# Toward a Community of Evolving Learners

Elizabeth Sklar, Jordan B. Pollack
DEMO Laboratory, Dept. of Computer Science
Brandeis University
Waltham, MA 02454-9110 USA
sklar,pollack@cs.brandeis.edu
http://www.demo.cs.brandeis.edu/cel

**Abstract:** We discuss the *co-evolutionary learning method*, applied to human learning, as a means toward a mediated, competitively motivated, educational environment on the Internet. This method was developed in our work with machine learners, where we have been examining environmental characteristics that enable successful and effective learning through "self-play" in games. Critical features include the ability to provide tasks consistently just beyond or just within a learner's grasp. We carry these observations into the human education arena, using them to help us enable a Community of Evolving Learners (CEL) on the Internet. This paper describes the design of the CEL system.

## 1. Introduction

In a machine learning system, the learner is a computer program (also called a software agent or just *agent*), and the goal is to produce agents that *learn* to perform intelligent tasks, expanding their own capabilities as they run, without needing human programmers to update them. In artificial *co-evolutionary learning*[1], the learning environment automatically and incrementally becomes more challenging as the learner advances – often because the environment consists of other learners [Hillis, 1992, Sims, 1995, Pollack & Blair, 1998]. We carry these ideas into the human education arena and use them to construct a co-evolutionary tutoring system called the Community of Evolving Learners (CEL).

Early Intelligent Tutoring Systems often tried to model human learning by carefully engineering training environments [Soloway et al., 1981, Anderson, 1982, Kolodner, 1983]. More recent efforts make use of the Internet to provide, for example, collaborative learning spaces, curriculum sequencing, solution analysis and adaptive presentation [Suthers et al., 1995, Brusilovsky et al., 1996, Bruckman, 1997]. Our work differs from these and other related efforts in several respects, particularly in the use of: evolutionary techniques to adapt to users' needs; a competitive game playing environment; indirect user interaction; and graphical presentation elements.

## 2. System Overview

The CEL system, implemented using Java and released on the Internet, injects specific curricular activities into a multi-user environment (see figure 1). Inside, simple competitive games[2] help users reinforce basic arithmetic and language[3] skills, targeted (though not restricted) to primary grades [Sklar et al., 1998]. Software agents act as learning partners, mediating interactions. In this way, communication between users is considered *indirect*, a methodology which distinguishes our work from others in which users interface *directly* via a "chat" mechanism. One advantage is that through this design, we avoid issues such as censoring conversations to protect users and restricting user behaviours to stay focused on the learning task.

We use a student's performance against the agents as a measure of that student's abilities. A database maintains a profile for each user, indicating which agents the user has encountered and how the user has performed in regard to the skill(s) tested by those agents. Data collected on human acquisition of these skills shows emerging partial orderings which can be used to offer students multiple paths to higher skill levels. A clustering algorithm matches users, and a co-evolutionary process selects agents, maintaining a balance between skills already learned and skills just beyond a user's reach.

[1] inspired by the "arms race" phenomenon between species in natural evolution
[2] for example, the traditional spelling bee
[3] currently only in English

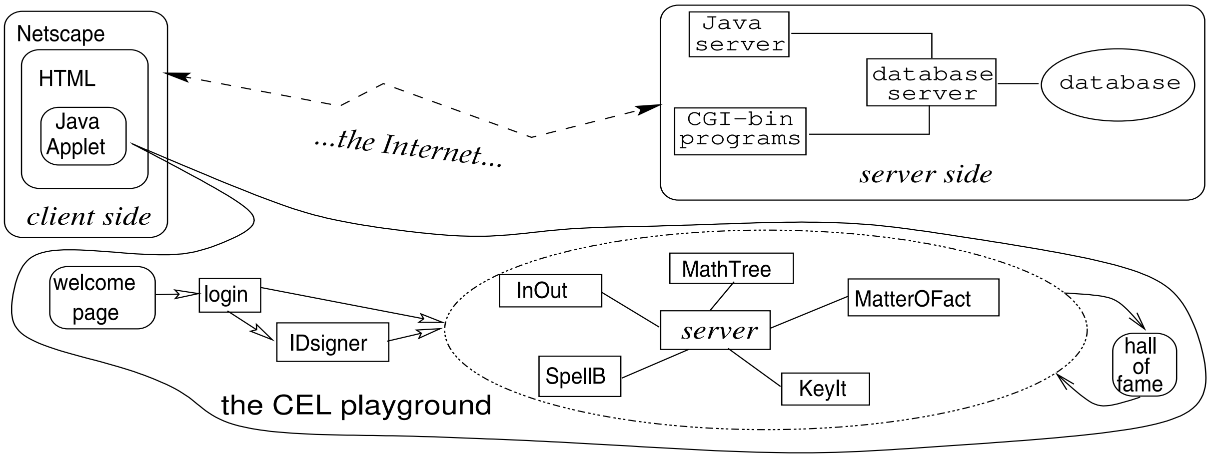



**Figure 1 The CEL System.** An HTML welcome page introduces users to the system. Each user creates a unique 2-dimensional design – called an "IDsign" – to identify him/herself. Users enter the virtual space – the "CEL playground" – where interactions are controlled by our server. Humans and software agents are matched in competitive, two-player games. Some sample games are depicted.

## 3. Challenge and competition in education

The CEL provides feedback to the student on his/her individual progress, while at the same time encouraging the learner to continue "playing". One simple reporting mechanism is a *hall of fame*, which displays a straightforward ranking of the players in the system, similar to that in a traditional video game. In earlier work [Funes et al., 1998], we found several players returning to our game-playing web site in order to outdo each other. This type of global ranking system may be inappropriate for some students, and so we are exploring alternatives: displaying a history of a student's personal achievements; using a normalizing algorithm to contrast individuals' performances; and limiting the other players' scores that a given user can see. The key is to offer a progress report that will challenge students, intriguing them to stay involved in the CEL; and we note that users' needs vary and thus it is necessary to enable several mechanisms and then customize output for individuals.

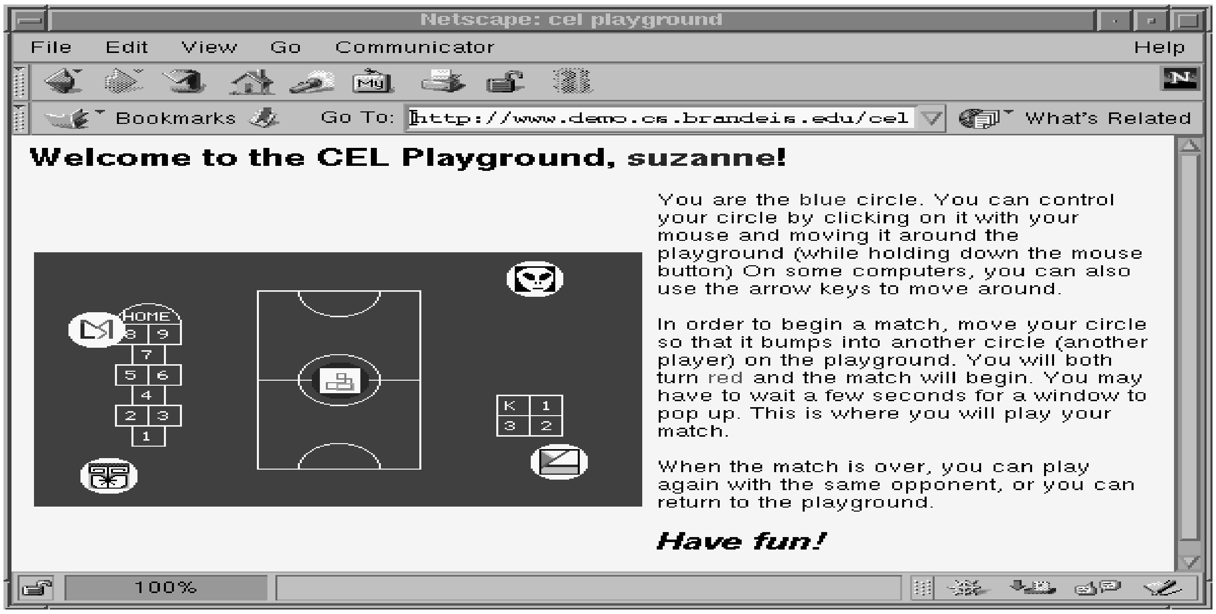
The use of competition in academics – particularly in the United States – is quite controversial and has been eliminated in many school districts. [Kohn, 1986] has mustered strong evidence that competitive games in classrooms lead to lower educational outcomes; as motivators, they hurt more students than they help. However, we hypothesize that the difficulty may lie in repeated competition inside one classroom, with local peers. To overcome these issues, the CEL takes advantage of the Internet: allowing social anonymity wherein students can fail and succeed *incognito*; and maintaining challenge continuously by expanding the pool of competitors beyond the traditional boundaries of age and geography.

## 4. Discussion

The application of artificial intelligence techniques to tutoring systems has often been met with skepticism by educators. We know that the element of creativity that human teachers supply will never be replaced by computers. Consequently, our methodology does not rely on "'solving the AI problem", but rather takes advantage of a computer's particular abilities – e.g. search, memory, calculation – to perform tasks like record-keeping and user-matching. The challenges inherent in the CEL are provided by the students themselves, in their interactions with each other, not by some mechanism artificially engineered into the system.

The CEL environment provides us with opportunities to explore many avenues of research: examining motivational aspects by using different reward schemes to structure the presentation of feedback; varying the mix of humans and software agents; observing group learning, matching students in heterogenous and homogeneous teams.

The ultimate goal of the CEL, in establishing a community of evolving learners, is to help: learners in classrooms where challenges are not readily and/or consistently available; learners in isolation, such as in hospital; and distance learners. The advent of the Internet allows us, as researchers, to address learning situations like these, where even 10 years ago such enabling technology did not exist.




## 5. References

[Anderson, 1982] Anderson, J. R. (1982). Acquisition of cognitive skill. *Psychology Review*, 89.

[Bruckman, 1997] Bruckman, A. (1997). *MOOSE Crossing: Construction, Community, and Learning in a Networked Virtual Community for Kids*. PhD thesis, MIT.

[Brusilovsky et al., 1996] Brusilovsky, P., Schwarz, E., & Weber, G. (1996). Elm-art: An intelligent tutoring system on world wide web. In *Intelligent Tutoring Systems (CS Lecture Notes, Vol.1086)*. Springer Verlag.

[Funes et al., 1998] Funes, P., Sklar, E., Juillé, H., & Pollack, J. (1998). Animal-animat coevolution: Using the animal population as fitness function. In *Proc SAB-5*.

[Hillis, 1992] Hillis, W. D. (1992). Co-evolving parasites improve simulated evolution as an optimization procedure. In *Proc ALIFE-2*.

[Kohn, 1986] Kohn, A. (1986). *No Contest: The case against competition*. Houghton-Mifflin.

[Kolodner, 1983] Kolodner, J. (1983). Maintaining organization in a dynamic long-term memory. *Cog Sci*, 7.

[Pollack & Blair, 1998] Pollack, J. B. & Blair, A. D. (1998). Co-evolution in the successful learning of backgammon strategy. *Machine Learning*, 32:1–16.

[Sims, 1995] Sims, K. (1995). Evolving 3d morphology and behavior by competition. In *Proc ALIFE-4*.

[Sklar et al., 1998] Sklar, E., Blair, A., & Pollack, J. (1998). Co-evolutionary learning: Machines and humans schooling together. In *Wkshp Current Trends and Applications of AI in Educ: 4th World Cong Expert Systems*.

[Soloway et al., 1981] Soloway, E. M., Woolf, B., Rubin, E., & Barth, P. (1981). Meno-ii: An intelligent tutoring system for novice programmers. In *Proc 7th Int'l Joint Conf on Artificial Intelligence (IJCAI)*.

[Suthers et al., 1995] Suthers, D., Weiner, A., Connelly, J., & Paolucci, M. (1995). Belvedere: Engaging students in critical discussion of science and public policy issues. In *Proc AIED-95*.

**Acknowledgements**

Thanks to Travis Gephardt and Maccabee Levine for implementation help and to Alan Blair for providing constructive comments. Special thanks to the University of Queensland Department of Computer Science and Electrical Engineering for hosting the first author during the writing of this paper. Partial support for this research was provided by the Office of Naval Research under N00014-98-1-0435.