Title: **"Evolve and Conquer: Using immersive video games to teach Evolution in Action"**
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Introduction: The Adami Lab studies evolution in many different computational environments, including the popular game development platform Unity3D, which supports our research in 3D virtual physics environments. A group of students in our lab (R. Olson, J. Schossau, and D. Phillips) started a game project with the preliminary title Evolve and Conquer (E&C), a real time strategy game which incorporates the core principles of evolution: inheritance, variation, and natural selection. E&C immerses the player in a world governed by these evolutionary principles, allowing the player to experience evolution in action first-hand as a core aspect of the game mechanics. The player must understand the core principles of evolution in order to prevail and either overcome or learn to coexist with an evolving computer opponent.

Previous work has suggested that computer games and simulations "enable learners to see and interact with representations of natural phenomena that would otherwise be impossible to observe," and allow students to learn difficult material in a context that is personally meaningful to them [1]. As such, we have designed E&C with the idea of teaching evolutionary principles using an implicit, immersive approach, which can allow the learning experience to be more exciting, engaging, and effective [2, 3], as opposed to other games that teach evolutionary principles explicitly. Instead of releasing the game as-is (see Fig. 1), we have the unique opportunity to align this game with BEACON's mission, outreach, and educational goals, and guide its future development decisions accordingly.

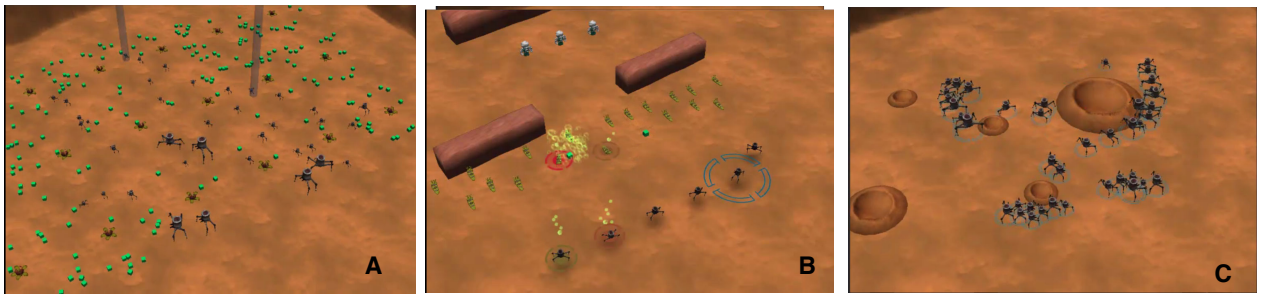

Figure 1: Screen shots from the development version of the "Evolve and Conquer" game. The current version is fully playable. In A, "spider bots" are moving within a field of resources (green) that allow them to spawn offspring if they manage to consume a sufficient number. The vertical grey cones denote two such spawning events, and in each such event mutations can occur to the genome encoding the spider bots, leading to variation. In B, a battle rages between spider bots and an army of "protozoa" (light green with antennae), with a group of "stone monsters" standing by in the background. In C, we can see groups of "spider bots" navigating around obstacles as a group. Note that all interactions between agents and their environment occur according to the fully simulated laws of physics, creating a fitness landscape with unpredictable opportunities.

Implicit, immersive approach: In the implicit, immersive teaching approach, the player experiences the three evolutionary principles (inheritance, variation, natural selection) and must use them to accomplish a given set of goals. However, all scientific terminology is avoided, and the in-game tutorial only demonstrates how to perform basic game controls such as unit movement, eating food to survive, and attacking enemies to defend territory. This allows the player to discover the underlying principles him/herself, which makes the learning experience more sustainable and emphasizes the engaging aspect traditional computer games provide.

Explicit approach: With the explicit teaching approach, the player is confronted with the evolutionary game concepts in a direct fashion. The tutorial uses scientific language and describes the game elements explicitly. Additionally, the game highlights that the units controlled by the player experience artificial selection,

whereas the computer opponent uses natural selection, and explains the role of breeding explicitly. The idea is to make the concepts clear to the player from the beginning, with the drawback that this extra step may diminish the players' engagement with the game due to the explicit teaching component. **We propose a comparison between both approaches** and their impact on the understanding of the core evolutionary principles: inheritance, variation, and natural selection.

Goals: We would like to further develop the already existing prototype of E&C into a releasable version. Our future design decisions will be guided by scientific data that is informative about which teaching approach (indirect immersive or explicit) is best to achieve our outreach and educational goals. We will verify that after interacting with the game, players will have a deeper understanding of variation, inheritance, and natural selection.

Methods: We will design different game versions and collaborate with Julie Libarkin from STEM E.D. LLC, who will perform the educational evaluation. This evaluation will take advantage of two settings to collect data on the game's efficacy: Amazon Mechanical Turk [4] and a Player Focus Group; these settings are also being used by a project for design studies unrelated to STEM E.D. assessment. Turk workers will engage in brief game play aligned with one of the three conceptual areas (variation, inheritance, natural selection). Players will then complete the understanding, enjoyment, and demographic surveys for the implicit or explicit condition. We anticipate a minimum of 36 cohorts of N=20 Turk players each. Two control groups (N=50 each) will complete the understanding (implicit and explicit) and demographic surveys without engaging in game play to provide a baseline for incoming conceptual understanding of the three concepts. After design studies and initial assessments, a group of N=20 players will be recruited to engage in live play. During the recruitment process, participants will complete understanding and demographics surveys. About 2 weeks after recruitment, participants will assemble in a computer lab to engage in game play for two hours. After this period, participants will retake the understanding survey and will complete enjoyment questions. A debriefing conducted by the Project Leader will also be conducted during this time period.

Team: Chris Adami is an expert on evolutionary theory and computational evolution. Arend Hintze has released more than 20 iPhone and Flash games and successfully competed together with Randy Olson, Jory Schossau, and David Philips in various computer game design competitions, and he teaches the MSU iPhone Game Development Class. David Philips is a specialist in Game Design and Development, and Julie Libarkin is an expert on educational assessment of teaching in science.

Intellectual Merit: First and foremost, we will evaluate the efficacy of an immersive computer game as a teaching tool both inside and outside the classroom. Additionally, we will determine whether an implicit or explicit teaching approach is better suited to teach evolutionary principles using a computer game.

Broader Impacts: The current game design aims for a broad audience including both genders and all age groups. Besides the teaching aspect, we suggest that raising the understanding of evolution will also increase its acceptance, and inspire student's interest in science, as America's Army did for the military [5]. This game also allows us to customize and release additional levels, which provides a platform to teach more specific scientific concepts to a smaller audience, such as a classroom. We encountered many students from other BEACON sites who were interested in contributing to this game. Using this pool of volunteers can strengthen the communication and collaboration ability between sites, and is also an effective method to teach evolutionary concepts to these students.

Future Funding: This research will improve the quality of the E&C game, verify its application as an education tool, and allow this game to be officially endorsed by BEACON, which are all important aspects to improve the marketability and success of E&C as an enjoyable computer game and teaching tool. We would like to release E&C for free or as low priced as possible in order to reach a broad audience, which we would not able to do if the game had to finance our development costs (i.e., David Phillips' salary). Moreover, this game project will likely lead to the development of a new game development company which specializes in making immersive computer games for teaching specific topics, such as the core evolutionary principles.

References

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