VESIC Institute, Inc.

Mission Statement and Intentional Foci

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Mission Statement

The Virtual Environments for Situated Inquiry of Complexity (VESIC) Institute is a participatory design, development and research institution focused upon fostering multi-generational informal exploratory learning about complex systems and problem solving with interactive data-driven digital tools -- as well as continued cognitive-based research and development for improvement of learning with such tools. Driven by a conservation ethos founded upon ecological awareness, environmental stewardship, and evidence-based decisions, VESIC Institute strives for its learners to achieve systems wisdom, ecological literacy, and systems thinking abilities in pursuit of continued environmental stewardship and increased conservation behavior.

Intentional Foci

Beyond forming a proactive perspective of systems events, humans that have become systems thinkers can not only reduce possible further damage to systems equilibrium from short-sighted reactive solutions, they can understand systems interactions well enough to prevent truly major disasters in the future. A key to this prevention is an ability (and willingness) to become stewards for the natural processes requisite for maintaining resilience within and across the interacting subsystems of the global ecosystem. This stewardship is based partly upon the allowance of any given system to pursue its own boundaries, even if that means socio-cultural discomfort or even a mild economic recession (in the short-term) for the human species.

To facilitate such stewardship, educators and designers must work together to build learning systems for practice of this stewardship – systems that foster both the appreciation and the understanding necessary for achieving the adaptive capacity crucial for accepting (and celebrating) these socio-cultural discomforts and economic recessions. Considering the high complexity of these interacting systems, virtual environments can be an appropriate platform for guided experiential learning about stewardship within these interacting systems. Such guided experiential learning can serve as a model for how environmental education -- all education -- will continue to be transformed in the 21st century.

Complex Systems and Emergence

What is a complex system? Paul Cilliers (1998) has provided what he calls a sketch of complex systems, which is a set of fundamental principles – adapted from three key sources (Nicolis & Prigogine, 1989; Serra & Zanarini, 1990; Jen, 1990). This sketch appears to be the most flexible and holistic framework of fundamental principles for complexity in the literature, especially from the perspective of a learner approaching complexity (Cilliers, 1998). The fundamental principles are:

- Complex systems consist of a large number of elements.
- The elements in a system interact dynamically.
- The level of interaction is fairly rich.
- Interactions are non-linear.

- The interactions have a fairly short range.
- There are loops in the interconnections.
- Complex systems are open systems.
- Complex systems operate under conditions far from equilibrium.
- Complex systems have a history.
- Individual elements are ignorant of the behavior of the whole system in which they are embedded.

While these principles provide a good framework for establishing the parameters (or defining boundaries and recognizing interactions) of any complex system, no framework gets at the heart of the matter. What is the essence of complex systems? What makes a complex system complex? In other words, what, exactly, is complexity? Cilliers (1998) provides the following definition of complexity:

> "Complexity is the result of a rich interaction of simple elements that only respond to the limited information each of them are presented with. When we look at the behavior of a complex system as a whole our focus shifts from the individual element in the system to the complex structure of the system. The complexity emerges as a result of the pattern of interaction between the elements" (p. 5).

Hmelo-Silver and Azevedo (2006) are not surprised that many people struggle to understand the emergent aspects of interacting complex systems, instead focusing upon most systems as collections of parts. They suggest that this is partly due to the huge burden that can be placed upon working memory resources when reasoning about the often counterintuitive concepts emerging from the interactions of these complex systems. When prioritizing generalizable characteristics of complex systems that should be understood in our technology-based society, Lesh (2006) notes three important precepts: globalization, knowledge economies, and organizational learning – all of which involve emergent properties of complex systems. Jacobson and Wilenksy (2006) see emergence as a concept of central importance to research on learning about complex systems. A final argument for the singular importance of emergence in complex systems comes from Capra's (2000) criteria of systems thinking, the first of which – a shift in perception from the parts to the whole – is defined as a person's "ability to recognize the systemic properties of a system" (p. 30). Here, Capra's term systemic is interchangeable with emergent.

It is apparent that no singular generalized definition of emergence in complex systems has yet been agreed upon by an interdisciplinary field of researchers. Cilliers (1998) notes that emergence in complex systems is often conflated such that students come away with an impression of mysterious outcomes from systems interactions that may be impossible to understand. Accordingly, he suggests replacing the term emergence with relational properties. Therefore, for the purposes of this study, emergence is defined as the relational properties of a given complex system that are apparent only through perception and analysis of that system as a whole, as opposed to an isolated analysis of its constituent components or elements.

Based on a review of Penner's (2000, 2001) work, Jacobson and Wilenksy (2006) suggest that the concept of emergence is difficult for students to learn solely in the classroom using model-based activities. Cilliers (1998) sees the modeling of system in a different light insisting a proper description of any system involves repeating the system in its entirety. Essentially, Cilliers' idea of modeling is much more participatory and constructive – with the learner modeling the system based on his or her actual perceptual experiences of that system.

Considering this participatory modeling approach, Jacobson and Wilensky (2006) – following an exhaustive review of the literature of research on understanding complex systems – conclude that the best approach to understanding complex systems involves *two reciprocal types of reasoning*:

1. an agent-based internal approach, analyzing the system from within its interacting components, and
2. an aggregate external approach, analyzing the system from outside its boundaries

Facilitating a learner's transition (or transcendence) to this reciprocal set of perspectives might best be accomplished in highly structured virtual environments that can serve as dynamic platforms for individualized guided practice (with plenty of scaffolding) within an array of complex systems.

Systems Thinking

Fritjof Capra (2000) offers a series of principles of systems thinking. These principles involve a shift in mindset from:

- the parts to the whole
- objects to relationships
- objective knowledge to contextual knowledge
- contents to patterns
- quantity to quality
- structure to process
- measurement to mapping

Concerning a shift from the parts to the whole, systems have “systemic” or emergent properties which cannot be observed by reducing the system to its parts. Essentially, this shift is focused upon seeking out the whole that exists beyond the sum of the parts of any system. This view can help us to better realize the connections and relationships that exist between the parts of a system -- and between this system and other systems. This leads to the second perceptual shift -- from objects to relationships --

which essentially entails that the networks of relationships within and between systems become the new "objects" of study when approaching and understanding complex ecologies.

The shift from objective knowledge to contextual knowledge implies a shift from pure analytical thinking (in a silo) to more contextual thinking (in addition to critical analytical thinking) with collaborative efforts from groups of teachers and learners -- much like the community of practice model of social learning theory (e.g., Wenger, 1998) Similarly, a shift from contents to patterns can allow for the recognition of similar patterns across seemingly different systems. Patterns of flows in earth systems might shed light on understanding flows with similar patterns in economic systems.

A shift from quantity to quality implies a shift from measurement to mapping. Essentially, there are many aspects of systems - emergence, relationships, etc. -- that lend themselves to qualification as opposed to quantification. Measurement tends toward quantification, while mapping can allow for descriptions and understanding of relationships (including measured quantities and unmeasurable qualities) -- and mapping system qualities can help us to see the patterns inherent in these systems above and beyond the evidence we can gather from measuring individual parts and/or processes within the system.

Finally, complex systems tend to be quite dynamic in nature, and understanding this dynamism requires a shift in mindset from structure to process. Of course, structure is important, but the change in the structure of a system due to its inherent processes can shed light on the emergent properties of this system. From another perspective: the path to the result is just as important as the result that is observed.

Systems Wisdom

Definitions and perceptual frameworks can only take one so far as he or she attempts to describe how any learner approaches complexity and eventually understands the complex system(s) with which he or she is interacting. *What should learners actually do as they approach an understanding of complex systems?* Donella Meadows (2008) outlines fifteen principles of *systems wisdom* for anyone encountering complex systems:

- Get the beat of the system
- Expose your mental models to the light of day
- Honor, respect, and distribute information
- Use language with care and enrich it with systems concepts
- Pay attention to what is important, not just what is quantifiable
- Make feedback policies for feedback systems
- Go for the good of the whole
- Listen to the wisdom of the system
- Locate responsibility within the system
- Stay humble – stay a learner

- Celebrate complexity
- Expand time horizons
- Defy the disciplines
- Expand the boundary of caring
- Don't erode the goal of goodness

Meadows' suggestion to watch system behavior -- getting the beat -- relates directly back to Capra's (2000) and Cilliers' (1998) emphasis on the importance of an individual learner appropriately perceiving interactions of elements within a system, especially considering her own clarification of the point, focusing on dynamic versus static analysis – including how a person or population arrived at given situation within a system, and which possible positive and negative outcomes lie ahead, based on current and alternate future behavior (Meadows, 2008). Meadow's optimistic view of any learners' dynamic analytical approach to the interactions of complex systems – coupled with the relational perspectives of Capra and Cilliers – indicates that a definitive prerequisite skill for understanding complex systems is a learner's ability to recognize the emergent properties of any given system.

Diving further into some of Meadow's (2008) principles of systems wisdom, one can get a sense of the knowledge, skills, and abilities inherent in each principle. For example, as a person begins to "get the beat of a system," he or she is encouraged to watch for system behavior *before* disturbing the system, watching it work, learning its history, and asking those more experienced with the system what has happened (and is happening). An emphasis is made on graphing actual data from the system over time -- focusing on actual facts as opposed to theories -- and watching how elements in a system do and do not vary together. Furthermore, plotting the history of several variable together, a better understanding of the interconnections between these variables over time can begin to be formed. As a person gets the beat of the system, he or she can begin to define one or more recognized problems based on the systems actual behavior(s) -- as opposed to based on the person's desired solution.

If one wishes to expose his or her mental models to the light of day, Meadows (2008) suggests *mental flexibility*, which includes a willingness to redraw boundaries and the ability to notice if the system has shifted to a new mode -- both in order to see how to redesign the system's structure. Additionally it is of utmost importance to put one's model in full view, inviting others to challenge one's assumptions and add their own. A person that properly exposes his or her mental models collections as many explanations as possible and considers each of them plausible until it can be ruled out with evidence.

When a person uses language with care, enriching it with systems concepts, he or she is apt to avoid language pollution -- keeping language as concrete, meaningful, and truthful as possible. A person would continuously expand her or her vocabulary in order to talk about complexity -- enlarging his or her language to be consistent with one's enlarged understanding of systems.

The principle of making feedback policies for feedback systems implies that a dynamic, self-adjusting feedback-oriented system cannot be governed with static, unbending policies. As such, a person pursuing this principle would design policies that change depending on the state of the system -- including feedback loops and meta-feedback loops -- essentially, policies which design learning into the management process.

A person who stays humble and stays a learner is one that is prepared for surprises, and when presented with these surprises (and mistakes), doesn't bluff or freeze, but *learns* through experimental iterations of trial and error. A humble learner recognizes that it is not appropriate to charge forward with undeviating directives, and that doing so is almost guaranteed to lead to mistakes from which one does not learn. A humble learner recognizes working within systems requires small steps and constant learning, with a willingness to change course as he or she learns more about the direction in which he or she is headed with the system.

When a person expands his or her time horizons, it becomes apparent that the longer a horizon stretches (forward and backward in time) the better chances are for understanding the system (and planning for survival of the system). This expansion also entails an understanding that systems are constantly uncoupling the large and the small, the fast and the slow. A person with expanded time horizons watches the whole system: the short term and the long term.

When defying the disciplines a person follows a system wherever it leads, learning from any number of experts: economists, chemists, biologists, engineers, psychologists, theologians, etc. A person that defies these disciplines is able to penetrate discipline-specific jargons, integrating expertise across these disciplines by discarding distortions in language and paradigm-limited perceptions.

Ecological Literacy

Concerning the pursuits of VESIC Institute, the terms *environmental literacy* and *ecological literacy* are interchangeable. Perhaps Stables' (1998) deceptively simple definition of ecological literacy is the most poignant: "...the ability to make sense of the world around us and our relationship with it" (p. 156). David Orr (1992) emphasizes knowledge, care, and practical competence in his definition of ecological literacy, as well as a broad understanding of sustainable relationships between individuals, society, and the natural systems – all based upon a fundamental knowledge of how the world works as a physical system. Golley (1998) outlines a scientific, systems-oriented approach to environmental literacy, based on three foundational concepts: the environment, the system, and hierarchical organization.

Similar to Stables' definition, Fritjof Capra (2000) provides an amorphous, holistic perspective, involving a basic understanding of organization within and between ecological communities, including an ability to embody these organizational relationships as part of one's daily life within human communities. To specify the basic principles of ecological systems, Capra (2000) outlines several fundamental concepts of ecology: networks, nested systems, cycles, flows, development, and dynamic balance. Affirming Capra's emphasis on human communities, Berkowitz, Ford, and Brewer (2005) emphasize an understanding of the interface between ecological science and society as a key element of ecological literacy. Recently, Jordan, Singer, Vaughan, and Berkowitz (2009) have presented a knowledge space framework for ecological literacy, which includes: 1) evidence-based habits of mind, 2) ecological concepts and connections, and 3) self knowledge (i.e., human-environment connectedness) – with a focus upon the intersection of these three elements.

Each of these theoretical frameworks suggests similar concepts at its core – a gravitation toward critical thinking about the self and the environment in a systematic web of relationships, as well as how those relationships fit within the hierarchical (or heterarchical) order of the ecosystems of which our planet is comprised. Essentially, ecological literacy consists of an understanding of the manifestations of relationships and connectedness in environment, other complex systems, and the hierarchies and heterarchies inherent in those systems and relationships. To clarify, heterarchies are a reorganization of assumed hierarchical networked relationships that avoid pre-classification of these relationships as hierarchical.

Berkowitz, Ford, and Brewer (2005) have hypothesized several reasons why environmental education fails to reflect the appropriate nature of ecological literacy, and two of their points seem most appropriate to an argument for the gravitation toward critical thinking:

- ecological literacy requires hard-to-develop thinking skills, and these critical thinking skills are made more difficult through marginalization of environmental education within the broader institution of the educational system
- many practitioners in environmental education see concepts of ecology as building blocks for specific action, and therefore they tend to show less interest in holistic, dynamic views of ecology involving critical thinking and understanding

To make a case for improving environmental education through a focus upon critical thinking, Stables and Bishop (2001) insist that, based on the nature and scope of its broader holistic view – including its less narrowly defined concerns and an emphasis on critical thinking – ecological literacy can transcend beyond its traditional role as a desirable portion of environmental education, enriching the entire approach to environmental education along the way.

Still, what does critical thinking actually mean in the context of ecological literacy? In other words, how can critical thinking be operationalized in such a way so as to allow for appropriate facilitation and promotion of ecological literacy – throughout any cycle of learning, assessment, and guided practice? Stables (1996) grounds his theoretical framework for ecological literacy using the fundamental conceptualization of humans' perceptions and understanding of our surrounding environment as a series of cognitive processes that are comparable to the reading of a text.

Based on this textual analogy, Stables (1998) delineates *three types of ecological literacy*: *functional*, *cultural*, and *critical*. He provides a general scale and scope for these types of literacy – with critical literacy considered to be the highest level of cognitive sophistication in an individual. From a domain-independent perspective, he describes critical literacy as an "active exploration of significance and meaning" (Stables, 1998, p. 158).

A person demonstrating high levels of *functional* ecological literacy would exhibit an ease with the remembrance and recognition of species (and the integration of these species into appropriate organic and synthetic systems), as well as a keen ability to use partial clues to identify and/or differentiate species within a variety of these systems. While Stables (1998) notes that functional ecological literacy is based primarily upon an accumulation of knowledge and complex skills with a relatively unlimited capacity for growth, a person exhibiting high levels of functional ecological literacy does not engage with what the environment means – neither to the self or other individuals or groups. However, in recognition of the interspersed nature of the three types of literacy, Stables (1998) notes that *neither cultural nor critical literacy is possible without functional literacy*.

Achieving *cultural* ecological literacy involves a person's recognition of the significance of natural images in human culture – think of the annual deluge of calendars containing pleasing natural images – as well as why (and to whom) they are important (Stables, 1998). While cultural ecological literacy can empower the learner through access to socially powerful perspectives, it alone cannot empower the learner into action. Essentially, a person exhibiting high levels of cultural ecological literacy is more aware (and likely better with navigation) of socio-ecological systems – as well as the human impact upon natural systems (and vice versa) over time. According to Berkes, Colding, and Folke (2003), the navigation of socio-ecological systems is the dynamic nature of human societies dealing with change during the interaction of social and ecological systems – as well as any individual increasing his or her capacity to adapt to this change.

Stables (1998) insists that it is only *critical* ecological literacy that can facilitate effective environmental action by any individual, as the achievement of critical ecological literacy entails forming a critical perspective of human factors contributing to environmental change – a critical perspective that includes action-oriented solutions for ameliorating such change. Stables and Scott (1999) reiterate this point from the perspective of environmental education, noting that fostering such a critical perspective is truly education *for* the environment.

Finally, Stables (1998) recognizes two potential avenues for a positive contribution to society from those that have achieved acceptable levels of functional, cultural, and critical ecological literacy:

- "understanding how and why approaches to the environment have changed and developed over time" (p. 161)
- "ensuring that choices about environmental action take into account ethical and aesthetic, as well as scientific considerations with respect to their likely consequences..." (p. 161)

Both of these avenues for positive societal contribution point toward an holistic perspective of ecological literacy that relies upon critical thinking ability as a central component.

Similarly, Capra (2000) insists that systems thinking is the core (i.e., a central component) of ecological literacy, a sentiment readily mirrored in Staples' two avenues – especially considering two concepts: 1) perceiving changes over time and 2) accounting for the ethical and the aesthetic in environmental decision-making. Essentially, Stables' (1998) three phases of ecological literacy can serve as a road map for a better understanding of the relationship between a generalized perspective of critical thinking and Capra's (2000) perspective of systems thinking, as well as how this concept of systems thinking fits into ecological literacy for the individual learner.

Capra's (2000) model of ecological literacy centralizes systems thinking at the intersection of four foundational concepts:

- understanding principles of ecology, experiencing them in nature, and acquiring a sense of place
- incorporating the insights from the new understanding of learning, emphasizing a child's search for patterns and meaning
- implementing principles of ecology to nurture a learning community, facilitating emergence and sharing leadership
- integrating curricula through environmental project based learning

While this is perhaps the most holistic model (in terms of teaching, learning, and doing) for ecological literacy in the literature, most of the theoretical frameworks previously described recognize that systems thinking is crucial for achieving ecological literacy. Essentially, achieving ecological literacy is impossible for the individual without an appropriate systems thinking mindset. Orr (1992), for example, would concur, noting that ecological literacy is grounded in a fundamental understanding of natural history, ecology, and thermodynamics (and the interrelatedness between these domains).

Comprehension of this interrelatedness – grounded in these subject domains – is certainly an example of gravitation toward the systems thinking mindset. Additionally, Berkowitz, Ford, and Brewer (2005) propose an ecological thinking toolkit comprised of seven essential components – including systems thinking – which they relate directly to scientific ways of knowing identified in the National Science Education Standards (National Research Council, 1996). They provide further emphasis on the relationship between systems thinking and ecological literacy, noting that systems thinking is a "contextual module of thinking skills...central to ecological thinking" (Berkowitz, Ford, & Brewer, 2005, p. 240).

It is important to note in this discussion of systems thinking that the term *mindset* is used instead of ability. Capra (2005) is careful to point out that achievement for any learner in the domain of systems thinking is based upon substantial shifts in his or her *perception*, not necessarily an increase in any sort of *ability*.

Before these perceptual shifts can be achieved by an individual, he or she must gain a certain level of understanding with each of the complex systems with which he or she interacts on a regular basis. This is not to imply that these shifts cannot begin to occur before a complete understanding is had of the systems about which the perceptual shift is to occur. Instead, a sort of cognitive symbiosis exists in the learner between his or her understanding of and perceptions about a given system or set of systems.

Why is it important to increase our knowledge base concerning the interaction of these literacies with the perceptual shifts toward a systems thinking mindset, coupled with declarative knowledge of the elements of any complex system approached for understanding? Perhaps Berkowitz, Ford, & Brewer (2005) state it best:

> "From research on learning and cognition in ecology that identifies basic patterns of student thinking, and from embedded assessments during instruction that reveal specific mental constructs and conceptions held by students, teachers can devise strategies to help learners develop more robust and accurate understandings" (p. 251).

Virtual (Immersive) Environments

In a discussion of the complex nature of the vast array of natural systems that make up our global ecosystem, Capra (2005) makes a timeless remark in regards to reflective analysis of any experience within this environment of natural systems: "You can't take a photograph of the web of life, because it is nonmaterial – a network of relationships" (p. 20). This is precisely the reason why virtual environments may be a viable platform for the facilitation of exploratory learning about complex systems ecology: learners can experience this network of relationships in a constructed, mediated environment, individually guided through appropriate methods for understanding these systems, eventually acquiring a set of experiential skills (based on the principles of ecology) that will lead to the perceptual shifts necessary to maintain a systems thinking mindset – to *become a systems thinker*.

Berkowitz, Ford, and Brewer (2005) take a strikingly similar stance in regards to the use of emerging technologies in the process of learning about complex systems ecology:

> "We need to make the invisible visible and tangible for students if they are going to develop strong ecological thinking skills and come to understand the critical ecosystems they are a part of. Fortunately we know a lot about some of the major stumbling blocks (e.g., microbes, chemistry, slow or long-time processes, large-scale systems, and distant influences) in this regard and how they manifest and influence learning, and the effective means of addressing them. The availability of new tools provides optimism in this regard..." (p. 252).

Virtual environments are computer-based immersive worlds -- both two- and three-dimensional -- that allow a person to interact with digital artifacts in artificial spaces that have been constructed to simulate real world objects and processes. These environments can be leveraged to provide *in situ* learning experiences that allow for a scaffolded approach to engaging in real world scenarios.

From the perspective of ecological literacy and systems thinking in such virtual environments, a learner must deal with increasingly complex, emergent systems – and in the process, hopefully increase his or her ecological literacy. In endeavors of research into the processes of understanding complex systems, virtual environments can allow for real- time assessment of real-world behavior performed by learners (using integrated user/system tracking mechanisms). To reiterate a previous point, virtual environments are perhaps the single best mechanism available for facilitating the reciprocal approach to understanding complex systems (Jacobson & Wilenksy, 2006). Potentially, learners can instantaneously switch between the internal (agent-based) and external (aggregate) perspectives of any complex system as they see fit, all within the boundaries of a single virtual world (or networked series of virtual worlds) using any number of interactive features inherent in a virtual environment software application.

Beyond the provision of this reciprocal approach, there are several positive affordances that virtual environment technology can provide to the experiential learning processes associated with learners exploring complexity – inherent in ecological and environmental education, and leading to ecological literacy – such as:

- the ability for a learner to transcend space and time (individually or collaboratively)
- simulations of experiences not yet possible for the learner in the real world
- the persistence of individual and/or group learning trajectories (or identities) across multiple sessions

Additionally, virtual environments can provide guided inquiry practice (e.g., Nelson, 2007) for many learning processes fundamental to a learner's achievement of ecological literacy (such as observation and measurement) in a safe environment that allows for repeated mistakes without the risk of physical harm to the learner – or destruction of expensive equipment or fragile property. Further, this guided inquiry practice can be highly individualized using an integrated learning, assessment, guidance cycle that can be accomplished in a relatively unobtrusive manner when embedded directly into the experience of interactions that take place in virtual worlds. Finally, virtual environment technology can provide realistic immersive virtual access to natural environment types that may not typically be accessible to a learner, such as non-local ecosystems (e.g. desert, tropic, tundra) or extreme environments (e.g. volcano rims, ocean floors).

Why is realistic experiential access to remote ecologies (ecosystems) important to the individual learner? In a continued discussion of their ecological thinking toolkit, Berkowitz, Ford, and Brewer (2005) indicate that each individual must be aware of (and develop personal relational understandings of) the following *five ecological system*s:

- the ecological neighborhood, or the learner's home ecosystem
- the ecological basis of human existence
- the ecology of the systems that sustain us
- the globe as an ecosystem (and humanity's impacts upon it)

- genetic and evolutionary systems

Consider, for example, a learner's perception of the global water cycle as it might be related to each of these five systems – with the understanding that the two primary emergent properties of the global water cycle system are the movement and storage of water in, on, and around the earth. Obviously, water storage and movement are both integral parts of a learner's home ecosystem – even at the most basic social level, such as weather patterns (Do I wear a raincoat today or not?). Considering the percentage of the human body consisting of water, the global water cycle certainly plays an integral role in the ecological basis of human existence. As all of our sustenance is derived from the natural sources of the earth, and an overwhelming majority of the earth's surface is covered with water, it is clear that how water storage and movement occurs in the global water cycle plays an integral role in the ecology of systems that sustain us. Certainly humanity's impact on the global-level ecosystem is directly reflected in fluctuations (over varied temporal ranges) of the patterns of water storage and movement inherent in the global water cycle.

Pragmatic Goals

As VESIC manifests and matures, several pragmatic goals serve as guidelines for the growth of the organization:

- evidence-driven problem solving and decisionmaking
- multi-generational communities of learning
- digital tools design and development
- unobtrusive authentic performance assessment practice
- cognitive research

Throughout the growth of the organization, prioritization of these goals will change as necessary to fit the current climate surrounding VESIC and its community.

Evidence-Driven Problem Solving and Decisionmaking

What is meant by evidence-driven problem solving and decisionmaking? Simply put, evidence-driven decisions are those which are made based on objective analysis of data relevant to the context of the problem and proposed solution. While emotion- and belief-driven human factors are certainly relevant to any holistic approach to complex problem solving and decisionmaking, it is important to clarify that in evidence-driven problem solving, objective analysis takes precedence and should be the primary foundation for the decisionmaking process.

Evidence-driven problem solving and decisionmaking conducted as part of a sustainable relationship between humans and the natural environment in any socio-ecological system constitute a "wicked" problem (e.g., Rittel & Webber, 1973; Conklin, 2006; Palmer, Smith, Willetts, & Mitchell, 2007). To move toward a solution to this wicked problem, the public must first understand the complexity of the problem and the deceptive simplicity of the decisions that can lead to a solution. As designers of virtual simulation environments for learning by way of such decisionmaking and complex problem solving, how do we foster any given person's approach to learning about the complexity of this wicked problem?

VESIC intends to foster both collaborative and individual complex problem solving with or without the use of telepresence -- people will either be all in the same room or networked together via videoconferencing or other technological platforms, such as live chat around a cloud-based, collaboratively authored document, or perhaps a more directly immersive platform such as the Elumenati GeoDome system. Another mechanism for technological support of evidence-driven complex problem solving is a "decision theater" model, much like the one housed at Arizona State University: https://dt.asu.edu/ -- using a variety of complex modeling and spatial visualiazation tools currently available.

Multi-Generational Communities of Learning

VESIC intends to foster learning amongst community members ranging from middle school ages (10-11 years) to our wisest of elders, whatever age they may be -- with the intent of true "lifelong learning" and multi-generational interactions inherent in this learning process surrounding each and every project that VESIC pursues. We also intend to foster a "communities of practice" approach to learning (Wenger, 1998) that involves, among other things, a focus on practice-based learning centered upon participation at various levels of engagement, identity, and alignment within the community -- and how this can manifest across generations of community members.

Finally, VESIC maintains a particular interest in the way in which systems wisdom can be approached, practiced, and shared within these communities of learning, especially concerning the following principles of systems wisdom:

- Expose your mental models to the light of day
- Use language with care and enrich it with systems concepts
- Stay humble – stay a learner
- Expand time horizons

Digital Tools Design and Development

In support of evidence-driven decisionmaking and complex problem solving within multi-generational communities of learning, VESIC strives to design and develop data-driven digital tools that support the acquisition of knowledge, perspectives, mindsets, skills, and abilities relevant to systems thinking; systems wisdom; and functional, cultural, and critical ecological literacy.

These tools will be designed and developed as naturalistic, multi-modal, touch-driven experiences. Examples of such tools include simulations (such as a personal transportation "true cost" simulator) and interactive data visualizations (similar to many weather and stock trading apps). Tools for data collection, analysis, and annotation -- for use in bridging internal and external perspectives of complex problems -- will also be a primary focus of VESIC. All tools will be built in such a way that allows for unobtrusive performance assessment for individualized learner feedback (feedback that changes based on patterns that can be derived from his or her actions when utilizing these tools).

VESIC strives to maintain a design and development process that is human-centered, participatory, and multi-generational.

Unobtrusive Authentic Performance Assessment Practice

VESIC intends to develop tools and practices which combine learning and assessment as one continuous, cohesive, synchronous process -- learning is assessment is learning. To do so, VESIC will implement evidence-centered assessment design, its conceptual assessment framework models, and the associated four process architecture for learning/assessment task delivery (Almond, Steinberg, & Mislevy, 2002). Essentially, the four processes are activity selection, activity presentation, response processing, and summary scoring -- intended to structure the flow of data throughout a person's learning and assessment processes, with a primary focuses upon task-level and summary feedback to the learner as well as maintenance of learning growth trajectories.

Additionally, VESIC intends to adopt a newly theorized approach to assessment in simulation-based environments, the "four space" model -- consisting of a problem space, a tool space, a solution space, and a response space (Behrens, DiCerbo, & Ferrara, 2012). The problem space is defined by the context of the chosen task. The tool space is defined by the tools provided to the learner for completing the task. The solution space is more amorphous, essentially defined as the processes a learner goes through using provided tools to create iterative products as an attempt to reach the response space. The response space is defined as the point at which the learner submits a refined or polished work as an example of demonstrated ability for the task at hand.

Cognitive Research

In addition to serving as platforms for learning and assessment across formal and informal environments, tools developed by VESIC can serve as a platform for conducting cognitive task analyses and laboratory-based experimental research on factors of cognitive load (Sweller, Van Merriënboer, & Paas, 1998). VESIC tools can be built to facilitate a dual-task methodology (e.g., Brünken, Steinbacher, Plass, & Leutner, 2002) for isolating factors of extraneous, intrinsic, and germane cognitive load inherent in multi-touch interactivity and other knowledge, skills, and abilities inherent in the tools developed. Findings from these cognitive studies can be integrated into the established flow of learner growth reflected in the examinee record -- essentially another form of performance assessment. In this way, VESIC tools can serve collectively as a functional platform for advancing research on these isolated factors of cognitive load in the context of established learner growth across authentic learning/assessment tasks.

Schnotz and Kürschner (2007) call for a distinction of research findings across explicit and implicit learning processes, with implicit learning defined as "learning without the intention to learn and even without awareness of what has been learned" (p. 503) -- essentially play-oriented learning in a low-stakes solution/response space. By maintaining such a research focus across all types of learning, VESIC can begin to understand the scope of its developed tools and their ability to foster iterative cycles of experimental, data-driven research that can then inform the continued design and development of a cognitively-based platform for evidence-centered assessment of learning through analysis of task performances as learners demonstrate growth over long periods of time.

VESIC intends to work with a variety of partner research institutions, primarily at universities in the United States and abroad, to put its tools into as many experimental cognitive research studies as possible. In future phases of its growth, VESIC intends to run similar research studies in-house.

Summary

Berkowitz, Ford, and Brewer (2005) insist good environmental education practice is that which *promotes environmental citizenship in learners* – involving a keen mix of both ecological and civics literacies, including an emphasis on putting these two types of literacy into use. Specifically, they center their framework for environmental citizenship around practical wisdom and skills, including four components: ecological literacy, civics literacy, values awareness, and self efficacy. Together, these four components can empower people to identify values and goals for relationships between humans and the natural environment, and to use their knowledge to make appropriate choices and act according to these identified values and goals.

VESIC intends to model such citizenship through participatory design, development and use of advanced digital tools for understanding complexity -- disseminating its findings across appropriate academic and social channels.

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