Teaching Chemical Reaction Engineering Using Effective Capstone Integration

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Highlights

- Capstone in ChE Plant Design notably promotes student learning in chemical reaction engineering.
- Capstone design encourages students to practice theoretical concepts in real-world scenarios.

1. Introduction

The Chemical Reaction Engineering topics are essential to the chemical engineering curriculum worldwide. [1] According to the Body of Knowledge for Chemical Engineers by the American Institute of Chemical Engineers in 2015, the first stage chemical engineer should be able to apply kinetics, conversion in various reactor types, and chemical equilibria towards reactor analysis and design.[2] In chemical processes, Chemical Reaction Engineering can be claimed as a subset of Chemical Engineering, often called Reaction Engineering. Its content can be roughly divided into Reaction Kinetics and Reactor Design and Analysis.[3] Although the fundamental topics are taught in the Chemical Reaction Engineering course for junior students. However, typical design equations may not be the optimum solution for the aspects of reactor design in emerging times, for example, bioreactors, microreactors, reactive distillation, and membrane reactors.

One effective way to enhance the learning of Reaction Engineering is to integrate it with well-designed active learning, such as a capstone project. A capstone design project allocated for senior students becomes an essential component in mastering the complexities of Reaction Engineering. By integrating this project into the chemical engineering curriculum, the students can apply theoretical concepts in practical, real-world scenarios, providing them a competitive edge in their future endeavors.

2. Methods

In the ChE Department, KMUTNB, a mini-capstone design project has been implemented since 2017 as a learning platform for senior students in the Chemical Engineering Plant Design course. The project aims to implement an integrated approach for students to improve their critical thinking and conceptual learning of Reaction Engineering topics as the core process of chemical industries. The project statement allows students to select from the reaction pathways to equipment design with the final PFD and P&ID. The reaction systems must be prepared as a base case to satisfy requirements like reliability, optimized design, and economic, environmental, social, ethical, health, and safety considerations. After that, the separation system, heat exchanger network, and utilities will be designed to support the overall production.

In this course, students are separated into groups. Each group of 3-5 students must develop their design involving user analysis, problem definition, analysis, synthesis, and design optimization with proper engineering standards. The students must emphasize fundamentals, starting from a mass balance and thermodynamic analysis rather than working from design equations and process simulations. Numerous laboratory data from related systems must be analyzed for feasibility studies. The learning outcomes focus on the ability to complete the conceptual design of chemical processes for a desired product with a discussion of various processing alternatives. The instructors always ask students open-ended questions like "why," "how," etc., emphasizing group coaching to ensure understanding of their work.

The given time frame for the project is 4 months. Spreadsheet-based, finite element, and process simulation software can be used to provide a practical understanding of more realistic reactor modeling, i.e., ANSYS and ASPEN.

Apart from the design, assessment of economic performance and environmental impact for sustainability and safety concerns of the proposed process must be delivered. The students must also demonstrate awareness of ethical and contemporary issues (if any, by local laws and/or global concerns such as SDG) related to the design and operation within their report.

3. Results and discussion

The mini-capstone project in the Chemical Engineering Plant Design course has been selected as one of the direct instruments to assess ABET Student Outcome 2 (SO2) "Engineering Design" since 2018. The results of the project report assessment indicate that students have consistently achieved high attainment levels of setting outcomes. The attainment levels reported 79%, 89%, 98%, 96%, 92% and 81% for 2018, 2019, 2020, 2021, 2022, and 2023 respectively.

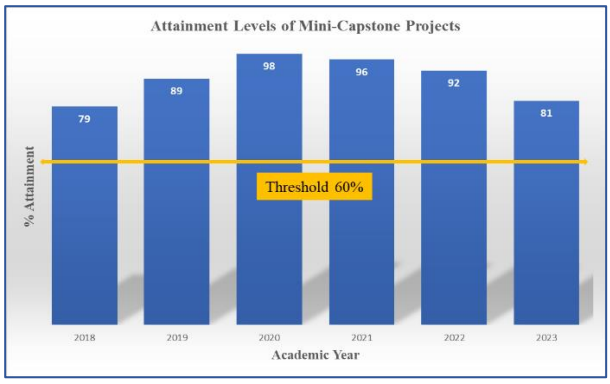

Figure 1. Attainment Levels for Mini-Capstone Projects

KPIs of Mini-Capstone Project "Reaction System Design"	
KPI 1	Formulate the chemical reaction problem and analyze constraints
KPI 2	Establish appropriate criteria for evaluating potential solutions and tradeoffs
KPI 3	Generate alternative solutions with discussion
KPI 4	Build an engineering design of the reaction system and analyze the design performance
KPI 5	Improve engineering design with major constraints

Table 1. Key Performance Indicators for Mini-Capstone

Figure 1. illustrates the percentages of attainment levels of mini-capstone report evaluations for student cohorts 2018-2023. The results are located above the Department threshold of 60%. Evaluations are based on the KPIs supporting the PIs of ABET EAC SO2 "Engineering Design," as in Table 1. The data confirms that teaching chemical reaction engineering using effective capstone integration can help students to equip with critical thinking and creativity with significant concern for the economy, environment, and safety. The students have some experience dealing with real-world problems before graduation. In maintaining this, the instructors thoughtfully reduced lectures and increased discussion and group problem-solving. A typical class size should not exceed 30 students unless more facilitators are provided.

4. Conclusions

The capstone-based learning approach is now practical for the ChE Department and senior students. The quality improvement plan is to assign students with more challenging problem statements according to Sustainable Development Goals: SDGs set by the Thai Government and Chemical Industries. Improved simulations and hands-on laboratories to support the optimum design are also essential and will be stressed for the coming academic year.

References

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Keywords
Chemical Reaction Engineering, Capstone Design Project, Chemical Engineering Plant Design