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Grade: 11th

Category: Bio Medical Engineering

Project Title: Using AI Optimized Cellular Scaffolds to Create Bio Printed Tissue (61 characters)

Will this be an individual or team project? Team

Team Member Name and Grade: Suryansh Sahitya(11th), Viraat Chauhan(11th)

Team Leader: Shaun Iyer

Part A: Rationale and Research Question / Problem

Identify the Gap: Currently scientists are well versed in the creation of traditional cell scaffolds including ones made of collagen and aerogel (Wu, 2022). These technologies have been found to decrease the cost of scaffolds by making them more affordable to more basic labs and allowing them to be tested in a wider range of circumstances. However, we want to take this further by using scaffolds created by AI. Scaffolds created by AI have never been seriously studied by scientists due to its relatively new appearance, however overviews of possibilities have been made about what could be accomplished using this new technology (Dave, 2024). Dave, R., Pandey, K., Patel, R., Gour, N., & Bhatia, D. (2025). Biological scaffolds in 3D cell models: driving innovation in drug discovery. *Stem Cell Reviews and Reports*, *21*(1), 147-166.

Define the Problem: How can AI-driven optimization of cellular scaffolds enhance the efficiency and accuracy of engineered human tissue regeneration? This topic is based on the current evolving field of AI as well as the relatively old but still new field of creating organoids.

Highlight Significance/Relevance: Our research deals with the already existing field of biomechanical engineering specifically using the field of creating organic tissue such as muscle, skin and bone tissue by growing it on inorganic scaffolds such as aerogel that are supplemented with organic products such as collagen to form an extracellular matrix.

However we build upon current research by trying to make a scaffold using ai technologies such as in optimizing analysis and simplifying cell cultures.

- Does it have real-world implications or applications? **Our product could in theory be used as a replacement for live donor transplants. This would greatly speed up the time taken for people suffering to find organs and organ transplants.**

- Is it relevant to a specific field, industry, or society? **This is relevant to fields such as medicine in which the creation of high-quality organoids can be essential to the survival of patients who need transplants since many patients end up dying on the transplant list and many turning to the black market to find organs.**

Describe Your Solution: Our goal in our experiment is to create a sustainable cheap way to produce organoids using a novel 3-d AI generated cell scaffold to accomplish this task. Using a RAG (Retrieval Augmented Generation) model to create the most efficient model for the matrix we hope to enhance the conditions in which cell lines can grow to help them achieve maturity and create an organ as close to real human organs as possible. Our hypothesis is that using AI to create cell scaffolds will help us create a good cellular scaffold to allow organisms or cell lines to grow well and communicate properly.

Part B: Hypothesis or Engineering Goals

Hypotheses:

- **Null Hypothesis (H_0):**
  There is **no difference** in the effectiveness of AI-generated scaffolds and traditional scaffolds in supporting colony growth.
  $H_0: \mu_{AI} = \mu_{Traditional}$
- **Alternative Hypothesis (H_1):**
  AI-generated scaffolds are **more effective** than traditional scaffolds in supporting colony growth.
  $H_1: \mu_{AI} > \mu_{Traditional}$

Where:

- μ_{AI} = mean colony growth metric (e.g., cell viability score) for AI-generated scaffolds
- $\mu_{Traditional}$ = mean colony growth metric for traditional scaffolds

Testing Method:

- Use a **two-sample t-test** assuming independent samples.

- Collect data from **multiple trials** (e.g., 10 scaffolds per type).
- Measure **cell viability**, **colony size**, and **maturation markers**.
- Set significance level: $\alpha=0.05$

Engineering Goals:

- Design and fabricate a 3D AI-generated cellular scaffold using a Retrieval-Augmented Generation (RAG) model.
- Ensure the scaffold supports efficient cell growth, communication, and organoid formation.
- Create a cost-effective, scalable, and biocompatible scaffold that can be used in regenerative medicine and organoid research.

Part C: Detailed Description of Procedures

***Experimental Design*:**

Testing Criteria

To meet the engineering goals, the scaffold must:

- **Support cell viability** ≥ 85% (measured via MTT assay).
- **Enable colony formation** within 14 days.
- **Show improved performance** over traditional scaffolds in at least 3 biological metrics (e.g., adhesion, proliferation, differentiation).
- **Be reproducible** across multiple trials.

Constraints

- Material: Must use biocompatible, 3D-printable materials (e.g., collagen, gelatin, aerogel).
- Computational: AI model must run on available GPU-enabled hardware.
- Biological: Scaffold must support human cell lines under standard lab conditions (37°C, 5% CO_2).
- Budget: Total cost must remain within school-level funding limits.

Statistical Hypothesis Testing Setup

- **Independent Variable**

  - Type of scaffold used:
  - AI-generated scaffold
  - Traditional scaffold (collagen/hydroogel)
    (Categorical variable)

- **Dependent Variable**
  - Colony growth performance, measured by:
  - Cell viability (%)
  - Colony size (mm)
  - Maturation markers (fluorescence intensity units)
- **Control Variables**
  - Cell line type
  - Culture conditions (temperature, CO_2, media)
  - Time of growth (14 days)
- **Number of Trials**
  - 10 trials per scaffold type
  - Total: 20 trials
  - Each trial includes identical cell seeding and growth conditions

List of Materials:

- **Collagen (Type I)** – 10 mL
- **Gelatin (food-grade or biomedical)** – 50 g
- **Sodium hydroxide** – 25 g
- **3D Bioprinter (e.g., BioX or similar)** – 1 unit
- **Sterile Petri dishes** – 50 units
- **Slime mold cell**
- **Cell culture media (DMEM or RPMI)** – 500 mL

- **Microscope (fluorescence or phase contrast)** – 1 unit
- **RAG model implementation (Python-based)** – 1 software setup
- **Computer with GPU (for AI training)** – 1 unit
- **AutoCAD or COMSOL Multiphysics software** – 1 license
- **Pipettes and tips** – Assorted sizes
- **Incubator (37°C, 5% CO_2)** – 1 unit
- **Sterile gloves, lab coats, goggles** – Multiple sets
- **Assay kits (MTT, Live/Dead staining)** – 3 kits

Procedure:

1. **Make the hydrogel matrix**
    - Combine PVA with and dilute sodium hydroxide/DMSO at a combination of 20 mg per 2 ml of solvent
    - Slowly add small amounts of water to the solution to form the gel matrix
    - Let rest for minutes to hours to form the hydrogel matrix
2. **Culturing slime mold for transplantation**
    - Take the Carolina Essentials Slime Mold grow kit
    - Transplant a pea sized amount of the plasmodium to a new plate using a sterile scalpel
    - Place 3-4 oat flakes to feed the plasmodium and make sure it grows
3. **RAG Model Development for Scaffold Design**
    - Collect scaffold geometry and tissue engineering data from biomedical literature to train the RAG model.
    - Set up a Python-based RAG pipeline that retrieves relevant scaffold features and generates optimized designs.
    - Export scaffold blueprints with ideal porosity and surface area for CAD simulation and 3D printing.
4. **CAD Simulation and AI Optimization**
    - Load AI-generated designs into AutoCAD or COMSOL to simulate mechanical properties like stress distribution and porosity.
    - Print scaffold prototypes using biocompatible materials, then test for cell adhesion and viability.
    - Use biological performance data to refine the AI model, improving scaffold design accuracy in future iterations.

Risk and Safety:

Potential Risks

1. **Biological Hazards**
    - Handling slime mold may pose a risk of contamination or exposure to biohazardous material.
2. **Chemical Hazards**
    - Use of collagen, gelatin, and hydrogel may involve exposure to powders or solutions that can irritate skin, eyes, or respiratory systems.
3. **Equipment Hazards**
    - Operating a 3D bioprinter and incubator involves electrical components and heated surfaces.
    - Use of pipettes and sharp instruments may pose minor injury risks.
4. **Computational Risks**
    - Running AI models on GPU-enabled systems may cause overheating or data loss if not properly managed.

Safety Precautions

5. **Personal Protective Equipment (PPE)**
    - Lab coat, gloves, and safety goggles will be worn at all times during wet lab procedures.
6. **Sterile Technique**
    - All cell culture work will be conducted in a sterile environment using aseptic techniques to prevent contamination.
7. **Proper Ventilation**
    - Work with powdered materials (e.g., aerogel) will be done under a fume hood or in a well-ventilated area.
8. **Equipment Safety**
    - All electrical equipment will be inspected before use.

- Training will be completed for safe operation of the 3D bioprinter and incubator.

9. Waste Disposal

- Biological and chemical waste will be disposed of according to school and local biosafety regulations.

10. MSDS/SDS Reference

- Safety Data Sheets (SDS) for collagen, PVA, DMSO, and any reagents will be reviewed and followed.
- Emergency procedures outlined in SDS documents will be posted in the lab.

Data:

Data Collection

- Metrics: Cell viability, colony size, maturation marker expression, time to formation, structural integrity
- Units: %, mm, fluorescence intensity, days, N/mm^2
- Trials: 10 per scaffold type (AI vs. traditional)

Statistical Analysis

- Two sample T-tests
- Hypotheses:
  - H_0: No difference
  - H_1: AI scaffold performs better
- Significance level: $\alpha = 0.05$
- Additional analysis: Mean, SD, confidence intervals, effect size

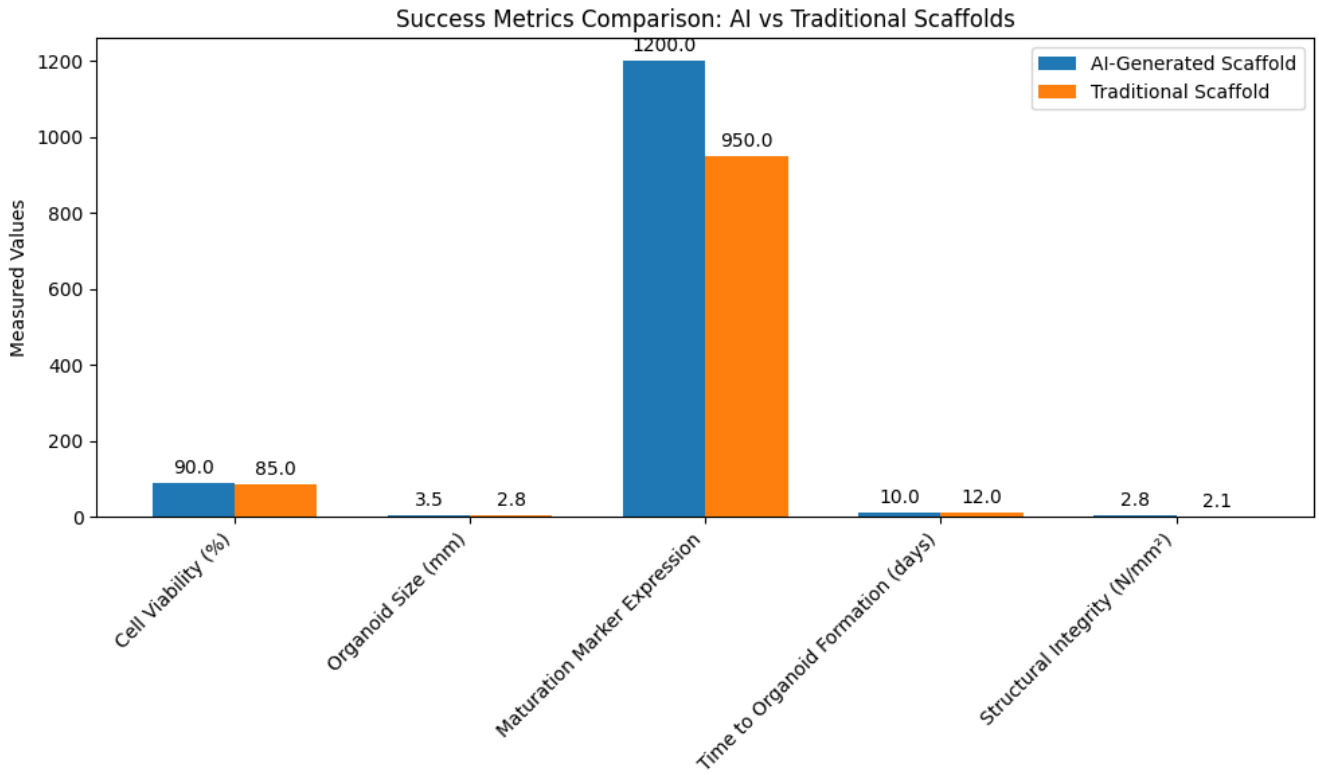
Success Criteria

- ≥3 metrics show statistically significant improvement
- Cell viability ≥ 85%
- Slime mold has developed communicative network
- Scaffold meets engineering constraints

Completion Markers

- All trials completed
- Data analyzed
- Final report with results
- AI scaffold validated

Metric	AI Scaffold (Placeholder)	Traditional Scaffold (Placeholder)	Unit
Cell Viability	90	85	%
Colony Size	3.5	2.8	mm
Maturation Marker Expression	1200	950	Fluorescence Intensity
Time to Colony Formation	10	12	Days
Structural Integrity	2.8	2.1	N/mm²



Part D: Bibliography

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Subject-Specific Guidelines (THESE DO NOT APPLY TO MOST PROJECTS)

1. **Potentially hazardous biological agents research:**
   https://sspcdn.blob.core.windows.net/files/Documents/SEP/ISEF/2025/Rules/Book.pdf#page=16
   a. Give source of the organism and describe BSL assessment process and BSL determination.
   Carolina biological is the source of the organism. The BSL level of slime mold is BSL-1 a BSL-1 safety level means the microbe is not known to consistently cause disease in healthy adults and presents minimal hazard to laboratory personnel. Protective lab equipment such as gloves, lab coats and goggles should be worn as needed. In addition to following safe microbiological procedures a handwash station must be present.

   b. Detail safety precautions and discuss methods of disposal.
   One method of disposal is to autoclave for 40 minutes at 121 C and 15 lb. per square inch another method of disposal is to cover them in a 10% chlorine bleach solution and let them sit for 2 hours. The disinfected scaffold can then be transferred to the trash. Make sure when using slime mold to wear PPE such as gloves, coat and goggles.