

Overview of Capstone Projects in Chemical Engineering

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Key points, typical structure, and best practice guidelines

1. What Is a Capstone Project?

Aspect	Description
Purpose	Integrates theory, laboratory, and design skills acquired throughout the degree into a single, real-world problem.
Scope	Usually 3–6 months (full-time) or a full academic year part-time.
Outcome	Technical report, oral/poster presentation, and often a prototype, simulation model, or process design package.
Stakeholders	Student team, faculty advisor, industry sponsor (optional), university review committee.

2. Typical Project Lifecycle

1. Project Selection & Definition

- Identify a problem (industry need, research gap, sustainability challenge).
- Draft a *project charter*: objectives, deliverables, constraints, timeline.

2. Preliminary Feasibility Study

- Literature review & patent search.
- Rough cost/energy balance and risk assessment.
- Decision gate: proceed or re-scope.

3. Conceptual Design

- Process flow diagram (PFD) and mass/energy balances.
- Selection of unit operations (reactors, separators, heat exchangers).
- Preliminary equipment sizing.

4. Detailed Design & Simulation

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- Use process simulators (ASPEN Plus, HYSYS, PRO/II).
- Refine thermodynamic models, reaction kinetics, and separation efficiencies.
- Conduct sensitivity analysis.

5. Economic & Sustainability Evaluation

- Capital cost estimation (equipment, installation, instrumentation).
- Operating cost breakdown (utilities, raw materials, labor).
- Techno-economic analysis (TEA) and life-cycle assessment (LCA) if required.

6. Safety & Environmental Review

- Hazard and Operability Study (HAZOP) basics.
- Process safety indices (e.g., Inherent Safety, OSHA PSM).
- Emission and waste handling plans.

7. Implementation / Prototype (optional)

- Laboratory-scale experiments or pilot-plant runs.
- Data validation against simulation results.

8. Documentation & Presentation

- Formal written report (executive summary + appendices).
- Oral defense / poster session.
- Deliverables to sponsor (if any).

3. Common Themes & Example Topics

Theme	Sample Project Titles
Sustainable Processes	• Design of a biorefinery for lignocellulosic waste • CO₂ capture using amine-based solvents
Energy Integration	• Pinch analysis of a petrochemical complex • Heat-pump assisted distillation
Process Intensification	• Microreactor for fine-chemical synthesis • Reactive distillation of azeotropic mixtures

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Theme	Sample Project Titles
Materials & Catalysis	- Development of a heterogeneous catalyst for selective hydrogenation - Scale-up of a nanomaterial synthesis route
Digital & Data-Driven Engineering	- Machine-learning model for real-time fouling prediction - Digital twin of a polymerization plant
Safety & Risk Management	- HAZOP of a high-pressure hydrogenation unit - Quantitative risk assessment of a chlorine plant

4. Deliverables Checklist

Deliverable	Minimum Content
Written Report	Title page, abstract, table of contents, introduction, methodology, results & discussion