Advances in Engineering Innovation Vol.17 Issue 9 EWA Publishing
Available Online: 19 August 2026 DOI: 10.54254/2977-3903/2026.36290

Design and operation of simulation experiments based on an AI-empowered predation model

*Ning Wang, Xuexiang Wang, Xiaoying Wu**

Taiyuan Normal University, Jinzhong, China

*Corresponding Author. Email: wuxy@tynu.edu.cn

Abstract. Predation is a key biological factor influencing population dynamics, yet traditional teaching methods often struggle to visually illustrate its synchronous periodicity and causal cycles. By leveraging AI to build a predation model, we have developed a predator-prey simulation system. The web-based platform employs a three-pane layout to integrate ecological simulations, data charts, and functional controls. It supports customizable parameters, allows for comparisons between J-shaped and S-shaped growth curves, and includes a CSV data export feature, all of which help foster students' interdisciplinary literacy.

Keywords: predation model, artificial intelligence, interactive simulation

1. Introduction

According to the Biology Curriculum Standards for Senior High Schools (2017 Edition) [1], students are required to analyze the factors affecting population dynamics and to construct mathematical models that explain the characteristics of population changes, and to understand the synchronous periodicity between predators and prey, the time lag of predators, and the causal cyclic relationships between them. These concepts integrate biological knowledge, mathematical modeling, and systems thinking, placing high demands on students' comprehensive abilities.

In traditional teaching, teachers mostly use static charts or abstract descriptions to present predation relationships, so students find it difficult to understand the dynamic process, time lags, and causal cycles involved. Although some researchers have attempted to use tools such as NetLogo for simulation, these tools are complex to operate and have poor interactivity, making them difficult to promote in regular classrooms [2, 3]. Fu Yong's study on the simulated experiment of the mark-recapture method showed that traditional simulation experiments suffer from drawbacks such as susceptibility to subjective factors, time-consuming operations, and limited data volume [4], and these problems also exist in the simulation of predation relationships.

We use an AI-assisted predation model to design an interactive tool that fits the realities of senior high school teaching. By transforming abstract concepts into visual operations and integrating biology [5], mathematics, and information technology, this tool cultivates students' comprehensive literacy.

2. Production process of the predation model simulation experiment

The web page requires setting up a local server testing environment, and the technical architecture is implemented through HTML5, CSS3, JavaScript, and Canvas drawing. The model is designed around core concepts in the textbook, such as J-shaped growth, S-shaped growth, and the dynamic changes in predator-prey population numbers, and key parameters such as population growth rate, environmental carrying capacity, and predation efficiency are set as independently adjustable variables.

The production follows the operating procedure of "clarifying requirements → inputting instructions → generating code → running and debugging". After clarifying the requirements, the teacher inputs the following instruction to the large language model: "I am a senior high school biology teacher and want to develop an HTML simulation web page to simulate the predation relationship between red foxes and rabbits in a grassland ecosystem. The web page adopts a three-pane layout, including an ecological simulation area, a data chart area, and a function control panel area, and should include functions such as environment switching, species introduction, and parameter adjustment. Finally, it should display the population change curves of the two species in real time in a visual form, support the comparison of J-shaped and S-shaped growth, and also have functions such as real-time data recording and CSV export."

The above instruction was entered into the Gemini large language model to generate front-end code, and the code was then pasted into a text document. The file was saved as bushi.html, and double-clicking the file runs the simulation. After running, the model was debugged: problems such as lag or chart delays were fixed, and a simulation web page suitable for classroom demonstration in senior high school biology and for students' independent inquiry was ultimately developed. The result is shown in Figure 1.

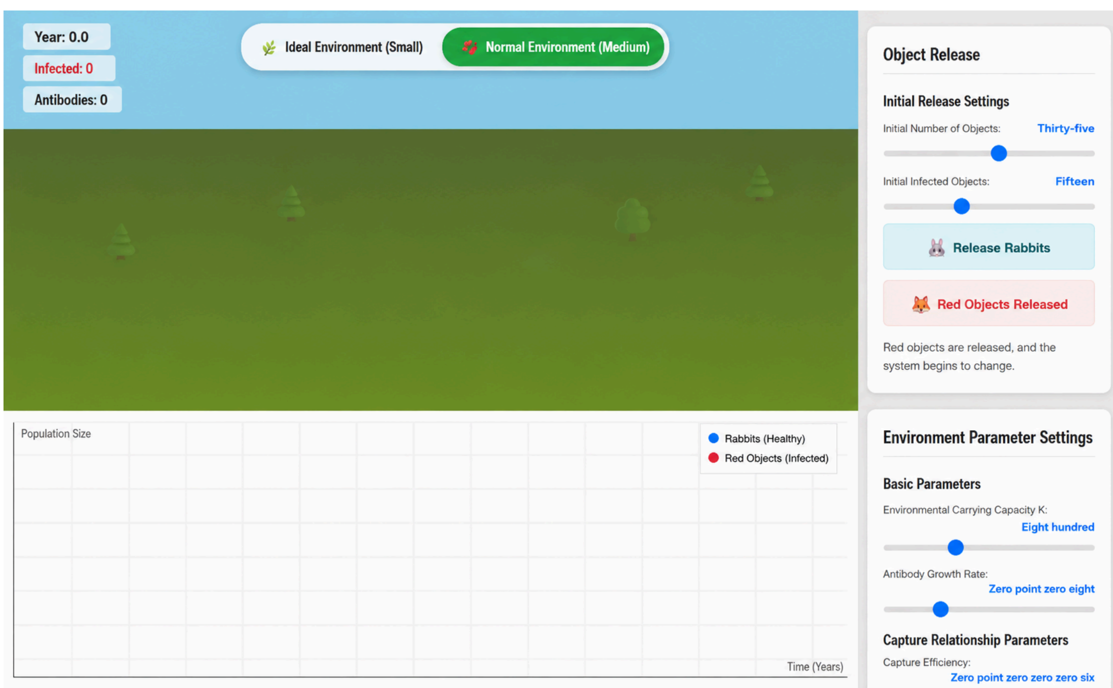

Figure 1. Interface of the predation model simulation experiment web page

During debugging, the generated code can be modified and adjusted. The whole system consists of three key links, namely "population change rule formulation – dynamic curve presentation – experimental data export". The key code fragments are interpreted in Table 1.

Table 1. Interpretation of key code snippets in the predation model

Functional stage	Implementation code	Interpretation

Implementation of population change rules	javascript
	function updatePopulations() {
	let r = state.rabbits, f = state.foxes;
	let dt = state.currentSpeed, K = CONFIG.rabbitCarryingCapacity;
	let dR = 0, dF = 0;
	
	if (!state.hasFoxes) {
	// No predator phase: J-curve or S-curve growth
	if (state.envMode === 'IDEAL') {
	dR = (CONFIG.rabbitBaseGrowth * r) * dt;
	//J-curve: unlimited growth
	}else {
	dR = (CONFIG.rabbitBaseGrowth * r * (1 - r/K)) * dt; // S-curve: limited by carrying capacity K
	}
	} else {
	// Predator present: rabbit natural growth minus predation
	let growthTerm = CONFIG.rabbitBaseGrowth * r * (1 - r/K);
	let predationTerm = CONFIG.predationRate * r * f;
	dR = (growthTerm - predationTerm) * dt; // Rabbits: natural growth − predation
	}}
		The updatePopulations function is defined to update the population numbers of rabbits and foxes in the simulation. state.rabbits is assigned to r and state.foxes to f to simplify the calculation; dt is the time step, and the larger its value, the faster the population changes; K is the environmental carrying capacity of rabbits, used to achieve S-shaped logistic growth; dR (change in rabbits) and dF (change in foxes) are initialized to 0.
		
		The if (!state.hasFoxes) statement divides population changes into two types: the ideal state and the presence of natural enemies. Under the ideal environment, the rabbit population grows exponentially, forming a J-shaped curve.
		In the normal environment, after the logistic factor (1 − r/K) is introduced, the rabbit population growth forms an S-shaped curve.

	// Foxes gain energy for reproduction by predation and suffer natural death
	let conversionTerm = CONFIG.foxConversionRate * r * f;
	let deathTerm = CONFIG.foxDeathRate * f;
	dF = (conversionTerm - deathTerm) * dt; // Foxes: energy conversion − natural death
	}
	state.rabbits = Math.max(0, state.rabbits + dR);
	state.foxes = Math.max(0, state.foxes + dF);
	}
		After red foxes appear:
		A predation term predationRate*r*f is added to the rabbit equation, and it is directly proportional to the product of the two populations, reflecting the probability principle that "once they meet, predation may occur".
		The fox equation consists of energy conversion and natural death; energy conversion depends on the number of rabbits r, reflecting the causal relationship that "an increase in the prey population leads to an increase in the predator population".

Table 1. Continued

Visualization of population dynamics	...javascript
	function drawChart() {
	    const w = chartCanvas.width, h =
	  chartCanvas.height;
	    chartCtx.clearRect(0, 0, w, h);
	
	    // Dynamically calculate y-axis maximum
	for adaptive scaling
	    let maxPop = 0;
	    state.history.forEach(d => { maxPop =
	Math.max(maxPop, d.r, d.f); });
	     if (maxPop < 100) maxPop = 100;
	     maxPop *= 1.2;
	
	    // Draw double-curve comparison chart
	    function drawLine(color, dataKey) {
	      chartCtx.beginPath();
	      chartCtx.strokeStyle = color;
	      chartCtx.lineWidth = 2;
	      state.history.forEach((d, i) => {
	        let x = (i / state.history.length) * w;
	        let y = h - (d[dataKey] / maxPop) * h;
	        if (i === 0) chartCtx.moveTo(x, y); else
	chartCtx.lineTo(x, y);
	      });
	      chartCtx.stroke();
	  }
	
	   drawLine("#007bff", 'r'); // Blue: rabbits
	   if (state.hasFoxes) drawLine("#dc3545", 'f');
	// Red: foxes
	    // Draw K-value reference line
	    let kY = h -
	(CONFIG.rabbitCarryingCapacity / maxPop) *
	h;
	    chartCtx.setLineDash([5, 5]);
	    chartCtx.beginPath();
	    chartCtx.moveTo(0, kY); chartCtx.lineTo(w,
	kY);
	    chartCtx.stroke();
	}
		The clearRect method is used to first clear the contents of the canvas, and then a grid is drawn as a coordinate reference. After traversing the historical data, 1.2 times the maximum population value is selected as the upper limit of the y-axis to achieve adaptive scaling.
		When drawing the comparison curves, drawLine maps the historical data according to time and quantity, turning them into continuous polylines. Red and blue lines are then used to represent the predator and the prey, respectively,making it easy for students to distinguish different populations and observe the phase difference. Finally, a K-value reference line is drawn to provide a visual reference.

Table 1. Continued

Experimental data export	...javascript
	 function exportData() {
	  if (state.history.length === 0) {
	   alert("No data to export, please run the simulation first.");
	   return;
	  }
	
	  // Add UTF-8 BOM to prevent Chinese garbled text in Excel
	  let csvContent = "\uFEFF";
	  csvContent += "Time(year),Rabbit Count,Fox Count,Rabbit Instant Growth Rate,Fox Instant Growth Rate\n";
	  state.history.forEach(item => {
	  let t = item.t.toFixed(4);
	  let r = Math.floor(item.r);
	  let f = state.hasFoxes ? Math.floor(item.f) : 0;
	  let rg = (item.rg * 100).toFixed(2) + "%";
	  let fg = state.hasFoxes ? (item.fg * 100).toFixed(2) + "%" : "0.00%";
	  csvContent += \`${t},${r},${f},${rg},${fg}\n\`;
	});
	  // Create Blob and trigger browser download
	  const blob = new Blob([csvContent], { type: 'text/csv;charset=utf-8;' });
	  const link = document.createElement("a");
	  link.setAttribute("href", URL.createObjectURL(blob));
	  link.setAttribute("download", \`EcoSimulationData_${state.year.toFixed(1)}.csv\`);
	  link.click();
	}
		To prevent garbled Chinese characters in Excel when exporting CSV data, a "\uFEFF" UTF-8 byte order mark is used for recording. The five core fields of the CSV correspond to key ecological observation indicators; the file download uses a pure front-end solution involving a Blob object and a temporary a tag.

These three key links constitute a complete chain of "input parameters → computational evolution → output data", corresponding respectively to the cultivation of modeling thinking, observation and induction ability, and data analysis ability, jointly helping students achieve the cognitive leap from perceptual understanding to rational analysis.

3. Operating methods of the predation model simulation experiment

After logging into the page, students can clearly see the layout of the three functional areas on the interface: the upper part simulates the interaction process between biological species, the lower part displays the population change curves, and the right side contains control elements for environmental parameter configuration and experimental operations. The model is implemented in four steps. The first step is the selection of the environment mode. Selecting the ideal environment mode enables observation of J-shaped population growth, while selecting the normal environment mode enables exploration of the S-shaped growth curve. The second step is the stepwise introduction of species. Rabbits are introduced first to begin observation of a single population; after continuous observation for 15 to 20 simulated time cycles, red foxes are introduced to observe the changes in population numbers under the predation relationship. The third step is the adjustment of ecological parameters. Slider controls are used to independently set core variables such as the environmental carrying capacity and the intrinsic growth rate of the population. The fourth step is the export of experimental data. Clicking the "Export Data" control exports the data analyzed in the previous three steps as a CSV file, providing raw data support for subsequent quantitative analysis and mechanism exploration.

In the observation and recording stage, the focus can be placed on three core phenomena: the characteristics of population changes under the ideal environment, the characteristics of population changes under the natural environment, and the time-lag effects and periodic oscillation patterns of population fluctuations in the coexisting predator-prey system. During the experiment, the time lag between the peak of the red fox population and the peak of the rabbit population can be precisely measured. By sorting out the dynamic process of "rabbits increase → foxes increase → rabbits decrease → foxes decrease", students can clarify the operating mechanism of positive and negative feedback regulation in the ecosystem. When designing inquiry experiments, the single-variable principle should be strictly followed to quantitatively analyze the regulatory effects of various ecological factors on the stability of community structure and the patterns of population dynamics.

4. Significance of the application of the predation model simulation experiment

The predation model is mainly applied to the teaching content of Chapter 1 of Biology and Environment, the second compulsory selective textbook of senior high school biology published by the People's Education Press. In real classroom teaching, the introduction stage of a new lesson can use the ecological simulation context to naturally lead into the theme of "factors causing changes in population numbers"; in the stage of breaking through key and difficult points, dynamic demonstrations can visually present the time lag of the prey and the synchronous periodicity of predators and prey; in the inquiry activity stage, dedicated class hours can be arranged to carry out simulation inquiry experiments.

Beyond the limits of a single discipline, the tool also has diverse teaching value in interdisciplinary integration. The population growth curves generated by the predation model can be combined with the principles of exponential and logistic functions in mathematics to explain the laws of population growth and the characteristics of periodic fluctuations; when adjusting parameters independently, it can be combined with code reading and parameter modification in information technology to gradually develop students' digital thinking and basic algorithmic literacy; when adjusting the environmental carrying capacity, it can also be combined with the characteristics of different geographical environments in geography to explore the mechanisms and laws by which ecosystems maintain balance under different regional environmental conditions.

The tool can also be applied flexibly in different classroom teaching modes. When conducting experimental inquiry, three levels of inquiry tasks, namely basic inquiry, advanced inquiry, and extended inquiry, can be set according to students' cognitive levels to gradually deepen their inquiry abilities; when organizing chapter review, it can serve as a comprehensive teaching case to link and review core knowledge points such as populations, communities, and ecosystems, achieving a systematic organization of the knowledge system.

5. Conclusion

The AI-empowered predation model simulation experiment has multifaceted teaching value. First, it concretizes abstract concepts. Through immersive hands-on operation and observation of population change patterns, students can intuitively grasp knowledge points such as the synchronous periodicity of populations in predation relationships and the time lag of predator population fluctuations. Second, it develops students' scientific inquiry literacy. During inquiry, the model can fully reproduce the standardized scientific inquiry process of posing questions, variable control, comparative inquiry, data analysis, and drawing conclusions, further enhancing students' scientific inquiry ability and dialectical thinking ability. Third, it effectively develops students' computational thinking. The predation model supports the export and independent processing of experimental data, allowing students to understand the modeling logic and operating rules of complex ecosystems while avoiding the complexity of advanced mathematics. Fourth, it further enhances students' interdisciplinary comprehensive literacy. The model deeply integrates knowledge systems from multiple disciplines such as biology, mathematics, and information technology, in line with the reform orientation and educational requirements of interdisciplinary integration in basic education in the new era.

The AI-empowered ecosystem simulation experiment can serve as a teaching support resource for the ecology section of senior high school biology, especially for schools with limited experimental conditions. At the same time, the technical framework has good compatibility and scalability and can also be used in other ecological topics such as interspecific competition, mutualism, and community succession. In this way, a complete ecology simulation resource package can be formed, providing a replicable path for the digital transformation of biology teaching at the secondary school level.

References

[1] Ministry of Education of the People's Republic of China. (2018). *Biology curriculum standards for senior high schools (2017 edition)*. People's Education Press.

[2] Feng, X. L. (2023). *Development and application of a high school biology simulation model based on NetLogo* [Master's thesis, Jiangxi Normal University].

[3] Yang, Y. J., Liu, J. L., & Zheng, X. H. (2015). Application of computer modeling based on NetLogo to biology teaching in secondary schools. *Biology Teaching, 40*(2), 10–12.

[4] Fu, Y. (2026). Design and implementation of a mark-recapture simulation experiment based on artificial intelligence. *Biology Teaching, 51*(2), 56–59.

[5] Dai, W. Q. (2026). Research on the practical approaches of artificial intelligence empowering high school biology teaching. *Gaokao*, (12), 79–81.