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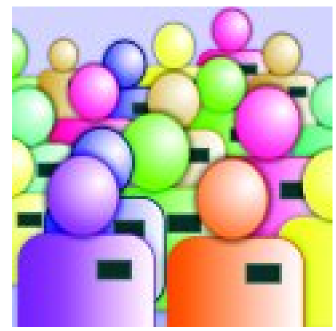
Becoming a Virtual Organism to Learn about Genetics

by ***Alexander Bick***



Introduction

Bioinformatics is the interdisciplinary intersection of computing and the life sciences. The National Institute of Health [6] defines bioinformatics as the use of computer techniques to explore biological problems. As computers have become more mobile -- evolving from mainframes to desktop workstations to laptop computers to personal digital assistants (PDAs) [3] such as Palm Pilots and Pocket PCs -- so too has bioinformatics. Recently, Riikonen and colleagues [10] wrote a client-server interface reminiscent of a thin client application that enables Internet-connected PDAs to search bioinformatics databases. Advances in technology have also led to advances in the teaching of bioinformatics, which is now supported by mobile platforms including the "thinking tag" and the Palm Pilot [4, 7]. In this paper, we explore the use of a Pocket PC genetics participatory simulation, an activity that embeds the investigator in a life-size simulation, in studying computational evolutionary biology, with particular emphasis on its value as a teaching tool.

Computational Evolutionary Biology

One challenge of studying evolution is the enormous time span over which it takes place. Early work by Darwin and others relied heavily on personal observation and inference. Researchers of today study microorganisms with short generation times so that thousands of generations can be observed over days and months [11]. Yet, this approach has its limitations, as complete control and observation of genotype are not yet possible. Computational evolutionary biology overcomes temporal constraints by modeling the statistical computations that occur through evolution with computer algorithms. For example, simulation software such as Adami and Brown's Avida [1] generates a population of virtual organisms that interact and evolve. Statistical analysis of the virtual population enables researchers to simulate in a matter of minutes and hours the evolution that could take nature millennia. Participatory simulations actively engage participants with real-world phenomena within constrained learning environments thus allowing researchers to simulate virtual organisms in a more educationally accessible way.

Thinking Tag Participatory Simulations

Participatory simulations are a new twist on the age-old concept of role-playing. Using computational technologies that support participatory simulation activities, it has become possible to simulate complex dynamic systems in science classrooms. Colella's thinking tag devices were an early use of participatory simulations in the classroom [4].

Thinking tags are small custom wearable computers approximately the size of a name tag. In one early game, the tags were programmed to model the spread of a virus in a population [4]. Participants "meet" one another by aligning their tags, thereby sending and receiving information from one another via their badge's infrared ports. As the game unfolds, participants become "sick" based on preset simulation settings, indicated by flashing lights on the badge. A virus outbreak ensues and participants use the scientific method to determine the source of the outbreak and how best to contain it. A second game developed by Klopfer and colleagues [7] utilizes many of the principles pioneered by Colella to model Mendelian inheritance of alleles and how genotype interaction affects organism phenotype.

Palm Pilot Genetics Participatory Simulation

Klopfer and colleagues' genetics participatory simulation "Live Long and Prosper" transferred the genetics game to the Palm Pilot platform [8,9]. The simulation leverages the device's increased computational and display capabilities to model a population of virtual organisms. Generating a random initial organism genome, the software displays a simplified genome of a virtual organism containing between one and eight genes, which characterize a single trait. Each gene is either homozygous dominant, heterozygous, or homozygous recessive for a single preset trait such as longevity, rate of aging, childhood disease, gender, or a noncoding gene that contains no relevant information. The virtual organisms age quickly and die depending on their genetic configurations. Before dying of natural causes, participants must mate their virtual organisms in order to survive to the next generation by beaming information through the infrared port of the PDA. After mating, the device generates a next generation virtual organism by combining traits in accordance with Mendelian genetics. Following this computation, the parent virtual organism dies and is replaced by an offspring. In this way, the virtual organisms live in discrete generations. Participants are also able to see the genomes of their organism's parents. The virtual organisms' initial genes and enabled traits are set at the instructor's discretion on each device.

As with other computational evolutionary biology software, the Palm Pilot simulation manipulates virtual organisms. Yet unlike desktop and laptop interfaces, Palm Pilots utilize the affordances of physical space. Virtual organisms travel with and among participants engaged in the simulation. Instead of using computer software to pseudo-randomly select for the best traits, Live Long and Prosper enables human participants to become active within the simulation, selecting for favorable traits.

Pocket PC Genetics Participatory Simulation

The Windows Mobile OS, run on the Pocket PC platform, has gained significant market share in recent years; in 2004 it surpassed Palm OS as the dominant PDA operating system. The Live Long and ProsperPC software written for this study is based on the same rules as Klopfer's Live Long and Prosper. It consists of a 2,000-line Microsoft C# program that runs on the Microsoft .Net Compact Framework. As with the Palm software, each simulation participant controls a virtual organism with his or her Pocket PC.

Like the Palm version, Live Long and ProsperPC is applicable in three broad categories of computational evolutionary biology: as an experimentation tool, an exploration tool, and a teaching tool. As a tool for experimentation, researchers can set up specific scenarios of virtual organisms and examine how the gene pool of the population evolves over time. As a tool for exploration, the simulation allows for informal investigation into what would happen under a variety of set circumstances. Despite these capabilities, the application was primarily designed to be used as a tool for teaching and learning.

Real World Application

Modern instructional practices at the middle school, high school, and university levels utilize inquiry-based learning methods to formulate ideas about genetics concepts such as independent segregation of alleles, the difference between genotype and phenotype, and testcrosses [2, 8]. This study sought to determine if our Pocket PC genetics participatory simulation increased high school biology student achievement. In addition, we were interested in the impact of student learning styles on the effectiveness of the simulation. We hypothesized that the simulation would increase student genetics achievement and that student learning style would affect the simulation efficacy.

Testing Methodology

To test this hypothesis, five introductory biology classes in a suburban, public high school were selected as a test group. The classes comprised 78 14-16 year old students, who used 20 Pocket PCs loaded with the simulation software during a 90-minute trial completed over two class periods. Summary statistics of the student population are shown in Table 1.

Biology Level	Male	Female	Total
Standard	17	14	31
Honors	12	15	27
Advanced Placement	11	9	20

Table 1: Participatory simulation study demographics.

Pre- and post-trial assessments evaluated participants' knowledge of the genetics concepts addressed by the simulation. Participants' learning styles were assessed using a version of the Felder and Soloman Index of Learning Styles [5], which describes each person in four dimensions. Each dimension has two mutually exclusive qualities: active or reflective, sensing or intuitive, visual or verbal, and sequential or global. For example, a person might be classified as a reflective, sensing, visual, global learner.

Results

Analysis of the data collected in this study indicates that PDA-enabled participatory simulations have a statistically significant positive impact on student achievement. A 95% confidence interval shows there was a difference of between 21.5% and 43.4% in pre-trial and post-trial exam scores. A paired t-test comparing the difference in performance yielded a t-value of 5.87, indicating that there was virtually no chance that the test scores did not improve. Students of all academic levels reported enjoying the participatory simulation. No significant difference was found between genders in pre-test/post-test improvement. However, a post-trial survey found a statistically significant difference between genders with respect to finding patterns. Boys in this study, on average, reported finding patterns more easily than girls did.

A student's learning style, as determined by the Felder and Solomon Index, was found to affect both the achievement increase resulting from the PDA simulation and the perception of PDAs as a teaching tool. Figure 1 illustrates the pre-test/post-test improvement grouped by learning styles. Active learners improved 12% more than reflective learners when comparing pre/post-test scores, and visual learners improved 6% more than verbal learners. Aligning students' learning styles with appropriate activities maximizes learning potential.

Figure 1: Percent improvement by learning style.

Conclusion

The PDA platform is clearly effective for computational evolutionary biology software. In fact, the portable form factor and infrared wireless communication properties of the PDA enable bioinformatics simulations that would not be practical on laptop or desktop computer platforms. The real world location of the virtual organism enables investigators to become a part of the virtual system, thereby understanding it more deeply. While we studied the teaching and learning application of this software, the simulation software is also applicable for researchers who wish to use it to experiment or to explore the complex, dynamic phenomenon that is evolution. Future work should consider the efficacy of this software for the latter two purposes. As the analysis of the data has shown, the software is an effective teaching tool, improving student achievement overall, while having a different degree of impact on students of different learning styles. In effect, genetics participatory simulations make the bioinformatics field more accessible to the introductory biology student.

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Biography

Alexander Bick is a freshman at Harvard University. He pursued this research while at Millburn High School in New Jersey as part of a four year Intel science talent search project to determine the impact of PDAs on high school student achievement.