Autobiography

Introduction

Throughout history, the industrial and sociopolitical needs of mankind have driven the evolution of chemical engineering research and its curriculum to best prepare students for assuming responsible careers in their post-educational endeavors [1]. At the turn of the 20th century, the rise of the petroleum and chemical industries to meet the demands of society catalyzed the development of chemical engineering education at several universities. The increasing demand of the CHE skillset from these industries provoked much of the chemical engineering research and curricula throughout many academic institutions to become catered towards incorporating petrochemical topics [2, 3, 4]. As developments in biotechnology have increased over the last several decades, there has been an evolutionary push to include biological concepts into chemical engineering education, which has given rise to the incorporation of Biochemical engineering in the CHE curriculum as industries such as pharmaceuticals, cosmetics, environmental and food benefit from incorporating the CHE skillset into their R&D through manufacturing efforts. Despite this a large majority of the CHE curriculum continues to foster material related to the petroleum refining and chemical production industries [3] and the incorporation of biological concepts into the CHE curriculum has been limited to those pertaining to cells, bacteria, and viruses.

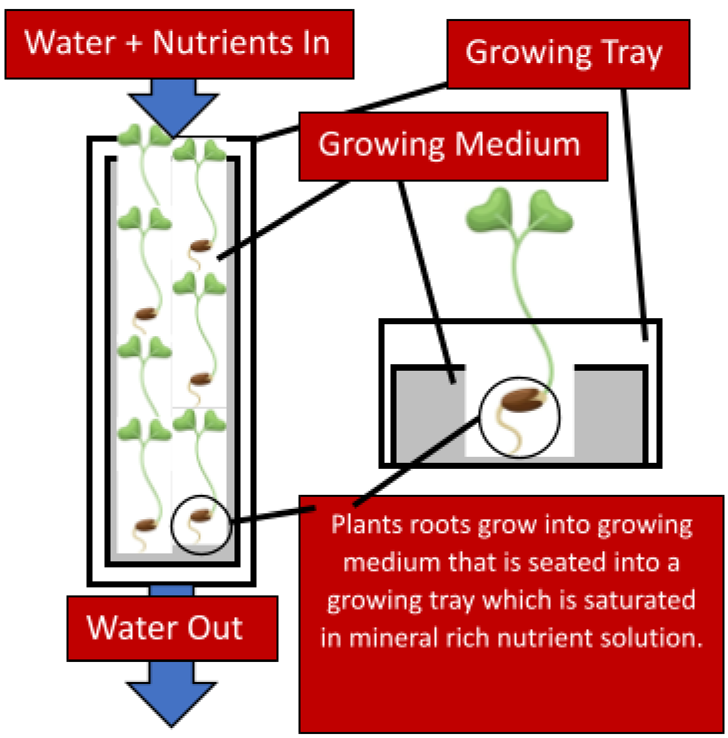
Chemical engineering education has always been heavily influenced by the industrial and sociopolitical needs of society. This is because the essence of CHE education is to emphasize concepts that are relevant to solving the industrial problems of the present and creating the innovations of the future. The interconnected relationship of food, water, energy and climate was first coined in 2011 as the water-energy-food nexus (WEF) by the World Economic Forum in Water Security: The Water-Energy-Food-Climate Nexus. In 2022, the National Academy of Sciences noted in their “New Directions for Chemical Engineering”, that chemical engineers will have a critical role in developing sustainable innovations to provide adequate amounts of food, energy, and clean water and air for the ever-increasing human population. One direction the National Academy of Sciences believes CHE education should shift its focus into is in the development of hydroponics and aquaponic technologies to address the WEF nexus challenge and pave the way for a more sustainable agricultural industry. This laboratory experiment utilizes a self-regulating hydroponics kit to analyze the effects of manipulating several different system parameters, such as pH, EC, DO, CO2, etc., to determine how to maximize growth metrics such as the nutritional densities or growth yield and time efficiencies of microgreens grown in hydroponic cultures.

Start by introducing senior process lab and features/lab requirements. One group completed hydroponic experiments.

Background:

Hydroponics is the technique of growing plants in soilless cultures with their roots immersed in mineral rich nutrient solutions, often with the combination of inert growing mediums such as gravel, perlite, and cellulose or other mineral wool. Microgreens refer to the immature greens or seedlings produced from the seeds of vegetables, herbs or grains. They are typically harvested at the base of the hypocotyls just after the cotyledon leaves and one set of true leaves have developed, usually between 7-21 days from seed germination depending on the species. Microgreens are particularly popular due to their enhanced phytonutrient content and possible bioactive value. In the 2017 Census of Agriculture from the USDA, approximately 420 million pounds of food crops were produced from hydroponic systems, a staggering increase from their 2012 Census since that metric wasn't even included. Many studies have noted that the rapidly growing microgreen industry faces several challenges that only further research and innovations can solve. Common methods for analyzing microgreen growth include assessment of nutrient profiles, growth yield

Hydroponics and microgreens what are they? How big is the industry? Common methods for analyzing growth.



It has grown in popularity due to the implications they have towards a sustainable food source. Studies have shown that hydroponics can successfully grow plants while using up to 85% less water than soil-based agriculture. [5] Hydroponic systems can also recirculate water, increasing the amount of water saved.

Minimal safety concerns with lab?

- General safety precautions
- Salts
- Make sure electronics are safe
- Lighting only works on visible light spectrum, no UV or IR light

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Objective

- ABET Outcomes
- Open ended experiment that allows for creative freedom
- Students must partake on outside research to understand related concepts and think of engineering in a global or societal manner.
- Also just a new experiment, that actually works
- **Practice communication skills**
- **Finding a topic that appeals to the general student body that'll excite them and increase their drive to learn.**

Apparatus & Methods (~~Add subsections?~~)

- Talk about how the class is operated (pick a topic, research it, and perform experiments)

Senior process Lab II is the continuation of a two-semester lab design course. Students are tasked with choosing an area of interest, researching the topic, then designing an experiment and analyzing data collected.

- How we performed each lab (For this experiment, students chose to conduct research in hydroponics using a fully automated hydroponics systems (HydroPod) to maintain system parameters. Electroconductivity readings, pH, water temperature, and flow rates were regulated using this system through the duration of a grow season. The HydroPod was also able to control multiple variables pertaining to lighting, include daily light integral, light intensity, and the color temperature of lighting used. A homemade nutrient solution was used to provide plants with the required nutrients for growth.
- What the HydroPod can control (Jump into this right after)
    - Lighting
    - Temp
    - pH
    - Feedback ctrl
    - Flowrates
- Subsection: Methods for each experiment/class covered (don't need just describe the general experiment)
    - Following is copied and pasted from last time edits will continued to be made
    - Biodegradable wood fiber hydroponic grow pads were cut to fit within the vinyl growing trays. The grow pads were allowed to soak within the system for 10 minutes for maximum water saturation, and the mass of the wet grow pad and tray was measured for each individual tray. The optimal seed densities found in previous studies were weighed out. The seeds were laid uniformly across the area of the grow pad based off of grams of seeds per m^2, and a weighted block was placed on the pad to apply pressure to the seeds and encourage germination. The seeds were allowed to germinate within the dark pod with applied pressure for 3 days and nutrient solution running at a drip's pace, before the blocks were removed.

On the third day, light was provided to the plants at _ lux, while the flow rate was kept at a drip for one more day. On the fourth day, the flow rates were set to their desired values, which varied based on what was being tested, and nutrients were supplied through the reservoir. Ideal conditions of a pH range between 5.6-6.2, EC values above 2,100 µS/cm, and a water temperature of 30°C were maintained with the HydroPod. After germination concluded, the trays were removed from the system once a day to dry for 10 minutes before being weighed. Microgreens were then picked from the grow pads and the dehydrated weight of the plants was measured. The average height of the plants was taken. The microgreens were picked from the mats then placed in a conventional oven set to 150°F for an hour before being weighed. Additional visual parameters were noted such as color, progression of vegetable leaves, roots and direction of growth.

Senior Process Lab II is the continuation of a two-semester lab design course. Students are tasked with choosing an area of interest, researching the topic, then designing an experiment and analyzing data collected. For this experiment, students chose to conduct research in hydroponics using a fully automated hydroponics system (HydroPod) to maintain system parameters. Electroconductivity readings, pH, water temperature, and flow rates were regulated using this system through the duration of a grow season. The HydroPod was also able to control multiple variables pertaining to lighting, include daily light integral, light intensity, and the relative light intensity of lighting used. A homemade nutrient solution with a concentration of 7.5 g/gallon was created and used to provide plants with the required nutrients for growth. Biodegradable wood fiber hydroponic grow pads were cut to fit within the vinyl growing trays. The grow pads were allowed to soak within the system for 10 minutes for maximum water saturation, and the mass of the wet grow pad and tray was measured for each individual tray. The optimal seed densities found in previous studies were weighed out[Need source]. The seeds were laid uniformly across the area of the grow pad based off grams of seeds per m^2, and a weighted block was placed on the pad to apply pressure to the seeds and encourage germination. The seeds were allowed to germinate within the dark pod with applied pressure for 3 days and nutrient solution running at a drip's pace, before the blocks were removed. On the third day, light was provided to the plants at _ lux, while the flow rate was kept at a drip for one more day. On the fourth day, the flow rates were set to their desired values, which varied based on what was being tested, and nutrients were supplied through the reservoir. Ideal conditions of a pH range between 5.6-6.2, EC values above 2,100 µS/cm, and a water temperature of 30°C were maintained with the HydroPod. After germination concluded, the trays were removed from the system once a day to dry for 10 minutes before being weighed and having stem length measured. Nine days after germination began, the grow season was concluded, and microgreens were picked from the grow pads and the dehydrated weight of the microgreens was measured. The average height of the microgreens was taken. The microgreens were picked from the mats then placed in a conventional oven set to 150°F for an hour before being weighed. Additional visual parameters were noted such as color, progression of vegetable leaves, roots and direction of growth.

Cleaning

After the plants have been removed from the trays, the remaining mats are thrown away, and the reservoir was emptied. Each tray was then scrubbed with water to ensure that they were clean. The HydroPod was run with a 1:20 vinegar: water solution to prevent bacterial buildup in the piping between grow cycles. The blocks used for germination, and the microtubing in the HydroPod were also washed. After the HydroPod was run with the vinegar-water solution for one hour, it was then emptied again and the platforms that the trays sit on were scrubbed down. The system was then run again with distilled water to rinse out any vinegar that remained in the piping, before being emptied and the next grow cycle was set up.

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- PFD comparison
- How we measure

Parameters which were measured included microgreen wet weight, height, and dry weight. Wet weight was measured by allowing excess water to flow out of the growing mats for 10 minutes on a 80° angle then weighed each day. Heights of the trays were measured in mm by taking the average height among three sections of the growing mat. Dry weights of each tray was conducted by pulling the microgreens from the growing mats. The microgreens are then placed in a conventional oven set to 150°F for an hour before being weighed.

Results and Discussion

- Subsection: Each experiment and class (focus only process lab for now)
- Graphs + data analysis
- Student survey + discussion
- Models?
    - Simple model for plant growth
    - Compare to bacteria maybe
-

DEI

- Many different disciplines of engineers
- Diverse team
- Diversity
    - Racial + ethnic
    - Social
    - Economic
    - Provides opportunity for interaction between other engineers
- Equity
    - Students get equal opportunity
- Inclusion
    - Everyone has a role
    - Ownership of aims

Conclusion/ Prospective Future Development?

- Explaining how this can be incorporated into labs and what it teaches the students
- Less time intensive while still covering key chemical engineering concepts
- Can be modified to cover other classes in curriculum

    - Can be a very open-ended experiment due to how much you can test
    - For lower-level classes you can key into a specific topic of interest
- Helps students that have tight schedules due to internships (has the flexibility to fit many people's schedules)

Scaling up the process creates the opportunities (conclusion)

- This paper presents a laboratory experiment that incorporates a majority of the current curriculum + introduces plant biology using a self-regulated hydroponics system --> introduction to these fields is required for students to both become interested in the field and thus create innovations in field to solve the issues of the future. Also, allows for better teaching of current curriculum
    - Experiment + Analysis > Classroom Learning (Could we ask this in the student poll? - Make anecdotal)
        - Student retention of info. + SOURCES
    - The experiment/ analysis creates Versatility as lab + experiment
        - Demos for other undergrad classes to teach the core curriculum such as...
        - Senior Lab unit operations
        - Research opportunities commercial farmer contract schools to do research
- What are the benefits of this lab? Needs no introduction sentence...
    - Set & forget, go in for 5 min to weigh, take a lot of data at the end of cycle lot of data in little time which is both beneficial/time considerate to students.... very flexible and can be integrated into a variety of different students.

References + Acknowledgments

[1] Alkaya, D.; Cruz, R. V. A. da; Grossmann, I. E.; Provine, W. D.; Silverstein, D. L.; Steininger II, R. J.; Talbot, J. B.; Varma, A.; McCreight, T.; Chin, K.; et al. Chemical Engineering Academia-Industry Alignment: Expectations about New Graduates, American institute of chemical engineering https://www.aiche.org/sites/default/files/docs/conferences/2015che_academicindustryalignmentstudy.compressed.pdf (accessed Apr 8, 2023).

Useful info from source **"To preparing students most effectively, it is important to explore and to seek alignment between the expectations of faculty members who educate students and employers who hire them. The goal is insight that will aid the content and style of chemical engineering education."**

[2] Safety education 4.0 – A critical review and a response to the process industry 4.0 need in chemical engineering curriculum, Safety Science
https://www-sciencedirect-com.proxy.libraries.rutgers.edu/science/article/pii/S0925753523000115#bib1301

Useful info from source : “The growth of petroleum and the chemical industries during this period stimulated both ChE research and curricula design.”

“Since 1960s, the ChE education has witnessed many major contributions, like the addition of catalytic studies applied to automobiles and industrial manufacturing to address environmental issues and optimizing operating efficiencies. The rapid development of biotechnology and nanotechnology also played an irreplaceable role in the development of the ChE curriculum. Tremendous values have been created with the combination of biological concepts with ChE principles, like reaction engineering, transport processes, and separation processes. As a result, the inclusion of Biochemical Engineering concepts and curricula in ChE education all seemed natural”

[3] The Origins of Academic Chemical Engineering; Nikolaos A. Peppas

https://link-springer-com.proxy.libraries.rutgers.edu/chapter/10.1007/978-94-009-2307-2_1#citeas

Useful info from source “The history of faculty development and course content of chemical engineering offered by institutions provide a fascinating study. For instance, discovery of mineral oil and petroleum refining gave a big boost to unit operations in US. Olaf Hougen, in his Bicentennial Lecture on Chemical Engineering History, admirably captures the decisive push from the emerging US Chemical Indust2~ that influenced the changing pattern of course studies. The conceptual basis of Davis analysis of British chemical process industry gained acceptance and the University Birmingham started a degree course in mining in 1907 and the syllabus of 1910-11 included unit operations like crushing, conveying, pumping, hydraulic separations, fluid flow, and so on. Thermodynamics, material and energy balances, reaction kinetics, etc. became newer fields of study during 1920-30 when continuous operation of chemical processes gained in importance. Chemical engineering is thus a product of industry, born to sub serve industrial needs. It has "no reason for existence at all except in relation to industry.”

[2] Westwater, J.W., "The Beginning of Chemical Engineering Education in the USA," Advances in Chemistry Series, No. 199, History of Chemical Engineering, American Chemical Society (1980)

https://rutgers.primo.exlibrisgroup.com/discovery/fulldisplay?docid=alma991031081896904646&context=L&vid=01RUT_INST:01RUT&lang=en&search_scope=MyInst_and_CI_2&adaptor=Local%20Search%20Engine&tab=Everything_except_research&query=any,contains,history%20of%20chemical%20engineering&offset=0

Useful info from source “Petroleum engineering gave birth to chemical engineering at several universities.”

[] CHEMICAL ENGINEERING Notes on Its Past and Its Future DONALD A. DAHLSTROM
file:///C:/Users/jonmf/Downloads/nlewis65-226-231-perspective-dahlstrom-28-no-4-fall-1994-cee%20(1).pdf

“ Professor Hougen clearly recognized that we have an obligation to train most of our undergraduates so that they can assume responsible jobs in industry. However, he also made it clear that at the graduate level we must be boldly pioneering in new fields.... Professor Hougen felt strongly that our teaching should emphasize topics which are useful for solving the industrial problems of the present and future

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[3] VARMA, Arvind; 2003 FUTURE DIRECTIONS IN CHE EDUCATION: A New Path to Glory

Useful info from source “All through this period, since the early days of the profession, a synergistic relationship existed between academia and industry. Much of university research was supported by industry, and the graduates were readily employed by the growing petroleum refining, petrochemical, and chemical industries... All these products satisfied a rising demand from a society that had an increasing standard of living. The growth of the petroleum and chemical industries followed, and in tum catalyzed, developments in chemical engineering.

“A striking fact is that while the discipline of chemical engineering has evolved significantly over the last forty or so years, the undergraduate curriculum has remained essentially unchanged.”

“The examples used in courses continue to come primarily from the petroleum refining and bulk chemicals production industries.”

[4] Jiménez-González, C., Ponder, C. S., Hannah, R. E., & Hagan, J. R. (2010). Designing a Sustainable Pharmaceutical Industry: The Role of Chemical Engineers. In *Chemical Engineering in the Pharmaceutical Industry* (pp. 57–65). John Wiley & Sons, Inc.
https://doi.org/10.1002/9780470882221.ch4

Useful info from source “Across the pharmaceutical industry, chemical engineers are employed in R&D through to full-scale manufacturing in technical and management capacities.”

“From R&D through manufacturing within the pharmaceutical industry, chemical engineering can be leveraged to bring competitive advantage to their respective organizations through process and predictive modeling that lead to process understanding, improving speed of development and developing new technology platforms and leaner manufacturing methods.”

[5] AlShrouf, A. Hydroponics, Aeroponic and Aquaponic As Compared With Conventional Farming. *ASRJETS-Journal* **2017**, *27*, 247-255.

https://asrjetsjournal.org/index.php/American_Scientific_Journal/article/view/2543

Useful info: Talks about how much water hydroponic systems can save when compared to soil-based farming.

“However, on average, hydroponic systems use 5-20 times less water than soil agriculture. Many studies showed a significant differences between the open and the closed hydroponic system”

Table 1 has a lot of the information that wold be extrmely helpful for us

[6] https://www.unwater.org/water-facts/water-food-and-energy

Useful Info: breaks down the water-energy-food nexus, and gives a lot of statistics regarding water usage

“72% of all water withdrawals are used by agriculture, 16% by municipalities for households and services, and 12% by industries. “

“It typically takes between 3,000 and 5,000 litres of water to produce 1 kg of rice, 2,000 litres for 1kg of soya, 900 litres for 1kg of wheat and 500 litres for 1kg of potatoes.”

- If we can find some kind of statistic for these crops we can really sell hydroponics being a good alternative

[7] https://www.frontiersin.org/articles/10.3389/fpls.2016.00250/full

Useful Info: shows that a higher concentration of red light supports the maturation stages of a plants growth

Red light is actually more reactive in the photosynthesis process than blue light is, which leads to larger sizes than blue light will

[8]
https://bioslighting.com/grow-light-spectrum-led-plants/grow-lighting/#:~:text=In%20general%2C%20blue%20light%20spectrums,leaf%20growth%2C%20and%20stem%20elongation.

Similar to source 7

Growth pads: drained and weighed. ‘