GROCS Proposal:
Local-Global: Building an Educational Framework for Multi-Device Simulations

I. Local-Global

Figure 1: *Mock-up of proposed demo game. Each handheld is displaying a detailed view of a portion of the environment that is displayed on the Tablet PC.*

II.

Modern software development is no longer limited to developing applications for single users anchored to their desktop computers: miniaturization and wireless communication advances have given us portable devices with very different form-factors, from small, lightweight devices like cellular phones and handheld computers to larger (and more powerful) laptops and tablet computers, all of which are capable of "talking" to one another. Most software developers, though, still create applications that are targeted for one form-factor or another; and any intra-device communication is usually limited to simple file transfers. There is no reason why people cannot build cohesive applications that *span* different devices, taking advantage of the different display size, portability, and computational power characteristics of the different devices. Further, there is no reason why these applications could not allow many people to participate *simultaneously*. Note, that this paradigm is not simply the networking of devices together; the idea is to actually draw users together into a single proximity, to promote communication and social interaction.

The goal of this project is twofold: **(1)** to create a framework that allows for the easy development of educational simulation games under a new, multi-device technological paradigm, and **(2)** the creation of a demonstration (demo) game, using this framework, to illustrate the educational benefits of this new paradigm, which we term **Local-Global**.

This paradigm draws upon the Participatory Simulation work done here and at the MIT Media Lab and is made possible by the form-factors of new computational devices, such as touch-sensitive handheld computers and Tablet PCs. A Local-Global simulation allows a **global simulation game** to be played ***simultaneously*** by multiple users, who are able to make **localized adjustments** to the simulation game's parameters, and observe how these small local-level manipulations can combine to impact the status of the global simulation environment (see Figure 1). The demonstration game will be something akin to a digital fish tank: an environment populated by autonomous creatures that feed and breed. The users will be able to inspect the creatures and manipulate them with the aid of the handheld "microscopes", and will be able to view the effect of their manipulations on the game environment by watching the simulation play out on the larger display of the tablet PC.

III. Makiko Kawamura, Undergraduate Student, School of Art and Design

Makiko Kawamura is a fourth year Industrial Design/Mechanical Engineering joint degree student. She has a strong background in fine arts, some experience in graphic design. Makiko is currently designing a foot-measuring device for small children for an individual who is interested in getting the idea patented. She is interested in designing toys and consumer electronics.

Joseph Lee, Graduate Student, Electrical Engineering and Computer Science

Joseph Lee is a second year PhD student in Computer Science, focusing on Intelligent Systems. He obtained his B.S.E. in Computer Engineering at the University of Michigan. In the last year, he has designed and programmed a pair of educational games for the Pocket PC. He is currently collaborating with the University of Michigan's Professor Elliot Soloway and the University of Illinois - Urbana Champaign's Professor Barbara Hug to develop interactive software for a high school biology curriculum. His interests include educational technology, cognitive psychology, and innovative human computer interfaces.

Leilah Lyons, Graduate Student, Electrical Engineering and Computer Science

Leilah Lyons is a graduate student in the Computer Science Department, with an Intelligent Systems concentration and a research focus on the design and development of innovative educational software. Leilah followed a self-designed curriculum in Computer Graphics (comprised of Computer Science, Art and Design, and Film courses) at the University of Toledo before transferring to the University of Michigan and earning a B.S. in Computer Science at the University of Michigan in 2000. After graduation, she worked for several educational software firms, designing and developing multimedia educational games targeted at schoolchildren, and helping to design and patent software targeted at college students and adults, the design of which drew upon cognitive psychology principles to aid users in assembling, organizing, and assimilating large bodies of textual information. Leilah returned to the University of Michigan and earned an M.S. in Computer Science in 2004, and is currently pursuing her PhD under the supervision of Dr. Elliot Soloway. She is also a member of the University's Museum Studies Certificate program, has designed educational software that is now installed in the Ann Arbor Hands-On Museum, and has consulted with museum staff on the design and implementation of educational computer games.

Richard Vath, Graduate Student, Combined Program in Education and Psychology

Richard Vath is a second year PhD student in Education and Psychology. He earned a B.S. in Physics from Tulane University (1999) and a M.A. in Science Education from the University of Texas at Austin (2003) before entering the Combined Program in Education and Psychology at the University of Michigan. His broad research interests include the study of student and teacher learning opportunities within technology-rich science learning environments. He is a member of the HICE (Highly Interactive Classrooms, Curricula, & Computing in Education) research group, and is currently involved in a project investigating the impact of handheld computing devices on science learning in urban classrooms. He will bring his experience in understanding student technology use and the design of science curriculum materials to this project.

IV. Chris Quintana, Assistant Professor, School of Education

Chris Quintana's research interests focus on the design and assessment of learning technologies. His research has included articulating a learner-centered design process for learning technologies, articulating design and assessment methods for developing scaffolded software tools (both desktop-based and handheld-based tools), and developing more specific definitions and examples of software-based scaffolding. Chris received his Ph.D. in Computer Science and Engineering from the University of Michigan where his work centered on the development of a science-based scaffolded work environment as a case study to (1) develop a conceptual definition for learner-centered design and (2) develop new scaffolding design and assessment methods. He collaborates with the Center for Highly Interactive Computing in Education (hi-ce) on many projects. Chris will bring his extensive knowledge of educational software design and inquiry learning to this project, and will help the team members design and build software and user interfaces that will properly scaffold the constructivist, collaborative learning experiences of the student-users.

Informal Assistance: Elliot Soloway, Professor, Electrical Engineering and Computer Science, School of Education, School of Information

Elliot Soloway is not the formal advisor for this project, but as the academic advisor of two of the students, Joseph Lee and Leilah Lyons, he will lend his considerable expertise and energy to this project. Dr. Soloway has spent years advocating the development of engaging and innovative educational technologies, and as one of the driving forces behind Participatory Simulations and the use of handheld technology in classrooms, will bring invaluable insights and advice to the project.

V. .

V.00. General description

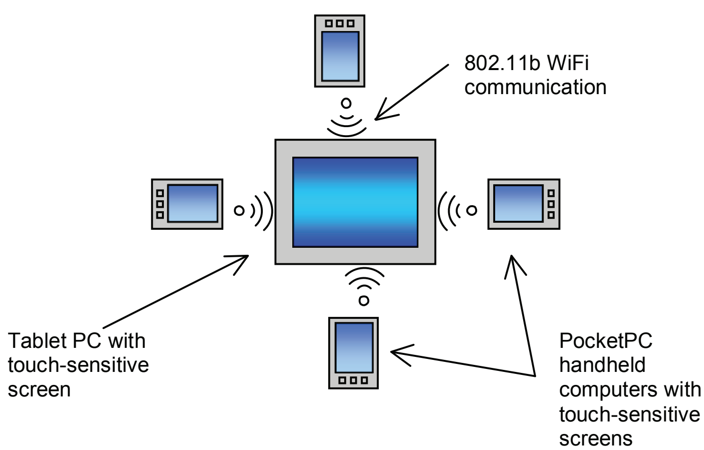

Figure 2: *Topology of proposed system*

The four or five players will use handheld computers to participate, via a wireless connection, in a larger simulation that is taking place on a Tablet PC (see Figure 2). Each player is associated with an entity in the larger simulation, and each handheld displays the region of the tablet screen surrounding the player's entity. As the entity moves on the tablet screen, the view on the handheld screen is updated. The players can issue commands to their entities via their handhelds, or can use the stylus on the touch-sensitive tablet screen to control entities or the environment.

V.01. Proposed Demo Application

Figure 3: *Imagined view of the proposed demo game, running on a Tablet PC. Expanded view shows the approximate level of detail that would be provided on Pocket PC devices.*

The demonstration game we will develop will allow users to manipulate the behavior of animal entities (i.e. "sprites" in computer gaming parlance) in a simulated environment. These behaviors include feeding on other animals or on resources found in the environment and breeding with one another. The beauty of nonlinear, systems-based simulations (as opposed to the linear, scripted games one often sees sold commercially) is that many variations of "games" can be played without the need for any additional programming work: the "games" consist of goals, like breeding an animal that is best-suited to surviving in the environment, that can be decided upon by the users, and their own in-game actions guide the simulated system towards their chosen goal. Such a game design will illustrate the property of **emergence** – the appearance of large, complex, systemic patterns as a result of the small, limited decisions of many entities present in the system. The form-factors of the devices used allow for collaborative experimentation and learning to take place, and the open-ended nature of the simulation supports the kind of inquiry-based investigations that are known to help students come to understand the purpose and methods of scientific investigation.

The task of the programmers will be to devise a list of manipulable parameters that will be used to describe the entities and environment, and to create a suite of rules that govern the reactions of the entities and environment to different values of these parameters. Several sample "games" will be devised and printed up on cards, so users can adopt one of these pre-established goals to guide their interactions with the simulation should they so choose. An effort will be made to devise "games" that illustrate important emergent scientific concepts or principles related to genetics and evolution, such as genetic drift.

V.02. Impact of Collaboration

The project we are proposing here is heir to the classic interdisciplinary problem: because it does not wholly belong in one academic unit, it belongs in none of them, and cannot exist without the interdisciplinary contributions of the team members. It is perhaps most effective to examine the different contributions in a subtractive manner: if the team was lacking that member, what would the project, in turn, be lacking?

Without the aid of a graphic artist, the interface and game design are likely to suffer, which would deleteriously impact the affective experience to be had by playing the game. Even the best software ideas can be ruined by an unattractive or unusable user interface, and this is doubly true for software produced for today's media-savvy children, who are likely to judge software by the same standards as the flashy video games they are accustomed to playing.

Without experienced programmers, the simulation framework is unlikely to be developed in a way that would allow for future re-use, or would perhaps not be created at all. The fact that the programmers in the team are also experienced with developing educational software for handheld computers shaves a tremendous amount off the learning curve, since the programmers will be able to focus on designing a clean API, and not on figuring out how to work with the technology. Thus, the team will be able to push farther and get more accomplished in a single semester than they would be able to otherwise.

Without a teammate with science education curriculum design expertise, we would have to rely on national standards to help guide the design of game scenarios. Although these standards provide good general content guidelines, they offer very little in the way of presentation guidance. Moreover, national standards are designed for use in traditional classrooms and traditional, pen-and-paper instructional techniques. The guidance of a person not only versed in curriculum design, but versed in technologically-mediated curriculum design, will be invaluable in ensuring we obtain the best possible curricular support for our game.

Without the aid and advice of a person well-read in the field of the learning sciences, and specifically how technology can be used to aid the learning of children, the team would run the risk of developing software that would fail to expose educationally valuable concepts to the users. Dr. Quintana is an authority on scaffolding technologies, and can help suggest and evaluate the structure of both the game design and the user interface design.

V.03. Specific tasks entailed by project

V.03.00. Creation of generalized communication framework API

This API should allow for:

- Generalized, game-independent communication via 802.11b wireless protocols (UDP and TCP/IP)

- Multiple handhelds to receive graphical updates from the simulation running on the tablet PC with a minimum of latency
- Multiple handhelds to receive game parameter data updates from the simulation running on the tablet PC with a minimum of latency
- Multiple handhelds to push game parameter data updates to the simulation running on the tablet PC with a minimum of latency

V.03.01. Creation of demo game

Demo game will make use of the API detailed in **V.04.00**, and will entail the following subtasks:

- Art creation
  - Animated representations of in-game creatures (estimated 8 varieties, with 20 frames of animation each: 160 discrete images)
  - Illustration of environment (1-2 general background images illustrating environmental terrain)
  - Images representing food sources and terrain hazards (estimated 5 varieties of food sources and 5 varieties of hazards: 10 discrete images)
- Determination of manipulable game parameters (estimated 5-10 parameters needed)
- Simulation rule system governing agent and environment interactions (rule base will likely depend on number of creatures and interactive environment elements: likely $\sum_{i=1}^{n} i + n \cdot (f + h)$, where n = number of entities, f = number of food sources, h = number of hazards.
- User interface design for handhelds
  - Must unambiguously indicate to the user how the on-screen elements relate to the on-screen elements on the tablet PC
  - Purpose and usage of control "widgets" (i.e. buttons, sliders, and comparable) must be intuitively designed, so that new users can quickly apprehend the range of options and engage with the game
- User interface design for tablet PC
  - Must unambiguously indicate to the user how the on-screen elements relate to the on-screen elements on the handhelds
  - Purpose and usage of control "widgets" (i.e. buttons, sliders, and comparable) must be intuitively designed, so that new users can quickly apprehend the range of options and engage with the game

V.04. Prior work

It has long been acknowledged, both formally and informally, that learning-by-doing is one of the most effective educational strategies, especially for science content areas. "Doing" can be very literal, as in conducting laboratory experiments, or it can take place in the context of a simulation that captures the essential properties of the concept being studied. Indeed, "simulations potentially offer students opportunities to explore physical or biological situations that may be impossible, too expensive, difficult, or time-consuming to accomplish with actual laboratory or real-life experiences." (Akpan)

Technologically-mediated simulations used in classroom education can be broken down into two major categories: Global-Level and Local-Level Simulations, each of which has its pedagogical and motivational advantages and disadvantages. The former category is perhaps best represented by Mitchel Resnick's StarLogo and Uri Wilensky's NetLogo emergent simulations. The operational paradigm is that each child will have a desktop computer that runs the software, and is able, via a simplified programming language, to specify simple behavior rules for on-screen agents known as "turtles." Such simulations have been shown to be very well suited for teaching about complex systems and emergent behavior (Wilensky). The child watches very many agents of his/her own creation react and interact in an environment, and a teacher helps moderate the experience. The Global-Level label refers to the user's perspective on the simulated world: the student has an omniscient, global view of his or her individual simulated system. These simulations can be very effective educational tools, but require the teachers and students to first learn a specialized programming language, which is used to specify the environmental characteristics and the agents' responses to those characteristics. Moreover, the students are isolated when using the simulation: each has his or her own experience with their respective simulated worlds, and the form-factor of desktop computers prevents much in the way of collaborative learning. The up-front learning curve and need for a computer lab are perhaps why Global-Level simulations have not been widely used in our out of classrooms.

In contrast, the Local-Level approach is so named because the students participate on the local level: the students themselves are the actors, participating in a larger simulation instead of just watching it unfold. For this reason, Local-Level Simulations are often called Participatory Simulations, and are exemplified by the early wearable computer tags developed by Rick Borovoy and Vanessa Stevens, and the PDA-based simulations developed separately by Elliot Soloway and Eric Klopfer. The canonical participatory simulation game is a disease transmission scenario, where students go around "meeting" each other in one-to-one interactions mediated by their device. When students begin falling ill, as indicated by their devices, they must trace back through the meetings to figure out which student was the original vector for the disease. These simulations are very effective in getting students engaged in the task at hand by capitalizing on many well-known learning strategies: immersion, social interaction, and collaboration. They also tend to be very intuitive for first-time users: the interfaces are usually designed so that not much more than the tap of a button is needed to commit an action. They lack, however, the larger, encompassing perspective provided by Global-Level simulations, and because of this myopia don't serve well to educate children about emergent systems.

We will combine handheld devices (which offer users access to local-level properties for inspection and manipulation) and a touch-screen tablet PC (to provide a global view of the simulation), and thus allow students to view and experience the simulation at multiple levels of detail, both local and global. We claim that this will be the best of both worlds, in that the beneficial motivational effects of participatory simulations will be retained, but the added global perspective will allow the students to better understand their actions as being part of a complex system.

V.05. Supporting educational theories

In the design of this educational software paradigm, we have drawn upon several well-known theories of learning and approaches to learning support: constructivism, social constructivism, collaborative learning, situated learning, inquiry learning, and scaffolding. Educators throughout history, from Socrates to Dewey to the modern day, have acknowledged the powerful role a good question can have in the process of learning. Although these questions can be imposed externally, by an erotetically-minded instructor who guides the learning process with targeted questions, modern theories of how individuals construct personal understandings of a subject matter suggest that self-driven questioning can also be a powerful educational tool. Piaget was one of the first theorists to describe the important role play has in the construction of personal understandings, and how play often takes the form of posing and answering many small questions – "What if I placed this wooden block *here*?" Educational theorists have also come to acknowledge that people do not construct their personal understandings in a vacuum: most often, people develop their understandings in a social context, through apprenticeships, collaborations, or even just conversations with peers. Theorists like Vygotsky posit that learners progress through developmental stages, and that other students who are more advanced, but still within zone of proximal development of the learner, can help the learner bootstrap him- or herself into the next level of development in ways that an expert would not be able to. Lave and Wenger have noted that placing concepts in a situated context can help students learn the concepts in ways that an abstracted presentation of those concepts would not.

The structure of most classroom-centered inquiry-based learning, then, draws on all of these theories: it involves bringing students together in groups, so that the students can attack a problem together and share insights, in a situated context, so the concepts under study are more meaningful, and structures the problem so that the students will have to construct knowledge to answer the problem, by posing questions, devising hypotheses, and devising and performing experiments to test the hypotheses. Scaffolding is the process by which an instructor, peer, curriculum, or tool helps a student to advance in his or her development: as the name suggests, it is the idea of providing a learning aid that helps a student reach the next level of development, in such a way that the support can be removed after the next level is attained, without causing the newfound progress to "collapse". In the realm of educational software design, then, attention must be paid to how the software and user interface design can be used as learning scaffolds: how can the software be designed so as to impart the desired concepts, but to allow the understanding of those concepts to persist outside of the software use experience? For example, if a student learns that mixing two quantities of chemicals together in a simulation produces a third chemical, but he or she does not make the connection that this reaction indeed occurs in real life, the simulation-as-scaffolding has failed. Additionally, how can the concepts be properly problematized, while still producing software that is intuitive to use? For example, a calculator might be able to solve a Newtonian-motion equation for a student, requiring only the specification of initial masses and velocities, but if the student walks away without developing a personal sense of how forces interact, the calculator has failed as a physics scaffold.

VI.

- 4-5 Pocket PC Handheld Computers
  - Wifi-enabled
  - Touch-sensitive screens
  - 24-bit color screens
  - Preferred make/model: HP iPaq 4150
- 1 Tablet PC
  - Wifi-enabled
  - Touch-sensitive screen
  - Preferred make/model: HP Compaq TC 1100
- 1 Wireless hub
- 2 copies MS Visual Studio .NET[1]
- 1 copy Adobe Photoshop 7.0[1]
- 1 copy Adobe Illustrator 10[1]

VII.

A content specialist would be tremendously helpful in developing our demo game – someone with knowledge of evolutionary biology in particular – to select important concepts to be exemplified by our game and to bring their erudition to bear on the design of the parameterized rule systems used to drive the simulation.

VIII.

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IX.

IX.01. Member websites and contact information

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Chris Quintana: quintana@umich.edu
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[1] New software licenses need not be purchased for software generally available to students on the Duderstadt Center computers

Richard Vath: vathrich@umich.edu

IX.02. Equipment references

Handhelds: www.hp.com
Tablet PCs: www.hp.com

IX.03. Relevant academic references

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X. Word-of-mouth, from other students.