425

STEM CELL INNOVATION CONTEST 2026

11TH EDITION | THEME: STEM CELLS & AI

CTRL CELLS

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VirtualLab: An AI-Powered Platform for Simulating and Teaching hBM-MSC Culture

INTRODUCTION

BACKGROUND

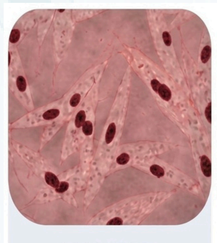
- Human bone marrow-derived mesenchymal stem cells (hBM-MSCs) play an important role in regenerative medicine.
- However, training in cell culture is constrained by costly consumables, expensive equipment, and limited opportunities for repeated practice.

EDUCATIONAL GAP

- Current learning materials mainly describe procedures without interactive practice, making underlying concepts harder to grasp.
- The proposed virtual laboratory enables repeated practice and safe learning from mistakes before working in a real laboratory.

OBJECTIVES

- Provide interactive training in cell culture procedures and aseptic techniques.
- Simulate how experimental choices affect cell proliferation.
- Use AI to predict outcomes and provide automated feedback, including scoring and learning reports.



hBM-MSCs (Spindle-shaped, adherent cells)



Biosafety cabinet (BSC)

Traditional practice

- High cost
- Equipment limitations
- Limited practice opportunities

VirtualLab

- Flexible
- Repeated practice
- Safe and cost-effective

METHODS & EXPECTED OUTCOME

METHODS

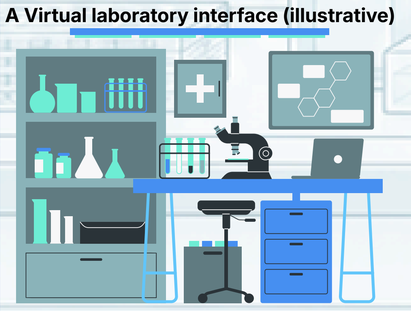
- Build growth models using published data.
- Clean and standardize the data.
- Extract features and train AI models to predict cell proliferation.
- Develop a 3D simulation featuring a biosafety cabinet, CO_2 incubator, and microscope; changes in culture conditions alter predicted growth curves and cell morphology.
- Use AI to compare experimental scenarios, assess procedural performance, and provide automated feedback.

Data & references → Biological–AI models → Virtual lab development → Assessment & feedback

EXPECTED OUTCOME

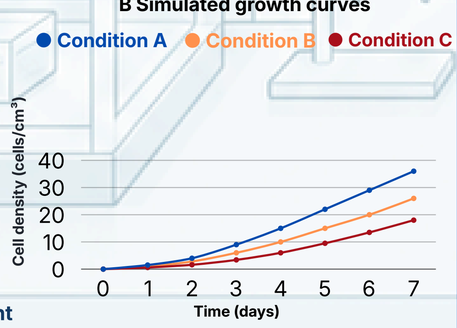
- A virtual laboratory interface for practicing MSC culture protocols.
- Simulated visualizations of cell proliferation over time.
- Predicted growth curves, optimal conditions, and tailored recommendations.
- AI-based comparisons and recommendations for suitable culture conditions.
- Automated reports and assessment of learning outcomes.

A Virtual laboratory interface (illustrative)



- Biosafety cabinet
- CO_2 incubator
- Microscopy equipment
- Cell culture equipment
- Reagents and pipettes
- Procedural guidance

B Simulated growth curves



Illustrative simulated data—not experimental results.

PROCESS/WORKFLOW

A INPUT DATA

1 hBM-MSC biological data collection

- Published datasets
- Growth measurements
- Seeding density
- Culture duration
- Environmental variables
- Protocol information

Sample	Density	Duration	Medium	02
S01	3x10³ cells/cm²	7D	α-MEM	5%
S02	5x10³ cells/cm²	7D	DMEM	21%

2 Data preparation

Raw data → Cleaning (noise removal, missing-value handling) → Standardized dataset

B BIOLOGICAL & AI MODELS

3 Feature extraction

Input features

- Initial cell density
- Culture duration
- Culture medium composition
- Oxygen conditions
- CO_2 concentration
- Culture substrate

→ **Derived features**

- Growth rate
- Doubling time
- Cell confluence
- Culture environment metrics
- Derived parameters

4 Biological & AI models (Random Forest, XGBoost)

Biological model

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$$

Growth kinetics

+ **Machine learning**

Input → Model → Output

→ **Predicted growth curve**



C INTERACTIVE VIRTUAL LABORATORY

5 Run a cell culture simulation



Figure 1. Biosafety cabinet • CO_2 incubator • Microscope

Adjust culture conditions

- Medium α-MEM
- O_2 concentration 5%
- Seeding density 5,000 cells/cm³
- Culture duration 7 days

Run simulation

MSC morphology over time (illustrative)

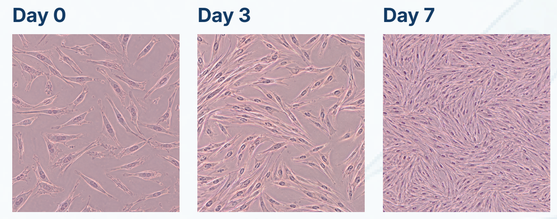


Figure 2. Images of mesenchymal stem cells

Simulated growth curves (illustrative)

Illustrative simulated data—not experimental results.

D DECISION SUPPORT & LEARNING ASSESSMENT

6 AI-assisted decision support

Scenario comparison

	Growth	Stability	Feasibility
A	●●●●○	●●●○○	●●●●○
B	●●●○○	●●●●○	●●●○○
C	●●●○○	●●○○○	●●●●●

Predicted growth curves by culture condition



Recommended conditions

- Optimal culture medium
- Seeding density
- Culture duration

Rule-based procedural alerts

- Non-aseptic handling
- Incorrect equipment use
- Incorrect incubator settings

Explainable AI

- Why scenario A performs better
- Key contributing factors
- Recommended next steps

7 Validation & reporting

Model evaluation

- Comparison with reference data
- Predictions and uncertainty
- Model limitations

Learning assessment

- Protocol completion
- Experimental interpretation
- Feedback and scoring

Experimental report

- Automatically generated
- Downloadable

FUTURE SIGNIFICANCE

Practical significance

- Education: Practice procedures and see biological outcomes before the real lab.
- Cost: Fewer consumables and failed cultures.
- Complements hands-on training.

Future development

- Integrate 3D visualization to improve realism.
- Validate and refine the models using experimental data.

CONCLUSION

VirtualLab proposes an educational platform combining biological knowledge and artificial intelligence in an interactive laboratory simulation, enabling safe, repeatable, data-informed practice.

REFERENCES

Phone: 028 3636 1206 (nhánh 3)

Website: 2026.stemcellinnovation.com.vn

Email: sci@sci.edu.vn