediating process" such as interactions between participants, use of tool affordances, participation in activity structures, or elicited discourses. We use this conjecture mapping approach to ensure that our development process meets criteria for rigor (e.g., as described in the Common Guidelines for Education Research and Development (IES & NSF Report, 2013), and as a way to build connections between the distinct disciplinary activities of design and learning research in a principled way.

For example, in our prior NSF-funded work, we began with the conjecture that "failing to see" morphological features of larval insects may be due in part to the lack of visual resolution and fidelity in the learning resources (keys) currently used. Furthermore, our early user studies suggested that inadequate lighting and wet lab resources for manipulating and viewing a specimen (alcohol, tweezers, brushes) as well as insufficient magnification, may also be contributing factors. Thus, one design conjecture we tested was whether pairing our high-resolution digital teaching collection with viewing aids (flashlights, low-cost 5x MacroLens, transparent plastic ware, and the provision of medium blue background preferred by entomologist for contrast) enabled learners to improve their perceptual skills and identification accuracy. Our evaluation results support this design conjecture—participants were more accurate when using the digital tools and viewing aids. But, more importantly, by framing the design conjecture as providing access to high-quality images and better observational materials, we found ourselves needing to be more specific about potential mediating processes that could explain the increases in performance, and account for other features of the learning environment or learner experience that could be contributing to our results. In other words, our conjecture mapping approach going forward will highlight more than just whether something works, it also supports a deeper analysis about why a designs works, and for what kinds of learners, under what conditions. [Supplementary Documents: *Prior Work Evaluation Findings].*

We will draw our design conjectures from three well-established theoretical frameworks in the learning sciences: cognitive apprenticeship, modeling expert performance, and scaffolding inquiry processes. We situate the design of our training environment in a cognitive apprentice framework that outlines a productive sequence of instructional strategies—modeling, coaching, scaffolding, articulation and reflection—and which emphasizes learning as participation in a culture and community (Collins, A., 1991, 2006). Cognitive apprenticeship theory is particularly applicable to citizen scientist work, which requires participants to join a scientific community of practice; in our case an entomological tradition of classification and observation with particular inscription systems and cultural conventions. Within this cognitive apprenticeship model, we will source our conjectures for how to appropriate technology productively as a cognitive tool in two well established methodological lines of research–cognitive task analysis to study expert practice (Hollan et al., 2000; Qin & Simon, 2000), and scaffolding frameworks for inquiry learning, in particular forms of science inquiry which draw on observation and visual interpretation of scientific representations (Edelson & Gordin,1998; Quintana et al., 2004; Smith & Reiser, 2005). We fully recognize that scaffolding needs to be distributed across the whole training environment, not only in the technology, but also in resources in the physical environment and in social supports (Tabak, 2004; Pea, 2004). Our design research program, explained next, will produce a description of expert practice in entomological identification activities and derive an evidence-based set of scaffolding guidelines for in-system and in-environment supports to guide learning observation and classification tasks.

B. Project Design

Our goal is to create an effective socio-technical system that support volunteers learning to identify aquatic insects for research projects that require biomonitoring. We envision a training system that will be used by volunteers during in-person training sessions, for online practice sessions (skill development games/challenges), and while performing taxonomic ID analysis for water quality assessment. We partner with five volunteer biomonitoring organizations (VBMOs) as design collaborators throughout the project to ensure that key participants and stakeholders are involved at critical phases throughout the research and development process. Over three years, our interdisciplinary project team will work closely together to design, prototype and implement the Macroinvertebrate ID Training Environment (MidTE) that includes an innovative taxonomic ID software tool, facilitation guides and training materials. We organize the main project work into four integrated strands of activity: design-based learning research, creation of an entomological teaching collection, cyberplatform development, and the external evaluation of the training system. Table 1 provides an overview of project activities and associated project deliverables. We describe these activities in more detail below, and provide an overview of the external evaluation plan in Section E.

Table 1: Project Workplan

YEAR 1 Design & Development Activities	Project Deliverables	Evaluation Activities
Design Research (Generative) [UPCLOSE, CMU Design, Stroud] ▪ VMBO Case Studies ▪ VBMO Training Materials/Practices Inventory ▪ Expert Performance Analysis ▪ Visual/Navigation/Interaction Design Studies ▪ Design Conjectures Workshop [Full Team]	*Typology of VBMOs [UPCLOSE, Stroud] *VMBO Training Best Practice Review [Stroud] *Expert Performance Analysis [UPCLOSE] *Design Exemplars [CMU Design] *Program & Volunteer 'Scenarios of Use' *VBMO Baseline Evaluation Report [REA] *MidTE Conjectures & Vision Document	**VBMO Baseline Evaluation** [Rockman et al, REA] - Embedded Assessment of ID Accuracy - Engagement & Attitudes Survey (Volunteers) - Instructional Strategies Survey (Trainers) - Trainer Self-Efficacy Survey (Trainers) - VBMO Interviews (Program Staff) - VBMO Volunteer Participation & Retention Survey (Annual) *Advisor review of baseline evaluation instruments (Phillips) ** (5 x VBMOs)
Scientific Collection [CMNH, Clemson, Stroud] ▪ Entomological collection planning ▪ Voucher specimens (50+) collected, verified, prepared ▪ High-resolution macrophotography ▪ Scientific Content Development	*Validated list of macroinvertebrate taxa *Macroinvertebrate type images completed (ventral, lateral, dorsal views) [CMNH] *Multimedia digital annotations of diagnostic characters [Clemson]	

Cybertechnology System [CREATE Lab] ▪ Evaluate system architecture ▪ Transition to client/server model ▪ Custom CMS optimized and scaled	*Implemented CMS system w/data entry tool, multimedia overlays and diagnostic character annotations, and taxa pages copy editing	
YEAR 2		
Design Research (Implementation) [UPCLOSE, CMU Design, Stroud] ▪ Design Conjectures Synthesis ▪ Design Conjecture Studies ▪ Study MidTE Prototype I & 2 ▪ Develop test, refine training materials for Prototype System 1 & 2 *Advisors reviews instruments, prototypes (Koedinger, Zimmerman) *Advisors review of training materials, prototypes (Stepenuck, Donkersloot)	* Conjectures–Design Propositions Map [UPCLOSE, CMU Design] *Guiding vision document and user scenarios signoff [Project Team + Advisors] *Design Storyboards, wireframes, info arch [UPCLOSE, CMU Design] *Training Materials & Activities v1, 2 [Stroud] **Name that Macro* paper-based game [Stroud+CMU Design] *Formative evaluation reports w/baseline data	<u>MidTE Prototype System v1Eval</u> - Embedded Assessment of ID Accuracy (Volunteer) - Engagement & Attitudes Survey (Volunteer) - Focus Groups (Volunteer) - Survey Instructional Strategies (Trainer) - Self-Efficacy Survey (Trainer) - VBMO Program Staff Interviews *Advisor review instruments/coding scheme <u>MidTE Training System v2 Eval</u> - ID Accuracy Embedded Assessment (Volunteer) - Engagement & Attitudes Survey (Volunteer) - Focus Groups (Volunteer) - Survey Instructional Strategies (Trainer) - Self-Efficacy Survey (Trainer) - Training Observations &Interviews - VBMO Program Staff Interviews - VBMO Volunteer Participation & Retention Survey (Annual) *Advisor reviews analysis, report (Phillips)
Scientific Collection [CMNH, Clemson, Stroud] ▪ Production/refinement of scientific content and annotations ▪ Macroinvertebrates specimen casts	*Diagnostic character annotations and taxa page content completed [Clemson] *Physical collection of macroinvertebrate casts for training kit. [CMNH]	
Cybertechnology System [CREATE Lab] ▪ Tech feasibility studies for visioning ▪ Iterative software development of MidTE Prototype System 1 & 2 ▪ Develop/instrument MacroID game ▪ Integrate custom learning analytics	*Technical system requirements doc *Offline and online version of MidTE tested *Prototype Training System 1 (Implemented) *Practice MacroID game released *Prototype Training System 2 (Refined)	
YEAR 3		
Design Research (Synthesize) [UPCLOSE, CMU Design, Stroud] ▪ Research Analysis and write-up ▪ Prepare materials for dissemination *Advisors review data analysis, training materials and learning products	*Release MidTE training materials *Project website and blog documentation *Academic / practitioner publication submits *Creative dissemination activities *Summative Evaluation Report	<u>MidTE Summative Evaluation</u> - Engagement & Attitudes Follow-up Survey (Volunteer) - Survey of Instructional Strategies Follow-Up (Trainer) - Self-Efficacy Survey Follow-Up (Trainer) - VBMO Project Staff Interviews - Scientist Interviews - VBMO Survey of Volunteer Participation & Retention (Annual) Summative Evaluation Analysis (Volunteer, Trainer, VBMO Org Impacts) *Advisor review of summative evaluation instruments to be fielded
Scientific Collection [CMNH, Clemson Stroud] ▪ Media Rights Clearances [CMNH] ▪ Peer review science content [Stroud] ▪ Museum review system copy [CMNH]	*Peer reviewed system for scientific accuracy *Dissemination activities with entomology, biomonitoring professional community *VMBO engagement activity workshops	
Cybertechnology System [CREATE Lab] ▪ QA/QC online & offline versions ▪ Cross platform/device interoperability ▪ Search optimization	*Release MidTE application (online & offline versions for PC and tablet devices) *Open source documented code for Taxonomic ID collection platform	

YEAR 1 PROJECT ACTIVITIES

We begin with preparatory work to develop a fully realized sociotechnical system to engage learners in improving observational skills and classification practices. As described above, our work will be guided by design conjectures we develop around modeling expert practices, scaffolding disciplinary ways of observing, and supporting participation through a cognitive apprenticeship model. There will be opportunities for modeling, coaching, practice, articulation and reflection built into the system, training materials and facilitation activities. We will also track whether improved biomonitoring skills, accuracy and confidence translates into increased volunteer motivation, interest and participation outcomes.

STRAND 1: Design Research (Generative)
The core design team, led by UPCLOSE and including the CMU School of Design and Stroud Water Research Institute, will collaborate on a set of design research studies. The findings and products from this work will inform the Design Conjectures Workshop convening at the end of Year 1 with the full project team and advisors; and provide the basis for a shared vision document that describes a system design of a training environment that will be fielded for two cycles of testing and evaluation in Year 2 prior to public release in Year 3.

<u>Design Study 1: VBMO Case Studies [UPCLOSE lead w/CMU Design + Stroud]</u>
The five participating VBMOs represent a broad set of biomonitoring programs that range from urban to rural in focus, include state agency and community-based watershed organizations, recruit volunteers from diverse populations including seniors (+55), fishing hobbyists, and urban youth “ecostewards,” and involve volunteers with diverse motivations ranging from environmental stewardship to watchdogging and public engagement. Using a design case study approach, we will characterize the five VBMOs along sets of dimensions including: programmatic goals; audience type; biomonitoring data use; and training methods. We will draw upon participation frameworks that characterize citizen science activities along a contributory to co-design axis (Bonney et al, 2009), and also draw upon on our project advisor's work describing individual, community and program impacts in volunteer monitoring to establish these dimensions of analysis (Stepenuck, 2013). Working together, researchers from CMU Design and UPCLOSE will draw on cognitive ethnography and contextual inquiry methods to observe and document the VBMO training environments and practices—noting facilitation techniques, volunteer interactions, observational and reasoning strategies, and materials use (Hollan et al., 2000; Holtzblatt & Jones, 1993). Informed by these data, we will develop a training environment typology that the project team will use as a resource for design inspiration, conjecture mapping, and prioritization. This work will also lead to the user scenario development activity we will conduct in the Design Conjecture Workshop that leads ultimately to the guiding MidTE vision document to be produced at the end of the year.

<u>Design Study 2. Training Materials & Practices Inventory [Stroud lead w/UPCLOSE + CMU Design]</u>
Stroud’s education program manager will survey and review biomonitoring training programs across the nation [e.g. EPA, National Water Quality Monitoring Council (NWQMC)] creating an inventory of current training practices, identification tools and materials, data collection sheets, biotic data use, quality assurance and control protocols, and certification programs. Through semi-structured interviews with trainers from our partner VBMOs, we will identify best practices and perceived obstacles to training and volunteer participation. Particular attention will be paid to cataloging programmatic touch points with volunteers: during training (face-to-face and online), in-between sessions (program communications, and online skill building and activities), and during performance of macroinvertebrate data analysis activities. The interview questions, surveys, and data collection and documentation will coordinate with activities in Study 1 to realize a rich data set that we analyze to address multiple, emergent questions posed by the project team as the project evolves.

<u>Design Study 3: Expert Performance Analysis [UPCLOSE]</u>
Drawing upon methods and theories from the learning sciences to model expertise (Chi, 1997; Clark, 2008), and guided by project advisor Dr. Ken Koedinger who is expert in this area, we will conduct a study of 10 professional entomologists and “prototaxonomists” who identify macroinvertebrates as part of their water quality assessment research and graduate training. These experts will be recruited through our

science and VBMO partners. We will observe experts going through their typical identification processes, videotaping their practices and asking them to talk aloud as they work. Because the expert skills we seek to support in our training rely deeply on visual experience and perceptual reasoning, we draw on research techniques that pay particular attention to the ways in which experts marshal resources to aid perception and track the apparent advantages and limitations of certain visual resources and tools (e.g. key, illustration, flashcards or light tube microscope etc.). We will log verbal tips and tricks mentioned for positioning lighting, or manipulating a specimen to see barely perceptible features that are key to an accurate diagnosis. Additionally, the precise use of linguistic terms to describe color, shape, position and angle is highly developed in entomology, and more generally in the observational sciences. For example, a classic cognitive psychology paper on developing expertise in chick sexing showed learner performance could be dramatically improved by the use of short, simple instructions that provided precise descriptions of contour (Biederman & Shiffrar, 1987). The results of our expert study will help establish an understanding of perceptual learning that can inform the design of training materials, and provide insights into how multimedia overlays of diagnostic characters should be created in terms of activity sequencing, language choice, and use of visual representations.

Design Study 4: Visual, Interaction & Navigation Studies [CMU Design]

A faculty and graduate student team from CMU's School of Design will identify a set of "design precedents" to understand the configurations and affordances of various aspects of the system to be developed, including multiscalar, zoomable user interfaces, gigapixel viewers, digital annotation strategies, and innovative online training systems. The designer will also survey existing taxonomic learning resources collected in Design Studies 1 and 2 to analyze their qualities as information design artifacts. This ongoing activity requires sourcing inspirational (near and far) examples of visual, interaction and navigational design solutions, and synthesizing these into a presentation form that the project team will be able to reference collectively and to develop a language around in order to imagine and make design choices (Boling & Smith, 2012). We have found in prior work that this kind of synthesis of design exemplars can also serve as a front-end team building exercise that facilitates a shared visual vocabulary and set of references by which to imagine and assess various design directions as the team moves forward (Louw et al., 2014).

Design Activity 5: Design Conjectures Workshop [Project Team + VBMOs + Advisors]

Near the end of Year 1, the project team will convene a 2-day workshop with our collaborating VBMOs and external advisors. We will explore the implications of findings from the design research and baseline evaluation and collectively draw upon the VBMO training typology work, and volunteer user scenarios we have developed. We will also conduct a series of generative design activities and elicitation techniques to gather ideas and to prioritize system and training material requirements. The meeting will focus on developing a set of design conjectures based on modeling expert performance, scaffolding observational inquiry, and supporting a community of practice through a cognitive apprenticeship framework which emphasizes modeling, coaching, scaffolding, articulation and reflection. The outputs of the meeting form the basis for the vision document and system requirements list will guides design research and development in the second year.

STRAND 2: Creating the Scientific Collection

During Year 1, our scientific leaders at CMNH and Clemson will begin expanding the aquatic macroinvertebrate digital teaching collection from the three ETP (*Ephemoptera*, *Plecoptera*, and *Trichoptera*) orders to include 50+ taxa typically found in watersheds of EPA Level 1 Ecoregions 5, 8, and 9 (Northern and Eastern Temperate Forests, and Great Plains, respectively). This requires collection, expert verification and preservation of type specimens, followed by special preparation and mounting of the specimens for high-resolution, focus-stacked imaging across three views (dorsal, lateral, ventral), large file digitization, and photo treatment of final images. Entomologist Dr. John Wenzel, Director of the CMNH's Powdermill Nature Reserve, will lead these activities. Dr. John Morse, an aquatic entomology expert at Clemson University, in conversation with Stroud researchers, will determine the final selection of taxa for the collection, and direct the scientific content development and multimedia annotation of each diagnostic character for order-, family-, and genus level taxa. Approximately 600 individual multimedia annotations will be created to support positive identification. Based on the above studies, the designers will work with the science team to determine the appearance and layout of these annotations as expert guidance scaffolds.

STRAND 3: Technology Research & Development

The CREATE Lab at Carnegie Mellon University will evaluate the existing prototype system architecture in consideration of developing a full-scale cyberlearning platform. Lead programmer Chris Bartley will begin the front-end work of upgrading the underlying content management system (CMS) and the interest-spot-locator tool we developed for www.macroinvertebrates.org to support a more complex system by addressing usability issues, improving tool edit features and version control requirements for multi-user data entry scenarios. Other foundational upgrades we will make for full development include transitioning the system to a client/server model backed by a relational database platform (Node.js, MySQL). The software engineering team will also participate in the design exemplar building and workshop activities describe above.

YEAR 2 PROJECT ACTIVITIES

The second year begins the major implementation phase of the project and is divided into two cycles of iterative development, each testing a fully functioning MidTE system during training sessions run by our VBMO partners.

STRAND 1: Design Research (Implementation)

Design Study 4 | Mapping Learning Conjectures to Design Propositions [UPCLOSE, CMU Design]

Our work in the first part of this year will be to take instructional ideas and design conjectures coming from our evaluation findings, user studies, expert task analysis and workshop discussions and turn them into a usable set of design propositions which take form in tool affordances, information design elements, knowledge representations, and through discourse and activity structures. These design propositions will be spread across the training environment – in the ID tool, in facilitation strategies, and in training activities and materials. This conjecture mapping and synthesis work will result in the creation of a guiding vision document that we share with our advisors and the VBMOs for comment and revision.

Design Activity 5 | Storyboards, Wireframes, and Information Architecture [CMU Design]

Based on the vision document, CMU School of Design, in collaboration with UPCLOSE, will produce a set of system requirements with storyboards and wireframes that map MidTE user interactions, features, functions, navigation and information layers. To ensure technical feasibility, we will work closely with the CMU CREATE Lab in developing these design documents. Our external advisors and collaborating VMBOs will be engaged in reviewing these visual design products prior to any implementation. To support quick formative design and usability studies, CMNH will create a “pop-up” watershed exhibit area in the museum where we can test early prototype ideas and detect usability issues with museum-going audiences and youth programs.

Design Activity 6 | Training Materials and Activities Development. [Stroud]

Using insights gathered during the first year of design activities, Stroud will develop a training kit that includes a downloadable PDF training guide supporting MidTE. Although the details may change as a result of our design process, we currently expect the kit to include: 1.) An image-rich instructional presentation deck for trainers to adapt for biomonitoring training needs, and tied to a matrix of training goals and resource availability (e.g. family vs. order ID, half-day vs. full-day, dissecting scopes or hand-lens use, field vs. indoor ID, etc.); 2.) Narrated video tutorials showing trainers and volunteers how to use MidTE and the supporting tools and activity modules; 3.) A print-based “Name that Macro” game to practice ID experiences for skill building and self-assessment. This analog game will serve as the first iteration of an online version of an ID practice game we plan to deploy in the second round of field testing.

Field Tests: MidTE Prototype System 1 & 2

Mid-way through Year 2, we will field test the first version of the MidTE system including version 1 of the training materials developed by Stroud. This alpha training system will be tested with the five partner VBMOs that, on average, train 10-20 volunteers in a session. The design research team will continue to use using contextual inquiry, observation, and task analysis methods as well as surveys, focus groups and interviews with volunteers and trainers to collect data for video/audio transcription and analysis. The case study and typology work done in Year 1 will help us characterize the training environment, and detect the interplay between in-system and facilitation supports. External evaluation will focus on the questions of whether MidTE worked and whether it works as well with the different kinds of volunteers across the VBMOs. With the research and evaluation findings in hand, we will then analyze and reflect upon what is working, modify our design conjectures, and plan and build the next set of technical and training refinements. We will use the same methodologies to test the revised system on a second round of VBMO-based trainings.

STRAND 2: Scientific Collection Development [CMNH + Stroud]
Our science partners will continue production of high-resolution images and refinement of multimedia digital annotation. For example, if our prototyping or evaluation results show high ID error rates with a particular macroinvertebrate family, we will refine the relevant annotation scaffolds. Additionally, CMNH will create a physical reference collection of macroinvertebrates (specimens embedded in resin blocks) as another type of visual aid (actual size/scale) for the training kits. The museum will clear media rights for copyrighted images used in the collection. Stroud and CMNH will also perform a full review of the digital teaching collection for scientific accuracy, and communication with non-specialist audiences.

STRAND 3: Cybertechnology Platform Development [CMU Create Lab]
The CREATE Lab will conduct feasibility research to inform the vision document. Engineering time will be devoted to the iterative software development of MidTE prototype system 1 and 2 during this year. The system will serve both online web-based clients, and can be stored locally as an application to account for training and use in field environments where Internet access is very slow, or non-existent. Each VMBO will receive a set of touchscreen computing devices with the system loaded for testing and IT support to set-up MidTE for optimal performance for their site and volunteer population. Additional development activities include creating a working prototype of the "Name the Macro" identification game and a practice test instrumented with learning analytics and in-system tutoring tips. Underlying this specific deliverable is a view toward future project scaling for online volunteer certification programs. The Missouri Department of Conservations' flagship Stream Team Program certifies volunteers across four levels of training with the result that citizen collected data is used to inform policy and regulatory decision-making in that state. Our advisor Donkersloot who leads the NJ DEP volunteer biomontioring program is moving in this direction as well. Furthermore, project-trained volunteers will be given the opportunity to attempt the rigorous family-level and genus-level taxonomic certification examinations administered by the Society for Freshwater Science, Taxonomic Certification Program http://www.sfstcp.com/ for which collaborator Dr. John Morse serves as Co-Chair.

YEAR 3 PROJECT ACTIVITIES

The final year of the project is devoted to research analysis and building evidence to move our design conjectures into design guidelines and strategies. In project activity strands 2 and 3, the technical aspects of the system will conclude with final quality assurance testing across browsers and device platforms, and scientific activity will focus on a full peer review of the system's entomological accuracy followed by outreach to the entomological research and professional biomonitoring community. Each participating VBMO will receive pre-loaded, touchscreen tablets (final device TBD) with large data storage capacity for the entire MidTE collection to be served locally. In preparation for public release, the design team will complete usability studies and address final issues. With public release of the MidTE system, the final year focus is on generating learning design principles and strategies to scaffold observation and taxonomic ID skills.

Although our project focuses specifically upon biomonitoring of water, the underlying observation and diagnostic skills and practices we support are broadly applicable across topics of informal science (e.g., paleontology, geology, archeology, phenology, and, of course, other domains of biology). Our findings concerning facilitation and scaffolding will be relevant for other cyber-enabled training environments. Our findings with respect to the different volunteer audiences will inform to other citizen-science projects looking at volunteer skill development and training. Thus, in Year 3, the design research team will finish their studies and publish research findings on how a sociotechnical system can engage a wide range of volunteers and scaffold observational skill development and expert performance gains. Our design partners will also produce knowledge artifacts in the form of annotated portfolios to reveal design strategies for guiding observation, and produce design case studies that document the process and findings in ways that are relevant to this professional community (Boling, 2012; Gaver, 2013; Löwgren, 2013). Stroud and our partner VMBOs will engage the research and volunteer water monitoring community through their professional networks.

With volunteer certification and the NSF innovation cycle in mind, we see this project growing next towards a full scale Implementation Project. The proposed MidTE system will serve the Eastern United States, but could be scaled more broadly thereafter to include macroinvertebrates relevant to other regions and be moved toward a full online certification and training system for volunteer water quality monitoring.

C. Dissemination Plan

The project team will utilize multiple channels for dissemination and knowledge sharing. Co-investigators through their respective academic and professional communities will reach the learning science and educational research fields, design and human-computer interaction, ISE evaluation and media-making, entomology, freshwater biology, and computer science fields. Project materials will be disseminated in print and online formats, and a dedicated external project website will be created from our internal project blog. We will work with external advisors Dr. Stepenuck and Ms. Donkersloot and our VBMO partners to share project materials and insights with extension and volunteer water monitoring communities, and raise awareness of project resources through the National Water Quality Monitoring Council's network, via newsletters and conference presentations. Stroud regularly attends USDA's Water Monitoring Network meetings, the bi-annual USEPA National Water Monitoring conferences, as well as River Rally events and Water Conservation District Summits. Case studies and project information will also be shared in practitioner publications (e.g. The Volunteer Monitor) through online posts and project materials and reports will be uploaded to informalscience.org and citzenscience.org. To support our partner VBMOs in developing public engagement strategies, CMNH's exhibit and education staff will work with each group to develop creative hands-on tabling activities (which include presentation of the MidTE tool on a tablet device) to raise awareness about the role of macroinvertebrates in assessing water quality, raising awareness and interest in biomonitoring and recruiting for the programs.

D. Evaluation & External Review

External evaluator *Rockman et al* (REA) will use a mixed-methods approach that incorporates recommended guidelines for assessing outcomes from citizen science projects (Phillips et al, 2014). REA's evaluation focuses on three audiences: volunteers; trainers; and water biomonitoring organizations.

1. <u>Does MidTE impact **volunteers'** accuracy, confidence, and engagement in taxonomic classification activities related to macroinvertebrates?</u> REA will modify an embedded assessment activity previously employed in our pathways project, incorporating methods and analyses utilized by Newman et al (2010). Here, volunteers from each of the participating VBMOs will be asked to identify several unknown aquatic insects at the Family and Order level, list the diagnostic characteristics they used to make their determinations, and to self-report how confident they feel that their classifications are correct. In Year 1 of the project, REA will collect baseline information about volunteers' level of accuracy, use of precise terminology, and explanations for their classifications using existing training program materials, identification tool(s) and protocols. In Years 2 & 3 of the project, VBMOs will adapt and replace current training systems with MidTE to determine whether volunteers become more accurate when using the prototype and final versions of the system. Each year, the time that it takes volunteers to identify each insect will also be recorded to determine whether volunteers are also becoming more efficient in classifying aquatic insects with the digital teaching collection, compared to the baseline traditional key.

To investigate whether training with the digital teaching collection affects volunteers' attitudes towards and engagement in water quality biomonitoring activities, REA will survey volunteers after they complete the embedded assessment each year and three months after the training as a follow-up. Open-ended and Likert scale survey questions will probe for changes in volunteers' opinions of and participation in citizen science, in general, and water quality biomonitoring programs specifically, including their thoughts about the importance of accuracy in biomonitoring programs, their involvement in other citizen science efforts, and perspectives on the data they provide (Char et al, 2014; Crall et al, 2013). Volunteers' confidence in and opinions of the efficiency of the digital teaching collection compared to traditional classification resources will also be explored via the annual survey (Jordan et al, 2011).

In Year 1, REA will also conduct baseline focus groups sessions with volunteers at each of the participating VBMO's to find out what they think is most challenging about aquatic insect identification, what they think about the various tools and resources they currently use, and what gaps they see in their training. After using either MidTE system1 or 2, REA will again hold focus groups with volunteers, this time asking them what they liked and disliked about the tool and the training, what features they found to be particularly engaging, what they found out about macroinvertebrate identification from the training, any challenges they encountered in understanding or completing the training, and any suggestions they have for improving the materials (Rubin, 1994). REA staff will also ask volunteers to provide examples of their use of the technology, any additional citizen science-related programming in which they have participated, and what they have learned about citizen science, in general (Cronje et al, 2011).

To facilitate the above data collection and to gather additional information about how volunteers are being trained, REA will conduct site visits at each of the participating VBMO's and take observational notes during training to see how trainers incorporate the various tools (traditional key in Y1, MidTE Systems 1 & 2 in Years 2 & 3), whether volunteers maintain their focus during identification tasks, and the nature of volunteers conversations about and interactions with the training and technology.

2. Does the MidTE system impact the **trainers**? Do they develop a better understanding of, and increased self-efficacy for ways to use technology to support volunteers' learning macroinvertebrate ID? REA will distribute a survey to trainers (at baseline in Y1, after using MidTE in Years 2 and/or 3, and three months later) to examine changes in their self-efficacy around preparing volunteers for taxonomic classification tasks and their understanding of ways to use technology to support volunteer's training in macroinvertebrate identification. Survey questions will be modified from the *Self-Efficacy for Learning and Doing Science* protocol (Cornell Lab of Ornithology, 2014), created for the NSF-funded DEVISE project. In addition, trainers at participating VBMOs will be interviewed at baseline in Year 1 and again after the incorporation of MidTE Prototype Systems 1 & 2 to determine their strategies for assisting volunteers in identifying an unknown aquatic insect, and what they find difficult about training volunteers, and what aspects of the training and technology (if applicable) they felt were successful and unsuccessful (Kountoupes et al., 2008).

3. Does the MidTE system impact **volunteer biomonitoring organizations** (VBMOs)? Does the training increase the number of volunteers within these organizations and retain their participation over time? Do VBMO's increase their use of data to make decisions about water quality and the number of partnerships they have with outside organizations and policymakers? To investigate the impacts of incorporating the digital teaching collection into volunteer training on VBMOs, REA will interview program staff members at participating VBMOs in Year 1 (baseline), after the incorporation of MidTE System 1 & 2 (Years 2 & 3), and three months later. Interview questions will focus on differences staff perceive between past and current program offerings, their use of volunteer data, partnerships with outside organizations and policymakers, and use of the digital teaching collection in their public engagement, recruiting and outreach activities (Riesch et al., 2013; Conrad & Hilchey, 2011; Milne et al., 1996). In addition, REA will quantify the number of training programs each VBMO provides, and track the number of volunteers being trained over the course of the project within each of the participating organizations, to see if participation increases and is maintains over time (Bonney et al., 2009). To further address how data provided by volunteers within the participating VBMOs is valued, REA will also interview a subset of scientists (N~5) asking them about the potential uses they see for the data being produced through the VBMOs, and whether they have confidence in their accuracy (Riesch & Potter, 2014). REA will provide the project team

with feedback via annual evaluation reports, or as requested by NSF. The summative evaluation report will be uploaded on informalscience.org and we will continue to present our evaluation findings at conferences such as Citizen Science, AERA, and NARST.

External Review

To advise and deepen our thinking in critical areas, we have invited an advisory board to review our work plans, research design and learning products annually and to provide guidance on our implementation strategies and dissemination opportunities. Advisors will gather in person at the Design Conjectures Workshop in Year 1. In the second and third year, we will organize advisory working groups around project strands of work. Advising us in evaluation design and impact measures will be **Tina Phillips**, Evaluation Program Manager at the Cornell Lab of Ornithology, and **Dr. Cathlyn Stylinski**, Research Faculty at the University of Maryland Center For Environmental Science, Appalachian Laboratory. **Dr. Ken Koedinger**, Professor of Human Computer Interaction and Psychology at Carnegie Mellon University and **Dr. Heather Zimmerman**, Assistant Professor of Education in the Learning, Technology and Design Program at Penn State will advise our application of learning sciences theory to design research studies, and review our research instruments, data analysis methods, and learning analytics development. **Dr. Carl DiSalvo**, Associate Professor in the School of Literature, Media, and Communication at Georgia Institute of Technology and Co-Editor of *Design Issues* will provide guidance and review our design practice research, process and products. To bring a national perspective and expertise on volunteer biomonitoring programs**, Dr. Kris Stepenuck** of Wisconsin Water Action Volunteers Stream Monitoring Program, and Extension Volunteer Monitoring Network representative, and **Danielle Donkersloot**, the State Volunteer Monitoring Coordinator for the New Jersey DEP and Volunteer Monitoring Representative for the National Water Quality Monitoring Council, will contribute to our working group on our case study design and training material development.

E. Project Management

One of the strengths of this project is the interdisciplinary team assembled that represents significant expertise in (1) volunteer biomonitoring program development and training; (2) ISE and media project experience; (3) cyberinfrastructure development; (4) high performance software/hardware engineering (5) science communication, (6) evaluation and (7) learning sciences and design research. Core project team members CMU, CMNH and UPCLOSE work at institutions in short walking distance of one another enabling frequent face-to-face meetings, hands-on discussions with prototypes, and real-time white boarding to problem solve. The additional members of the team, Clemson and Stroud, have already established a working relationship through the development and implementation of a highly respected international taxonomic certification program sponsored by the Society for Freshwater Science and Clemson has taught intensive freshwater macroinvertebrate workshops at Powdermill Nature Reserve for the past 4 years.

In terms of management, we will continue with and expand the effective project management structure we developed in our Pathways grant, to include new core partners Stroud and Clemson. In addition to annual project meetings, we will collaborate on project design and materials developments via monthly Google hangout sessions. The PI Louw will coordinate, document, and manage the integration of three working groups along activity strands with a documented annual review session with advisors at key points in the design, implementation and dissemination phases. We will convene monthly working groups around Scientific Content and Image Collection Development (Stroud, CMNH, Clemson). The Design Team (CMU Create Lab, Design and UPCLOSE) meets twice a month with the PI on campus and includes Stroud in design and development conversations via teleconferences, online collaboration tools and prototype sharing.

Marti Louw, Research Faculty at the University of Pittsburgh Center for Learning in Out-of-School Environments (UPCLOSE) as PI will oversee the platform development, ensure the integration of activities across the technical, scientific, and design team, and cooperatively plan, coordinate and host the Design Conjectures Workshop, address recommendations for the advisory work groups, and manage the baseline, formative, and summative evaluation process and platform release into a fully develop sociotechnical learning environment for taxonomic identification. As Co-PI **Kevin Crowley**, Professor of Learning Sciences and Public Policy, and Director of UPCLOSE will assist Louw on project management, participate in the design research team, and supervise the learning sciences graduate student and undergraduate researchers who are part of the research team.

Illah Nourbakhsh, Professor of Robotics at Carnegie Mellon University's Robotics Institute and Director of the CREATE Lab will oversee the technical design and development of the MidTE system with technology inventor and big data expert **Randy Sargent**, Sr. Research Scientist. **Chris Bartley** principal software engineer, will lead the software engineering, development, implementation and documentation of the supporting web-based infrastructure to realize the system as a robust, open-access cyberlearning platform. Carnegie Mellon University is committed to hosting gigapixel data to be served directly, as well as embedded and served from educational outreach partners. **Cameron Tonkinwise**, Director of Design Studies at Carnegie Mellon University's School of Design will oversee the design research and PhD training. Dr. Tonkinwise has extensive experience in practice-based design research, having supervised and examined reflective practice and artifact-based research projects and written about the epistemologies particular to this kind of work.

John Wenzel directs the Carnegie Museum of Natural History's Powdermill Nature Reserve, a research field station and visitor center, where he leads a number of major programs including macroinvertebrates sampling projects with state agencies, and he partnered on the scientific development of www.macroinvertebrate.org. Dr. Wenzel runs professional entomological certification workshops for the Society for Freshwater Science jointly with Dr. John Morse, and he served as Professor in the Departments of Entomology and Biology at Ohio State University for 17 years where he and his students published scores of papers on insect behavior, ecology, and evolution.

John C. Morse, Professor Emeritus of Entomology at Clemson University and Director Emeritus of the Clemson University Arthropod Collection will oversee the scientific collection and content development in this project. His research specialty is the identification, biology, and historical development of caddisflies worldwide. With his students, he investigates the identification, biology, and distribution of other aquatic insects, in stream ecology, conservation, and of the use of insect communities to monitor water pollution. Dr. Morse is committed to supporting development of taxonomic skills by water quality monitoring professionals in the US, having taught 28 intensive 1–2 week workshops on mayflies, stoneflies, and caddisflies since 1989, and he continues to serve as a Founding Member and Co-Chair of the Taxonomic Certification Committee for the Society for Freshwater Science.

Tara Muenz, Education Programs Manager at Stroud Water Research Center will lead the design and development of training materials to support volunteer biomonitoring organizations' engagement with and use of MidTE system. She is a trained aquatic biologist and experienced environmental educator. Prior to her appointment at Stroud, Muenz was State Coordinator for *Georgia Adopt-A-Stream*, Georgia's Department of Natural Resources Environmental Protection volunteer water quality monitoring program. Stroud Director **Dr. Bernard Sweeney**, and Research Scientist **Dr. John Jackson** will oversee training material development, advise on the scientific aspects of the image collection and support outreach and dissemination activities.

Camellia Sanford is a Senior Researcher at Rockman et al (REA) and has extensive experience conducting research and evaluation within both formal and informal educational settings. Dr. Sanford is skilled in formative and summative evaluation design, data collection, and qualitative and quantitative analysis. Her area of specialty includes looking at engagement with and learning from educational technologies such as online interactives, mobile phone apps, and computer games. Recently funded NSF-funded projects include evaluations of Filament Games' *Game-Enhanced Interactive Physical Science*, University of Wisconsin-Madison's *CyberSTEM: Making Discovery Visible Through Digital Games*, and the University of Pittsburgh's *Gigapixel Cyberinfrastructure for Participatory Learning*. Dr. Sanford completed her PhD at the University of Pittsburgh's Learning Research & Development Center, and was a Research Fellow at the Children's Museum of Pittsburgh.