A WEB-BASED MODULE FOR TEACHING ENGINEERING STUDENTS ABOUT ENVIRONMENTAL EFFECTS OF FOSSIL FUEL COMBUSTION

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Abstract

A web-based module has been developed and implemented to introduce undergraduate engineering students to environmental impact of fossil fuel combustion. The subject matter is organized into five sub-modules namely, objectives/outcomes, virtual interactive, combustion chemistry, environmental chemistry, and environmental effects of emissions from combustion systems. Students learn to balance chemical reactions for fuel mixtures (in combustion chemistry sub-module), calculate interactively annual pollutant emissions from their own automobiles (virtual interactive sub-module), determine pathways for creation of smog and acid rain (environmental chemistry sub-module), and become acquainted with emission indices and EPA standards for pollutants, and pollutant remediation techniques (environmental effects sub-module.) The module has been implemented during the Spring 2006 semester, and module outcomes have been assessed using a test broadly covering materials contained in the module. Assessment results indicate that the module is an effective educational tool in promoting learning for topical areas related to environmental effects of fossil fuel combustion.

Introduction

Traditionally the topical area of combustion in the applied thermodynamics course at junior level has been taught with emphasis primarily on analysis of combustion processes, using the first and the second laws of thermodynamics [1]. Ability to calculate combustion generated heat release, adiabatic flame temperature and fuel-air ratio, parameters characterizing performance of a variety of combustion systems, are generally the outcomes of student generated activities for this topical area. Despite its growing importance to the engineering profession and the society, the related topic of environmental impact of combustion products has not received the attention in classroom instruction that it deserves. This environmental disconnect is not consistent with rising societal concerns about the impact of fossil fuel combustion on the environment, human health and the global climate. Stringent regulations have been enacted in the USA and elsewhere to curb emission levels from fossil fuels. Automobiles manufacturers are reengineering automobiles at an accelerated pace to meet emission standards imposed by various regulatory agencies. There is a growing need for engineers in industry who not only understand combustion systems modeling but also have knowledge of environmental and health effects manifested in pollutant emissions from fossil fuels combustion.

Rapid developments in computer software and Internet technologies have made it possible to design and develop wed-based modules that are interactive and user friendly, making them very useful as educational tools for student learning [2]. The authors have, under the sponsorship of an on going National Science Foundation engineering education grant, developed web-based modules that exploit the learning style of current generation engineering students. These students are more savvy with computers and video games, and consequently they are more at ease with web-based interactive educational resources. The authors have used a web-based module to incorporate materials that would otherwise not be covered in a traditional classroom instruction mode due to limited time constraint. Accomplishment of this “knowledge stretch” which refers to extension of the range of student learning from analysis of combustion systems to environmental effects of combustion through a web-based module, and assessment of module impact on student learning are the two principal goals of the present study.

Description of The Module

The web-based module titled “Environmental Effects of Fossil Fuel Combustion,” was developed and implemented under the sponsorship of a National Science foundation grant titled “Implementation Grant: Simulation and Visualization Enhanced Engineering Education”. This on going three year project aims at enhancing the quality of engineering education and student learning, using simulation and visualization. Twelve faculty from three engineering departments, namely civil and environmental engineering, electrical and computer engineering and mechanical engineering are participating in this project. A number of web-based modules are being developed for implementation in a variety of engineering science courses in all three disciplines. The motivating factor for pursuing this project is based on the following hypothesis: “Current students are more attuned to computers, Internet and video gaming, and as a result they are more inclined to learn by interacting with web-based modules, created through simulation and visualization software.” By creating, implementing, and assessing web-based modules we intend to demonstrate the validity of above-mentioned line of thinking.

The web-based module presented here (Fig. 1) has been implemented to educate mechanical engineering students in the applied thermodynamics course about environmental effects of pollutants emitted from fossil fuel combustion. The module has been designed to draw student’s attention to the fact that fossil fuel combustion and environment impact of emissions from fossil fuel combustion are in fact two inseparable sides of the same coin. The module is built utilizing three important characteristics namely interactivity, interconnectivity, and practicality. Interactivity allows students to become active and engaged learner by providing them opportunities to interact with the module with inputs and receive and interpret results from the module. For instance, to generate and sustain students’ interest, one of the web-based activities involves calculation of annual amount of emission such as NO_x, CO_2, CO and hydrocarbons (HC) from students’ own automobiles. Interconnectivity emphasizes the fact that combustion processes and environmental impact of pollutants are not disparate topics but are interconnected, with one affecting the other and vice-versa. Practically refers to all the real world related information in the module concerning environmental pollution generated by fossil fuel combustion.

The topics covered in the module are fossil fuel resources, combustion chemistry, environmental chemistry, and environmental effects of pollutants (Fig.2). Table 1 shows the sub-topical areas covered in the module. A virtual interactive module (Fig. 3) has been included that enables students to calculate the yearly production of CO_2, and other pollutants such as NO_x, HC, CO, from their own automobiles after specifying the automobile type (Fig. 4), miles driven per year and fuel economy in terms of miles per gallon. A sample of the CO_2 production calculations are presented in Appendix A. The module provides seven generic categories of automobiles ranging from hybrid to large SUV’s. The output from the virtual interactive module is also shown in Fig.4.

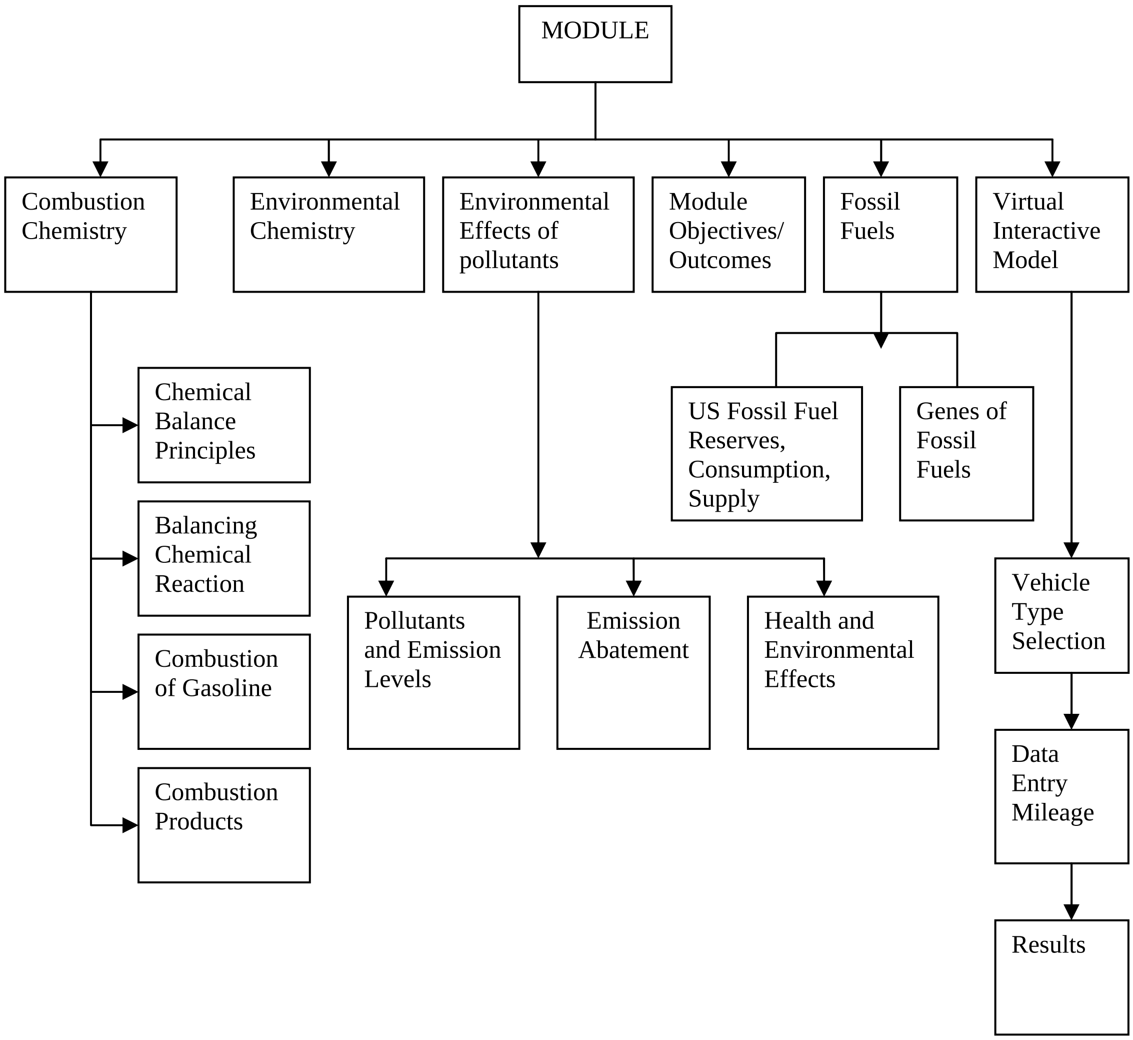

Fig. 1 Components of the developed web-based module.

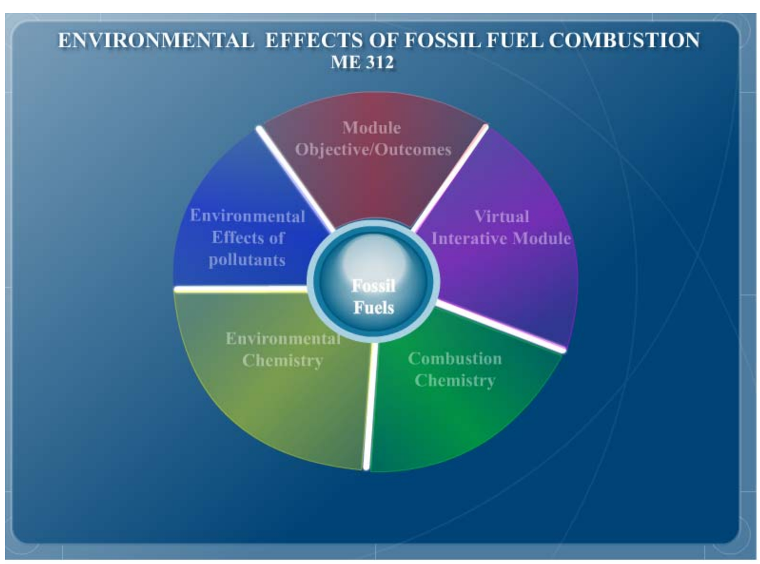

Fig. 2 Module structure.

Table 1. Sub-topics addressed through the module.

Topical Areas / Sub-topics	Fossil Fuels	Virtual Interactive	Combustion Chemistry	Environmental Chemistry	Environmental Effects of Pollution
1.	Genesis of Fossil Fuels	Pollutant emission from automobiles	Balancing chemical reactions from rich combustion, fuel-air and equivalence ratio.	Mechanisms for formation of NO_x, SO_2, and CO	Pollutants, emission law
2.	US Fossil Fuel Resources, Consumption, supply	____	Combustion products in fuel and fuel rich and fuel lean mistakes	Chemical reactions in formation of smog	Health and environmental effects
3.		____	Combustion of gasoline (example)	____	Emission abatement techniques

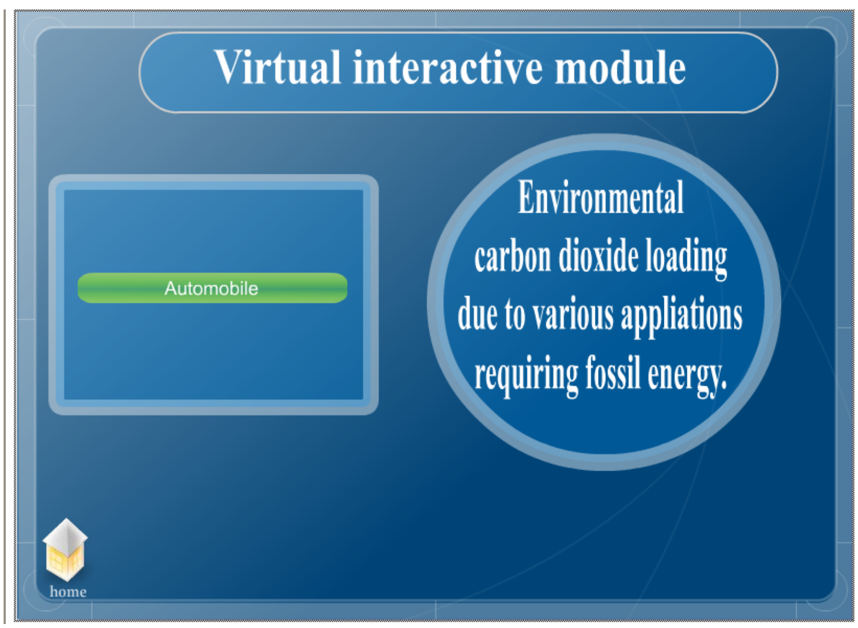

Fig. 3 Virtual interactive module.

Fig. 4 Virtual interactive sub-module inputs and outputs.

The module has two objectives and three outcomes. The objectives are:

1. Student will learn about chemical reactions occurring in fossil fuel combustion and in the environment.
2. Students will gain some knowledge of environmental impact of emissions from fossil fuel combustion, federal standards for emissions, and pollutant remediation techniques.

The three outcomes of the module are:

1. Students will be able to balance chemical reactions involving fossil fuel and fossil fuel mixtures, and will be able to define basic quantities related to combustion.

2. Students will be able to identify and calculate magnitude of emissions from fossil fuel combustion, and will be able to enumerate their effects on the environment.
3. Students will demonstrate their ability to identify chemical mechanisms for formation of smog, acid rain and other related effects, and will be able to explain mechanisms and devices used for limiting environmental pollutants to acceptable concentration levels.

Assessment Of Student Learning From The Module

The module has been implemented during the Spring 2006 semester in the applied thermodynamics (second thermodynamics) course in the mechanical engineering curriculum. Analysis of combustion processes is one of the five main topics in the course, namely psychometrics, thermodynamics property relations, introduction to combustion, chemical and phase equilibrium and one dimensional gas dynamics. The module was developed and implemented as part of the "Introduction to Combustion" topical area. The web-based module, its philosophy and contents were briefly discussed in one lecture class, one of six allocated to the combustion topic. Students were given about three weeks to access the web-based module and learn the material, mostly on their own. The emphasis was placed on self learning. As noted earlier, one of the three required outcomes of the module, namely chemical reaction balancing and related topics, was also covered in lecture classes. In that sense, the module contents related to outcome 1 provided supplementation to classroom instruction.

For assessment we have chosen an experimental design referred to as the Post Test-only Design [3] that uses baseline data for outcome 1. Assessment results from a post module test were compared with student test scores from a previous course offered without module implementation. Since for outcomes 2 and 3, no baseline data are available, a learning scale described in Table 2 was used to validate student learning. A close book and notes test was designed and administered after module implementation to determine level of learning demonstrated by students. Three parts of an hour long test contained a total of 27 multiple choice questions of which 8 related to outcome 1, 12 to outcome 2, and 7 to outcome 3. The results of all three parts of the test were normalized to 100 points. Five levels of learning were defined based on ranges in 20 point intervals. The range of 0-20, 21-40, 41-60, 61-80, and 81-100 were designated as "no learning", "inadequate learning", "marginal learning", "good learning", and "excellent learning". Table 2 shows levels of learning for all three outcomes. It is noted that for outcome 1, nearly 74 percent of students in the class placed in categories of marginal to excellent learning. Corresponding figures for outcomes 2 and 3 are 98% and 78% respectively.

Outcome	**Exhibit no learning [0-20%] (%)**	**Exhibit inadequate learning [20-40%] (%)**	**Exhibit marginal learning [40-60%] (%)**	**Exhibit good learning [60-80%] (%)**	**Exhibit excellent learning [80-100%] (%)**
1	6	22	30	22	20
2	0	2	16	41	41
3	0	22	25	33	20

Table 2 Levels of learning versus outcomes.

Table 3 Comparison of learning levels for outcome 1.

Year	Exhibit No learning [0-20%] (%)	Exhibit inadequate learning [20-40%] (%)	Exhibit adequate learning [40-60%] (%)	Exhibit good learning [60-80%] (%)	Exhibit excellent learning [80-100%] (%)
2005	17	29	25	4	25
2006	6	22	30	22	20

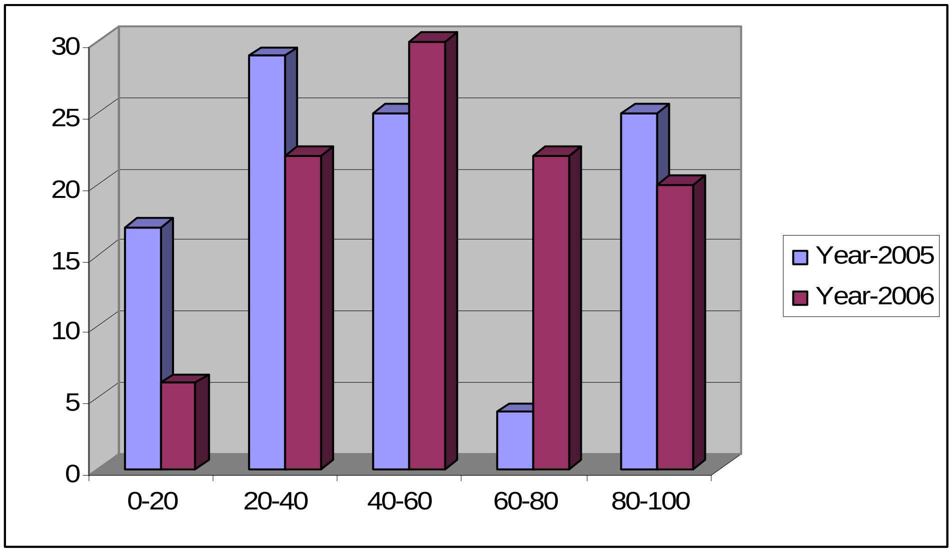

Fig. 5 Comparison of student learning levels for outcome1.

The outcome 1 of the module presented an opportunity to gage effect of the module on student learning since baseline results from a 2005 conventional (or unmodified) course offering were available from an equivalent quiz. Normalized results based on percentage of student population are shown in Table 3 and Fig.5. From Table 3 we note that in 2006 course offering, nearly 72 percent of students in the class exhibited marginal to excellent learning levels as compared to 54 percent of students in the conventional course offering in 2005. The improvement in student learning in outcome 1 is interpreted as resulting from implementation of the web-based module as a supplementation tool in the course.

Conclusions

A web-based module for teaching students about environment effects of fossil fuel combustion was designed, developed, implemented and assessed for its effectiveness in promoting student learning of a variety of topical areas included in the module. The module was used as an educational tool to supplement materials presented in the classroom lectures. A large part of the materials in the module related to outcomes 2 and 3 was new and was never covered in previous course offerings. The module was assigned to students primarily for self study and self learning. The combustion chemistry aspects of module pertaining to outcome 1 have also been covered in conventionally taught class from the previous year. The assessment results for outcome 1 were compared for both 2005 and 2006 year classes to gage the effectiveness of the module as a supplementation tool. Results indicate that students in the 2006 class performed better than students in the 2005 (unmodified) class. Since no previous assessment results were available for outcomes 2 and 3, the assessment results were interpreted on an absolute scale that defined five distinct learning levels described in the paper. Since new materials related to outcomes 2 and 3 were accessed by students in a self learning mode, the assessment results for those outcomes also indicated student success (or failure) in learning from the module materials in a self learning environment. The results for outcomes 2 and 3 were very encouraging indicating that 98% and 78% of students cumulatively exhibited learning levels ranging from "marginal" to "excellent". Results from this study point to the fact that web-based modules can be viable educational tools for self learning as well as for supplementation of learning from conventional classroom lectures.

Acknowledgement

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Appendix: A
EXAMPLE: COMBUSTION OF GASOLINE
(Carbon Dioxide Production)

Fuel is gasoline which is a blend of about several hydrocarbons. To simplify, we assume it to be a mixture of 90% octane ($C_8 H_{18}$) and 10% Heptane ($C_7 H_{16}$) by volume.
Combustion products are assumed to be N_2, CO_2 and H_2O (Note: Excess air will not change CO_2 amount).

Chemical Reaction Balancing

Number of miles driven/year	: N
Miles per Gallon	: mpg
Number of Gallons	:NG = N / mpg
Volume of Gasoline	: $V = (3.7854)NG * 10^{-3}\ m^3$
Volume of Octane	: $VO = 0.9V\ m^3$
Volume of Heptane	: $VS = 0.10V\ m^3$
Mass of Octane	: $m_o = \rho_{octane} VO$ kg
Moles of Octane	: $n_o = m_o / M_o$ kmols
Mass of Heptane	: $m_s = \rho_{heptane} V_s$ kg
Moles of Heptane	: $n_s = m_s / M_s$ kmoles

Balancing Combustion Reaction for Octane/ Heptane Mixture:

$n_o (C_8H_{18}) + n_s (C_7H_{16}) + A (O_2 + 3.76 N_2) \rightarrow B Co_2 + D H_2O + E N_2$

C: $8n_o + 7ns = B$

H: $18 n_o + 16 n_s = 2 D \Rightarrow D = 9 n_o + 8 n_s$

O: $2A = 2B + D \Rightarrow A = B + D/2 = 8 n_o + 7 n_s + 9/2 n_o + 4n_s$

$A = 12.5 n_o + 11 n_s$

N: $E = 3.76 A = 3.76 (12.5 n_o + 11 n_s)$

Annual production of $CO_2 = (8 n_o + 7n_s)$ C kg/year

(for chosen automobile) (M CO2 is the mol.weight of CO2)

Annual Production of CO_2 in metric tons = ((8no + 7 ns) /1000)* M_{CO2}

Note: A gasoline blend that matches the detonation characteristics of a 90 % Octane and 10% Heptane mixture is designated an Octane rating of 90% on a scale of 0 to 100.