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Integrating Technopreneurship in the Chemical Engineering Plant Design Course

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Highlights

- Relevant technopreneurial lessons and skills are integrated in the chemical engineering plant design course.
- The plant design course offers preliminary feasibility study for completed research outputs of the university and other research institutions.
- The students work on the feasibility study of an actual completed research while researchers are introduced to and engage in the business aspect of the research.
- Technopreneurship can be integrated in the plant design course to better realize the actualization of the plant design outputs.

Abstract

The chemical engineering plant design uses fundamental scientific knowledge and engineering skills to design industrial plants. On the other hand, technopreneurship is a technology-based entrepreneurship, which aims to develop scientific research ideas and technologies into profitable business ventures. Technopreneurship was integrated to plant design course and offered innovation to the conventional teaching method and provided better appreciation and more practical learning experience to students. The course outline of the plant design was initially compared to that of technopreneurship. The topics in the plant design, which can be further elaborated using technopreneurship concepts and examples were identified. These lecture and laboratory topics, which include research topic creation (ideation), team composition and formation, marketing aspect, business model formulation, management aspect, financial aspect, financing aspect and pitch presentations, were found to be the avenues for technopreneurship integration. The integration was done without altering the CHED-approved plant design course outline. The core chemical engineering plant design activities were not modified. These include the material and energy balances, equipment selection and sizing, and process and plant layouting. The students worked on an actual research project and experience collaboration with the project originator. The students then acquired more formal training and learned greater degree of accountability to the plant design project. The originator saw the business potential of the research project and learned more economic value in doing future projects. The output of the plant design course could be considered as a preliminary feasibility study, which could project business viability of a research. This course can then be offered by the Chemical Engineering Department as its income-generating service to the university and research institutions.

Key Words: plant, design, technopreneurship, chemical, engineering

1. Introduction

The chemical engineering plant design course aims to develop the students' ability to integrate fundamental sciences and engineering concepts in designing industrial plants. These concepts include chemistry, physics, thermodynamics, chemical reaction kinetics, fluid mechanics, strength of materials, unit operations and among others. Pertinent concepts are used to describe and solve the complexity of real systems. The students learn to design a process flow using various unit operations to transform a raw material into a product of desired quality, meeting specific standards.

In producing a product with particular specifications, there may be more than one process flows that include different sets of unit operations. The students, therefore, must learn how to generate technically feasible process flow alternatives. The material balance and energy balance calculations are then carried out for each process flow option. Suitable equipment are chosen, indicating the specific design, dimensions, operational capacities, materials of construction, etc. When the major and auxiliary equipment are identified, the process layout is designed with the incorporation of proper spacing and systematic material flow. With the estimation of the capital expenditures (CapEx) and operational expenditures (OpEx) for all process flow designs, the most economical design can be determined. The profitability of the process is also estimated in terms of the rate of return on investment, payback period and breakeven analysis.

With these activities, the plant design course helps the students learn to design chemical processes that are technically feasible and profitable. However, in the implementation of the course, the topics are conventionally chosen and based on the available related literatures, which typically do not present detailed experimental procedures and conditions that are essential in the design of the upscaled processing plants.

On the other hand, there are completed researches in the universities and research institutions in the form of thesis manuscripts and terminal reports. These researches were either core funded, internally funded or externally funded. Many believe that these outputs were promising and can solve problems in food and water supply, energy crisis, pollution in the environment, transportation and many others. Despite the excellent results, these outputs were shelved because many researchers lack plans and vision of mass production and creation of large-scale opportunities (business or public service works) out of these projects.

The extension of these projects into business ventures (i.e. technopreneurship) can bring out laboratory experimental data to the community as tangible, accessible and useful technologies. Technopreneurship is a process of creating innovative ideas and develop technology-based industries. It involves identification of problems and creation of technological opportunities. The team, composed of the scrummaster, maven(s) and connector(s), then defines the serviceable and obtainable market from the total available market. The team also generates the initial technological design or minimum value product, to which the customers make feedbacks and recommendations for product or service development. Iterations of testing, evaluation, recommendation and modification will be done until the acceptable design is achieved and validated. This leads to finding interested funding individuals or groups that may realize the plan to an actual startup business.

This paper aims to present the innovation of integrating technopreneurship in the plant design course, which may provide insights for teaching method development in chemical engineering or other engineering fields. This may also provide basis for the university to explore the capability of this course to support the business development of its research projects.

2. Methods

2.1. Review of Chemical Engineering Plant Design Course Outline

The course outline of the plant design course was reviewed in order to identify the possible topics that would be integrated with technopreneurship lessons. Based on the Commission on Higher Education (CHED)-approved chemical engineering curricula, the plant design subject typically has two meetings in a week: lecture and laboratory. The coverage and list of topics were compared to the topics included in the technopreneurship course. The aim was to integrate the concepts in technopreneurship without altering the curriculum of plant design.

2.2. Technopreneurship Integration

As the course outlines of plant design and technopreneurship were laid down side-by-side, the specific plant design topics were identified to become the enrty point for entrepreneurial discussion. Lecture topics were explained using the chemical engineering principles and further expounded using technopreneurial illustrations. Some laboratory activities were carried out using teaching methodologies used in technopreneurship. The class setup was a mix of conventional method and the Flipped Classroom method. Team formation, topic selection, project proposal, market feasibility study and project presentation or pitching for possible financing were examples of plant design topics used for technopreneurship integration.

2.3. Plant Design Project Selection and Team Formation

The class underwent ideation activity. Students identified problems and issues in the society that could be addressed with technology intervention and were required to propose solutions using titles of completed theses or research projects. The list of titles were available in the university libraries and/or in research institutions. The proposed plant design topics were expected to exhibit potential social acceptability and marketability. Submission of topics and selection of final topics were done online. The team formation, on the other hand, was done in the laboratory by conducting a simulated job hiring process.

2.4. Plant Design

The core activities of the plant design course included the creation of suitable process flowcharts, determination of design bases, material and energy balances, equipment selection and sizing, spacing, and process and plant layouting. After these calculations, project cost was estimated and profitability projections were also made in terms of return on investment, payback period and breakeven analysis.

2.5. Simple Business Model Proposition and Project Financing

A simple business model and business plan were proposed in order to attain the predicted sales in the plant design calculations. The business plan projected the sales and profit through time and would entail estimated cost for marketing activities. After all the cost calculations, the total project cost was determined, which became the basis for the financing aspect of the project. The means of finance (equity or debt) were presented during a business proposal pitching activity. This allowed the students to realize that plant designs could be proposed for funding and could become future business ventures.

3. Results and discussion

3.1. Technopreneurship Integration in Plant Design Course Outline

The main objective of this teaching method development was to improve the learning experience of the students and provide more tangible and practical applications of the chemical engineering plant design course. The technology-based entrepreneurship could provide new perspective to plant design process and outputs, making them more relevant and applicable in life and profession.

The lecture topics that had been considered avenue for technopreneurship integration include:

1. General considerations in process design development
2. Project feasibility aspects (Marketing aspect, Management aspect, Financial aspect, Financing aspect)
3. Project profitability (Internal Rate of Return, Rate on Investment, Payback period, Breakeven analysis)

On the other hand, in the laboratory activities, the technopreneurship activities were integrated in the following activities:

1. Topic proposal and pitching
2. Team formation (Simulated Job Fair) activity
3. Process description presentation for the proposed plant
4. Final presentation of the plant design for Financing aspect

It was ensured that the scope of the CHED-approved plant design curriculum was conserved in integrating the technopreneurship concepts. The business aspect of the project was also emphasized in this method compared to conventional plant design. The importance of the marketability and business model was highlighted without compromising the core lessons in designing an industrial plant.

3.2. Ideation and Project Team Formation

The ideation or idea creation was introduced to students as the initial phase of the plant design project. Students were allowed to identify problems in the society, local or global, by reading literatures, watching news, interview different people, etc. The students then chose interesting areas or specific issues: energy crisis, food supply, water scarcity, pollution control, health risks, agriculture and among others. They were instructed to browse through long lists of researches completed in the university that address interesting issues. These include thesis manuscripts and project terminal reports. Additional criterion to the selection process was the potential business sustainability of the product or service. The following guide questions were considered in choosing possible topics:

- Target Market *(Who will buy the product or service? Which fractions of the population are considered willing and capable customers?)*
- Selling Price and Strategy *(How much does the product or service cost? Will it be sold in retail or wholesale?)*
- Competition *(Who are the existing competitors? Are the competitors manufacturers or distributors? Are the products produced locally or imported?).*

It was observed that the entrepreneurial skill of the students must start at the topic selection stage. Although the bulk of market study was done during the marketing feasibility aspect of the project, the students initially made a screening of topics to generate a short list of marketable products or services. The students performed initial demographical segmentation and competition analysis, which were improved in the development of the project.

Topics with considered marketability were selected from the submitted research titles. When the number of the topics was insufficient, other plant design proposals came from a technology transfer office or research institutions such as National Institute of Microbiology and Biotechnology (BIOTECH), UP Los Baños. Selected students then pitched about the approved topic proposals in the class. They were considered team leaders and were tasked to pitch in order to invite other students to join them in their projects.

The group dynamics in performing the plant design activities were explained using the roles in a start-up business. The roles of scrummaster, maven and connector were defined in relation to the accomplishment of the expected outputs in the course. The team leaders were initially considered scrummasters and asked to interview and "hire" qualified mavens and connectors. This interview activity was conducted in a simulated job fair within the classroom. All students had to prepare *curriculum vitae* (CV) as basis for the interview. These CV documents also became the students' initial draft CV for future professional employment.

3.3. General Plant Design Considerations

Most of the projects considered in this plant design course were at least at the technology readiness level (TRL) 4, where the product or service technology was already validated in the laboratory. Other projects accomplished in the course were at TRL 6, where the products were already being used in the agricultural farms but the production was still at the laboratory scale and was ready for engineering and upscaling. Some notable startup project names that were accomplished in this course offered during the four semesters from 2017-2019 are presented in Table 1.

Table 1. Notable projects conducted under the integration of technopreneurship in plant design course.

Proposed Startup Project Name	Nature of the Project	Project Origin
Filyro Waste Solutions, Inc. and InnoTreat, Inc.	Treatment service for infectious wastes using thermal treatment with oil as the heating medium	MS ChE thesis in UPLB
CellTek	Cellulose nanocrystals (CNCs) production from bamboo culm	Project done in CFNR, UPLB
PolyFera	Polyphenolic powder production from waste mango seeds	Project done in BIOTECH, UPLB
Demeter Biofertilizers, Inc.	Production of a biofertilizer	Project done in BIOTECH, UPLB
Converde	Biogas production from market solid waste	BS ChE thesis in UPLB
PUPA	Pulp and paper mill utilizing banana pseudostem	Project done in FPRDI, DOST

The projects listed in Table 1 were based on completed researches, which developed laboratory procedures reported in their respective manuscripts or terminal reports. Their methodologies became the basis for the chemical engineering process flow diagrams, which illustrated all the materials involved in every unit operation and the operational conditions (temperature, pressure, pH, reaction time, etc.) necessary in transforming the raw material into the desired product.

In order to start the calculations, the plant capacity was determined. The plant capacity was based whether from the raw material supply or from the product demand. These information were analyzed for the sustainability of the project. The raw materials must be enough to supply the requirements of the plant for full and continuous operations. The product demand must be sufficient to sustain the profitability of the project. The demand was estimated by identifying the total available market (TAM), serviceable available market (SAM) and serviceable obtainable market (SOM). The SOM could become the basis for the capacity of the plant. This market demand must always be greater than the raw material supply.

3.4. Feasibility Aspects

A full-blown feasibility study must be comprehensive and should include many aspects in order to provide sufficient and objective information that would become the basis for decision-making, whether to continue a project/business venture or not. Among the feasibility aspects, the marketing, management, financial and financing aspects were the avenues for technopreneurship integration.

In the marketing aspect, market validation could be done to ensure that the product or service could potentially profit and considered to be worth pursuing. The connector was tasked to communicate with a possible taker (customer) of the product or service. This would validate the marketability of the product and could also invite suggestions for the product and business plan development. A marketing plan was proposed to increase the projected market demand from the SOM to bigger fraction of SAM. The designed full plant capacity might not be practically achieved yet in the first year of operations. The marketing plan would help in the attainment of full plant capacity. However, the cost for marketing activities must be included in the financial analysis of the project.

In the management and financial aspects, aside from the plant operation personnel, a number of employees are also working in the purchasing and sales departments. The business model for the product or service must be considered. The size of warehouse and the number of sales people are determined by the distribution channel from the plant to intended customers. The expenses on the warehouse and the labor cost depend on whether the products are sold in bulk or retail, as a final product or an input material to another industry, or create a trucking section or hire trucking service providers. The business model will inevitably affect the total project cost.

In the financing aspect, the students learned how to plan the debt obligations/composition in terms of debt or equity. They were also required to calculate the profitability of the project using Internal Rate of Return, Rate on Investment, Payback period, Breakeven analysis. These figures were used to convince potential funding groups or individuals to finance the project. This was done in a pitch presentation activity at the end of the plant design course.

3.5. Core Plant Design Activities

The central activities of the plant design course involved the chemical engineering calculations including material and energy balances, equipment selection and sizing, space sizing, and process and plant layouting. After these calculations, the project cost was calculated based on the fixed capital investment (FCI), material and utility costs, labor cost, auxiliary services cost, working capital, and marketing cost. These were not modified in any way.

3.6. Final Presentations

The final presentations included the technical presentation and the pitch presentation. In the technical presentation, the students presented all the chemical engineering calculations (balances and sizing) and designs (equipment, process and plant layouts). This also included other technical details such as plant location, material characterization, product specifications, and organizational structure. This presentation validated all the technical feasibility of the processing plant.

On the other hand, the last presentation covered all the money-related aspects: financial, market and financing. A number of business-minded personalities, representatives from the industry, people with management and marketing backgrounds, the project originators, and other technical people were invited to be members of the panel. They evaluated all projects based on the manner of presentation and the merit of the business proposition. A portion of the teams' grade came from the willingness of a panel member to fund the project.

3.7. Post-course Assessment and Developments

The students' assessment of the technopreneurship integration was mostly done by individual interviews with the recent graduates and the older alumni. The recent graduates were asked mostly about (1) useful skills acquired after taking the course, (2) level of appreciation for specific topics and the course in general, and (3) recommendations for the improvement of the course. The answers showed that, more than the improvement and appreciation of the unit operations in chemical engineering, the business component had been added to the students' knowledge and motivations. The results were also presented to a number of older alumni, who had not undergone technopreneurship integration, and this development received a mixture of feedbacks. While the students acquired important skills to improve plant design project qualities, which could be used in the profession and life, the additional time required in learning these skills, compared to the conventional method, might not be enough for one semester.

Since the projects developed in the plant design course were actual completed researches, the outputs could be considered preliminary feasibility studies. These outputs were reliable since the projects underwent iterative cycles of planning, design, presentation, evaluation and modification. These cycles involved the project team, the adviser/facilitator and the project originator (researcher). Some plant design outputs were included in the end-of-the-project presentations and terminal reports to the funding agencies such as the Department of Science and Technology (DOST) and the Department of Agriculture – Bureau of Agricultural Research (DA-BAR).

Other project outputs were improved and proposed to funding agencies. One example of this was the plant design outputs of Filyro Waste Solution, Inc. and InnoTreat, Inc. on the oil-based thermal treatment of infectious waste from healthcare facilities. The project was proposed to and received funding from the DOST–Philippine Council for Health Research and Development (DOST-PCHRD) for a two-year project duration. The expected outputs of this ongoing project include the working technology, patent and utility model, and the business model to support the project's sustainability plan. After the project duration, the project originator is expected to build a startup company for this technology.

4. Conclusions and Recommendations

The integration of technopreneurship in the chemical engineering plant design course provided the students a better learning experience and a more practical perspective about the development of a research topic into a large-scale plant and a business venture. This experience offered more formal training and could open up entrepreneurial mindset to chemical engineering students. The researcher or project originator realized more the economic value of the research because of its potential for market value and social impact. In the event that a project gets support and becomes a full industrial plant, it can create employment opportunities for people.

The plant design course can offer upscaling and preliminary feasibility study for researches in the university and research institutions. The university can institutionalize this service of the Department of Chemical Engineering to develop the research projects inside and outside the university. This can become an income-generating activity or service of the department. In effect, this can lead to more business opportunites for researches.

In order to improve the quality of the projects, it is recommended that an Entrepreneurship course may be included in the list of prerequisite or elective subjects of the students before taking the plant design. Another option is to offer this technopreneurship-integrated plant design in two semesters, which is the case in other universities offering the program. Also, the assessment tool for the course integration must also be developed further.

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