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# EDUCATION ON BIOFUELS TECHNOLOGY IN CHEMICAL ENGINEERING

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**ABSTRACT:** There are very limited biofuels courses or programs devoted to engineering undergraduate education. Contrary to the lack of efforts in undergraduate biofuels education, there are enormous specialized research centers on biofuels technologies established in the past few years, especially in the chemical engineering field. These research centers mainly focus on advanced research and graduate/post-graduate education in engineering. The research results generated from these centers are usually published on scientific journals, which involve high levels of technical knowledge and complexities that only specialized scientists can understand. As a result, the available biofuels educational materials are quite dispersed and no single comprehensive literature source on biofuels processes exists that is suitable for engineering undergraduate education. Consequently, there is a significant gap between advanced biofuels research and undergraduate biofuels education in engineering.

In this work, we will first discuss the need of biofuels education in engineering and the gap between advanced biofuels research and undergraduate biofuels education. Then we will talk about why among different engineering majors, chemical engineering is in a unique position to address this educational need. Existing efforts will be reviewed and their drawbacks will be discussed. Finally we will present our proposed solutions that address different learning styles. We will also discuss how the proposed solutions enhance students' active learning and engagement.

**BACKGROUND:** It has been shown that advanced biofuels industry will have significant impact on U.S. economic recovery and its transition to a green economy. Therefore, there is a pressing and immediate national need of skilled engineers and competent researchers in the biofuels technology field. Although many biofuels education programs have emerged in the past a few years, most of them target general non-engineering audience, and they do not provide the technical education that is required to train technologically advanced workforce and innovative researchers. As biofuels processes are governed by the same underlying principles as those that govern the traditional chemical or petrochemical processes, chemical engineer educators are in a unique position to address this need. However, existing undergraduate biofuels educational practices in chemical engineering are usually comprised of small-scale, fragmented, and isolated course problems or design projects. There are several reasons for the lack of effort to systematically incorporate biofuels education into undergraduate chemical engineering curricula. The major ones are that biofuels processes are in general too complex to be comprehended by undergraduate students directly and currently there is no comprehensive yet simple enough material on biofuels processes that can be easily adopted into chemical engineering curricula. In order to achieve a breakthrough in biofuels education that has broad impact in chemical engineering, we propose a modular framework based on a piecemeal approach. Specifically, we will create a set of comprehensive, flexible and apprehensible classroom and web modules that can be easily integrated into current chemical engineering curricula.

**PROPOSED SOLUTION:** Among different engineering majors, chemical engineering is in a unique position to address this educational need. This is because most biofuels processes are chemical or biochemical processes and all the underlying principles of biofuels processes, such as mass transfer, heat transfer and reaction engineering, are the same as those of traditional chemical or petrochemical processes. The differences are that in biofuels processes different unit operations are arranged in different ways, and different raw materials are processed in biofuels plants. This can be seen clearly from Figure 1, where a biofuels plant and a petrochemical plant are put side by side. Both figures show that reaction units are connected with storage tanks, heat exchangers and separation units. They look quite similar to each other, despite the different raw materials they process, different reactions they carry and different products they produce. These similarities indicate a much easier transition from a traditional chemical engineer to a biofuels engineer compared with students from other engineering disciplines.


(a) (b)

Figure 1 Photographs of (a) a biofuels plant (Vogels, 2007) and (b) a petrochemical refinery plant

However, despite the similarities between biofuels processes and the traditional chemical-petrochemical processes, biofuels processes have their unique characteristics and challenges. In general, biofuels processes are much more complex than the traditional chemical or petrochemical processes, especially when lignocellulosic biomass is involved (due to the complex nature of biomass, complex network of reactions with multiple pathways leading to a variety of products, highly sensitive product compositions to operation conditions, etc). This perhaps is the major reason for the lack of comprehensive yet simple enough material on biofuels processes that can be easily adopted into chemical engineering curricula. Although there are several excellent graduate textbooks on biofuels technology such as (Clark & Deswarte, 2008) (Demirbas, 2009) (Drapcho, Nghiem, & Walker, 2008) (Soetaert & Vandamme, 2009), undergraduates do not have adequate background knowledge to understand them. Due to the lack of appropriate educational materials, existing undergraduate biofuels educational efforts are often too fragmented to achieve critical mass for a visible impact on students' understanding of the biofuels technology when they graduate.

Over the years chemical engineering curricula have primarily focused on traditional chemical and petrochemical industry. In other words, most examples, homework problems, exams and design problems are developed based on the traditional chemical and petrochemical processes. As fundamental principles and concepts that involved in chemical processes (which are the same for biofuels processes) are introduced gradually and cumulatively throughout the chemical engineering curriculum, we believe that a better approach of teaching chemical engineering students biofuels technology is to adopt a piecemeal approach by creating a set of comprehensive yet flexible and apprehensible biofuels learning modules that spread across the entire chemical engineering curriculum.

Specifically, instead of developing a separate senior course that is devoted to biofuels processes, we propose to break down the biofuels processes into small pieces such as unit operations, and each piece can be further broken down and simplified to illustrate different chemical engineering principles or concepts. For example, a gasifier is one of the units in a gasification process; it can be further simplified to illustrate mass balance, or energy balance. Or it can be further broken down to different zones (e.g., drying, pyrolysis, partial oxidation and combustion) to illustrate different heat effects, such as sensible heat and heat of reaction. In this way, lower level students will not be overwhelmed by the complexity of a biofuels process when they do not yet have all the background knowledge to comprehend it as a whole; while higher level students will feel much more comfortable in designing a complex biofuels plant because they have seen all the pieces in their lower level courses, maybe even multiple times. We believe this piecemeal or “spread-out” approach will result in better students learning outcome than the “single-course” approach.

To achieve the project goals, we will first develop a series of classroom learning modules that can be easily integrated into existing chemical engineering curricula. The key components of each module are: learning objectives, background information, example problems and solution, as well as homework and design problems. The modular and extensible nature of the learning material will enable instructors to easily select, share, expand, and modify the materials to fit students with various learning capabilities and career goals.

Due to the complex nature of biofuels processes and students’ limited exposure to biofuels technology, most students feel incompetent in dealing with problems related to biofuels. To help students overcome this barrier, we will also create a series of web modules to accompany the classroom modules. The key components of each web module include: glossary, process introduction, process flow diagram, captured and animated process video clips, visual encyclopedia of equipment, reference shelf, solved problems. Besides assisting students with classroom modules, another intended goal of the web modules is to use recently emerged effective teaching strategies combined with the "hot" topic of biofuels to stimulate students' interest in learning traditional chemical engineering principles. All the web modules will be hosted on our recently established website http://www.BiofuelsAcademy.org, which is the first website that is dedicated to chemical engineering undergraduate biofuels education.

While classroom modules focus on the fundamental aspects of biofuels technology that are more suited to the current undergraduate chemical engineering curriculum, the on-line web modules will provide more background knowledge and other resources to assist students with understanding classroom modules. In this way, students will not only be exposed to biofuels technology, but also get fresh stimulus in learning chemical engineering principles.

The uniqueness of our proposed approach includes the following:

- The proposed modular framework based on the piecemeal approach is the first systematic strategy to provide comprehensive biofuels educational materials that can be readily integrated into any chemical engineering curriculum.

- The unique combination of classroom modules with the web modules will effectively enhance students' understanding of chemical engineering principles by relating to contemporary issues and by introducing new learning strategies. At the same time, students will be exposed to a broad range of biofuels technologies.

- The developed learning modules are fully compatible with any chemical engineering curriculum. We expect the easy implementation will enable wide adoption of the learning materials among chemical engineering educators nationwide.

**TEACHING AND LEARNING:** The proposed usage of self-paced web modules is inspired by our own experience and two recently emerged instructional strategies: computer-assisted instruction and visual learning.

Computer-assisted instruction is an innovative instructional strategy that has been receiving increasing attention in engineering education (Abu-Hajar & Holden, 2007). It has been shown that computer-assisted instruction provides students with rapid inquiry-based learning experiences, allowing students to proceed at their own pace and within their own schedule (Fang, Stewardson, & Lubke, 2008; MIT, 2010; Hogan & Pressley, 1997). Visual learning – the use of graphics, images, and animations to enable and enhance learning – has been shown to be effective in exploiting students' visual senses to engage students in active learning, support traditional lessons, and make their learning experience stronger and deeper. (Laws, 1998; Konyalioglu, Konyalioglu, S., & A., 2005; Blanchard, 2005; Konyalioglu A. , 2009; McGrath & Brown, 2005; Bransford, Brown, & Cocking, 1999; Frankel, 2005). This methodology also has the potential to increase the number of students in science, technology, engineering, and math (STEM) fields, especially of women and minority students (McGrath & Brown, 2005).

In addition, we have been using computer-assisted instruction and visual learning in their classes and the students' responses have been very positive. Specifically, we have used the animation tools (Adobe Flash and Microsoft Live Movie Maker) in the thermodynamics classes. For example, the qualitative behavior of a vapor/liquid equilibrium (VLE) system is illustrated though animation where the system pressure or temperature is varied with the other fixed. This helped students significantly in understanding the important yet abstract concepts and principles involved in VLE. We also have been using plant videos and computer simulations extensively in the process control and transport phenomenon classes, where complex system dynamics are visualized to facilitate students' understanding of difficult concepts and system properties.

Guided by these instructional strategies and our own experiences, we propose to create web modules, accompanying the classroom modules, to enhance students' active learning and engagement, which will be carefully assessed to contribute to the understanding and improvement of STEM education. As shown in Table 1, the web modules are designed to address all learning styles outlined in (Felder & Silverman, 1988). Therefore, we expect they will significantly improve students' engagement and enhance their learning experience, which will be validated through careful evaluations.

**Table 1 The proposed web modules address all learning styles**

| Learning styles | Addressed by module features |
|---|---|
| Active / Reflective | Web modules are self-paced in nature, suit both types. Students can proceed at their own pace and at their own schedule. |
| Sensing / Intuitive | Web modules provide real word examples for sensing learners; while still have rooms for intuitive learners to discover possibilities and relationships |
| Visual / Verbal | Web modules provide rich information both visually and verbally |
| Sequential / Global | Information is presented both sequentially for each process following process flow and globally for the underlying chemical engineering principles |

As we discussed earlier, to integrate biofuels learning modules into chemical engineering core courses, one major obstacle is the lack of learning materials that is appropriate for undergraduate.

In addition, there are other obstacles. One is that not all academic programs will be able to accommodate the addition of another course with all other programmatic requirements currently in place. Another is that any changes to the curriculum that requires significant effort from faculty or staff would be difficult to sell and would not be adopted widely. As discussed below, our proposed approach can effectively address these obstacles.

In the proposed framework, the classroom modules serve as the supplementary materials to existing chemical engineering textbooks. In other words, our primary goal is still for students to understand and apply chemical engineering principles. Introducing biofuels education is the secondary goal, which exposes students to contemporary issues and industrial/national needs. Therefore, the basic concepts and fundamental principles are still from the textbooks and are taught in the same way as in a traditional chemical engineering class. The examples and homework problems provided in the developed biofuels modules can be used to replace/supplement some of the textbook examples and homework problems. The advantages of this modular approach are summarized in

Table **2** from both instructors’ and students’ points of view.

**Table 2 Advantages of the proposed modular framework for biofuels education**

| Features | Benefits to instructors | Benefits to students |
|---|---|---|
| Compatibility | No textbook/syllabus change or addition | Reduces psychological barrier |
| Modularity | Independent modules/problems enable free choice of use | Learning of one module will not negatively affect their learning of others |
| Flexibility | Easy to modify/add example/homework | |
| Comprehensive problem collection | Ample examples/homework to choose from | Ample examples to learn and ample homework to exercise on |
| Solution availability | Solutions to examples/homework are provided– no extra burden for instructors | Example solutions help develop strong problem solving strategies and skills |
| Web modules | Reduce classroom time spent on modules and minimize disruption to existing curriculum because great details are provided in the corresponding web modules | Provide additional resource and assistance that enhance student learning; encourage self-learning; address different learning styles |

**CONCLUSIONS:** In this work, we have proposed to create learning materials that systematically integrate biofuels technology into chemical engineering curriculum. By showing the close tie of biofuels technology to chemical engineering principles, we hope to better engage students to not only improve their understanding of chemical engineering principles but also allow them to gain knowledge on biofuels technology. Our project will result in teaching materials and learning resources that can be used widely in the chemical engineering education community. We will also assess the outcomes and hope to contribute to the growing literature in understanding what works and what doesn't in engineering education.

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