Live Energy: An Initiative for Teaching Energy and Sustainability Topics with the most Up-to-date and Relevant Content

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Abstract

This paper presents the ongoing activities of a National Science Foundation (NSF)-funded collaborative research project, its iterative research design, and the preliminary findings. Five engineering professors at five university campuses, [Texas A&M University (TAMU) College Station, Prairie View A&M University (PVAMU), California State University Long Beach (CSULB), The Pennsylvania State University (Penn State), & Stanford University] as well as a technology expert and four learning scientists at the leading campus (TAMU) have worked in collaboration over two years on two objectives. One objective is to create an online textbook for teaching energy and its sustainability to all college majors. To provide the most meaningful and relevant information to students from all majors in their courses, our five professors, who are experts in their fields, are authoring an online textbook with embedded dynamic content that can be frequently updated according to emerging technical developments and sociopolitical, economic, and environmental events. To assess the pedagogical merit of the developed textbook, as our second objective, we identified several instruments and administered them at the participating campuses to collect the control data. In this paper, we discuss the nature of the courses taught in the five campuses, progress in the textbook project initiative, and the data collected over the five semesters. Our project activities, administration of the instruments, and the lessons learned provide insights to similar efforts aimed to implement online and up-to-date content material in teaching courses that are trans-disciplinary and dynamic in nature.

Introduction

In this three-year, National Science Foundation (NSF)-funded collaborative research project, five engineering faculty across university campuses in the US are co-authoring an online textbook with the most up-to-date and relevant content to teach energy and its sustainability to college students. Conventional printed textbooks on energy and its sustainability tend to be out-of-date from the moment they become available because the energy landscape is constantly changing in response to technical, political, economic, and environmental developments.

Research in learning sciences[1] and in engineering education[2] recommends that college students learn more effectively when they find connections between the material they learn in class and the information they receive in mass media and elsewhere in their daily lives. Students' intrinsic motivation is triggered when the course material is relevant to their daily experiences or to the public information they hear about in informal settings. Students who make use of the newly learned material in generating arguments are likely to learn and retain the course material comprehensively and develop skills to communicate effectively and more readily than students who do not make practical use of the course content. Recognizing the sources of information on mass media and the Internet are life-long learning skills.

Energy and its management, conversation, and sustainability are among the subjects that are discussed in mass media continuously. Unrest in many of major oil exporting countries, the oil spill in the Gulf of Mexico, and the impact of the recent tsunami in Japan on nuclear power are some recent events that influence the arguments one can develop on energy and its sustainability. Even though the professors teaching energy courses are accustomed to discussing these current events in their classes, the information in conventional printed textbooks is at best what was current at the time of printing. Online content that the course instructors (or any reliable and interested parties) can update appears to be the solution for the limited current event discussion of conventional textbooks. In addition, e-book technology enables ample use of color and the prospect for animated illustrations and even games.

Our engineering professors and the NSF have recognized the need to develop a textbook involving dynamic content in nature that can be updated frequently online by multiple authors to better serve the needs of the college students learning about energy and its sustainability. Led by the TAMU campus, five engineering faculty began working with technology experts and the learning scientists in October 2010.

The Study Context

Our five engineering faculty members teach courses in energy and its sustainability at five campuses across the US, one located at Northeast--The Pennsylvania State University (Penn State)--, two at West Coast--California State University Long Beach (CSULB) & Stanford University--, and two in the South--Texas A&M University (TAMU) College Station and Prairie View Texas A&M (PVAMU).

At the TAMU campus, the energy and its sustainability course attracts students from all majors. The average number of students enrolled in the course is 80 per semester. The instructional medium includes lectures taught by experts in industry and academy and recitation sessions taught by undergraduate peer-teachers and graduate teaching-assistants. Students complete a semester long and open-ended collaborative project of their choice that requires a final product. Among the final products students generated were an engineering model for solar water heating, survey instruments administered to public and/or online, and a presentation given to local stakeholders pertaining to installing wind turbines in a housing development. Developed by an NSF-funded TUES phase I grant, this course aims to enhance students' content understanding and their life-long learning and effective communication skills.

At the PVAMU campus, a graduate course in global energy systems is offered. This course was developed to assess the interest of the students in energy courses. The course is designed to be student interest driven requiring extensive independent work by the students.

At Penn State, State College, two energy courses are offered and hundreds of students enroll in the courses. The objectives of the courses are to provide basic understanding and appreciation of energy and environmental concepts, analyze energy consumption patterns, discuss various energy resources that power the modern society, examine the energy conversation processes, explore interrelationships between energy use and industrial progress, and discuss future energy alternatives and conservation methods.

At Stanford University, around 100-170 students enroll per year in two courses on energy and its sustainability taught consecutive quarters. In the first course, an engineering problem-solving approach has been implemented to analyze the existing energy landscape and guide designs for future energy supply. Students complete a group project, write a report, present their final projects, and answer questions from their peers in the first course. In the second course, students examine alternative energy processes, such as, renewables and nuclear energy, with the potential for low carbon intensity and environmental impact.

At CSULB, 100 to 300 students enroll in the energy and environment course in every semester. Roughly 20% of students are from engineering, another 20% from environmental science policy program, and rest from all majors across the campus. Students participate in a variety of activities including online group discussion and debate, projects and site visits.

The characteristics of the five faculty participants and their instructional contexts are summarized in Table 1.

Table 1. Faculty participants' characteristics and the context of their instructional media.

Faculty Member	Campus Location	Gender	Years of teaching in academia	Number of courses taught per semester or quarter	Approximate number of students enrolled in the energy course per semester or quarter
Faculty 1	TAMU	Female	>10	1-2	80-120
Faculty 2	PVTAMU	Male	>5	1-2	10-20
Faculty 3	Penn State	Male	>5	1-2	100-300
Faculty 4	CSULB	Male	>25	2-3	100-300
Faculty 5	Stanford	Male	>15	2	50-125

The Online and Dynamic Textbook

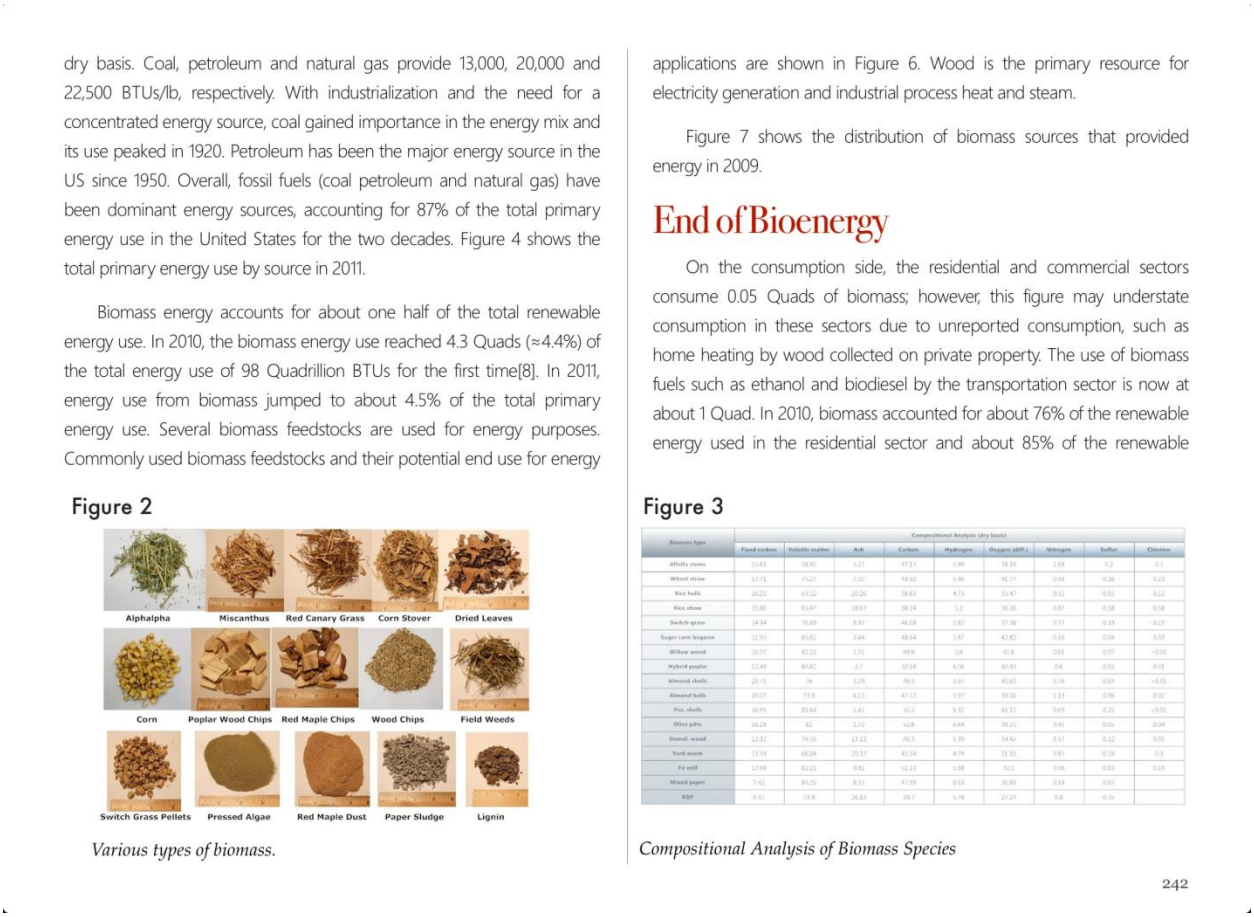
Our faculty members began drafting the book chapters in Summer 2011. Because of the geographic locations of the five faculty members, most of our communications were held on Adobe Connect conference calls. During the academic semester, the faculty members and the project collaborators met every week for one to two hours. In these weekly meetings, we discussed our project activities, such as (a) drafting the chapters by the faculty and (b) collecting data from the students. The table of contents for the most current version of the online textbook (version 0.9.4.4) is presented in Table 2.

Table 2. *The table of contents for the electronic textbook version 0.9.4.4 (2012).*

Section 1. Past, Present, and Future of Energy
Chapter 1.1 Energy Sustainability
Chapter 1.2 Energy Sources and Uses
Chapter 1.3 Energy Conversions
Section 2. Fossil Energy
Chapter 2.1 Coal

Chapter 2.2 Oil
Chapter 2.3 Natural Gas
Chapter 2.4 Unconventional Fossil Resources
Chapter 2.6 Environmental Consequences of Combustion
Section 3. Nuclear Energy
Chapter 3.1 Nuclear Energy Technology
Section 4. Renewable Energy
Chapter 4.1 Hydro Energy
Chapter 4.2 Geothermal Energy
Chapter 4.3 Solar Thermal Energy
Chapter 4.4 Wind Energy
Chapter 4.5 Bioenergy
Appendices
Appendix A: Mathematical Notation
Appendix B: Abbreviations and Acronyms

Up to now, our five engineering professors wrote the content of the book and reviewed each other's chapters. Our technology team used the iBook Author software[3] to publish the content of the book. In the below Figures 1 through 4, four illustrative screenshots are presented.



dry basis. Coal, petroleum and natural gas provide 13,000, 20,000 and 22,500 BTUs/lb, respectively. With industrialization and the need for a concentrated energy source, coal gained importance in the energy mix and its use peaked in 1920. Petroleum has been the major energy source in the US since 1950. Overall, fossil fuels (coal petroleum and natural gas) have been dominant energy sources, accounting for 87% of the total primary energy use in the United States for the two decades. Figure 4 shows the total primary energy use by source in 2011.

Biomass energy accounts for about one half of the total renewable energy use. In 2010, the biomass energy use reached 4.3 Quads (≈4.4%) of the total energy use of 98 Quadrillion BTUs for the first time[8]. In 2011, energy use from biomass jumped to about 4.5% of the total primary energy use. Several biomass feedstocks are used for energy purposes. Commonly used biomass feedstocks and their potential end use for energy

Figure 2

Various types of biomass.

applications are shown in Figure 6. Wood is the primary resource for electricity generation and industrial process heat and steam.

Figure 7 shows the distribution of biomass sources that provided energy in 2009.

End of Bioenergy

On the consumption side, the residential and commercial sectors consume 0.05 Quads of biomass; however, this figure may understate consumption in these sectors due to unreported consumption, such as home heating by wood collected on private property. The use of biomass fuels such as ethanol and biodiesel by the transportation sector is now at about 1 Quad. In 2010, biomass accounted for about 76% of the renewable energy used in the residential sector and about 85% of the renewable

Figure 3

Compositional Analysis of Biomass Species

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Figure 1. A screenshot from the Live Energy iBook version 0.9.4.4

In the electronic book, the reader can zoom in to the figures, graphs, or images by a simple click. The figure, image, or graph enlarges on the screen for a better view.

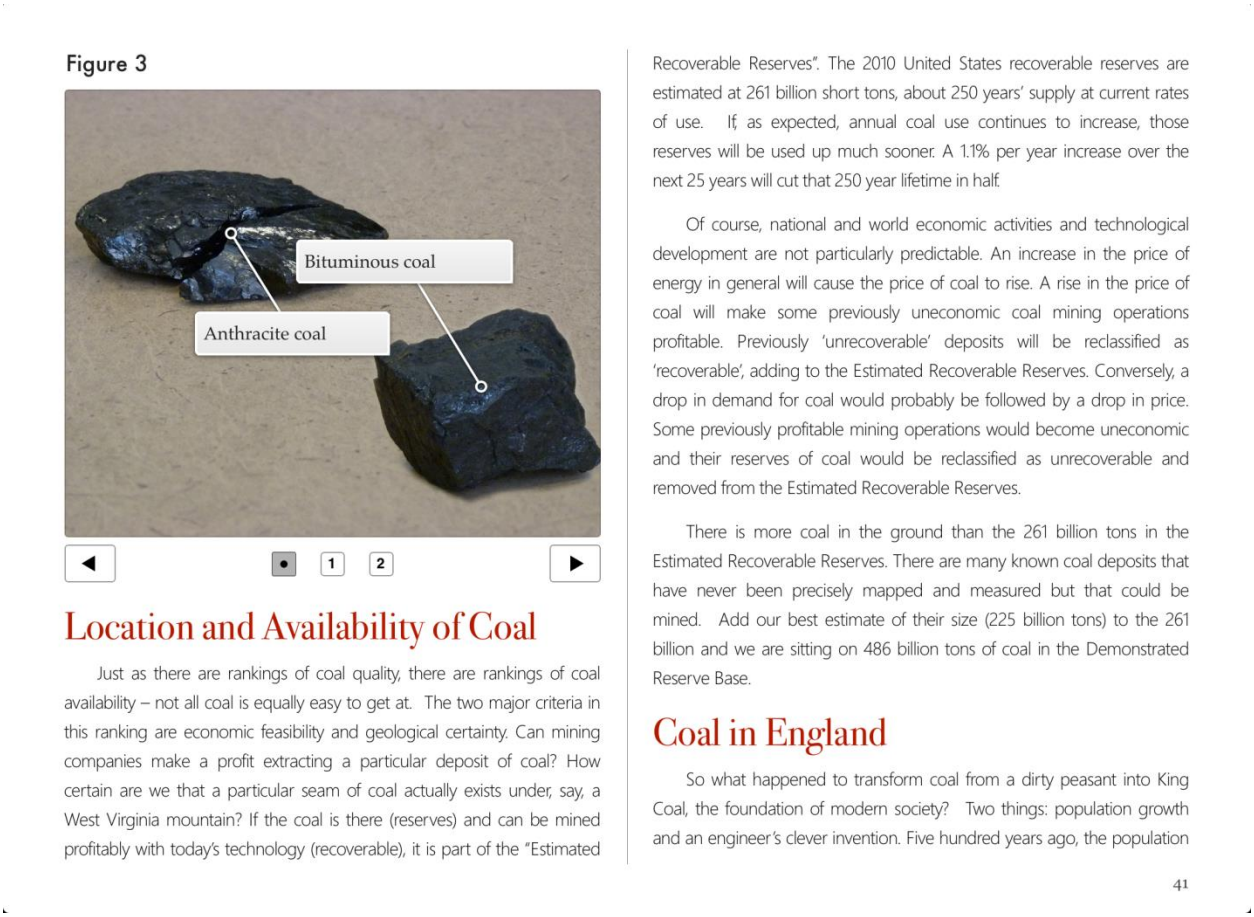
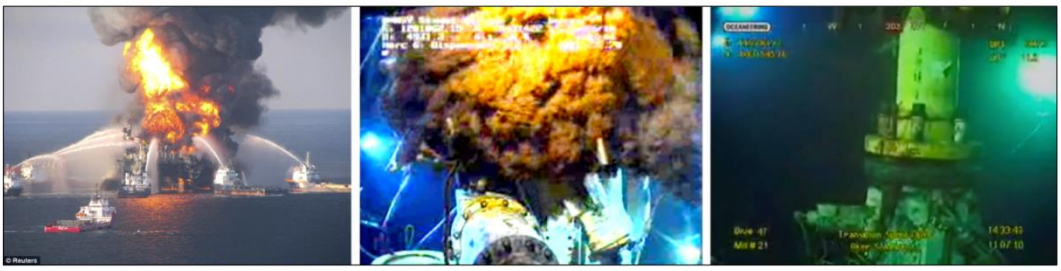


Figure 2. A screenshot from the Live Energy iBook version 0.9.4.4

IBook Author[3] allows authors to group two or more images together and list them in an order. In this way, when the reader zooms in to the grouped images, she views a series of images, which will more meaningfully illustrate the conceptual continuity or the difference among the images. Some of the images included in the Live Energy iBook are interactive, that is, the reader views different explanations when she clicks on different parts of the image.

Figure 26



Eleven crewmen were killed in the BP Macondo well blowout. The well was being drilled about 40 miles offshore at a depth of nearly 1 mile below sea level. The nation watched in horror a constant video stream showing the oil flowing at rates more than 50,000 bpd into the Gulf of Mexico. The well was successfully capped after 85 days after spilling nearly 5 million barrels.
[http://commons.wikimedia.org/wiki/File:Deepwater_Horizon_offshore_drilling_unit_on_fire.jpg]

such activity would be barely visible from land. Nonetheless, both coasts rely heavily on beautiful beaches for tourism, and opposition to offshore oil and gas development was likely to be acute.

On April 20, 2010, this scenario changed when the BP Macondo well had a blow out that killed 11 oilfield workers (Figure 2.39). On May 30, 2010, U.S. Secretary of the Interior Ken Salazar declared a 6-month moratorium on offshore drilling in the Gulf of Mexico while a nation watched numerous attempts to stop the oil flow. Until it was capped successfully on July 15, the Macondo well produced an estimatedtotal of about 5 million barrels of oil that soiled beaches and wetlands primarily on the Louisiana coast, killed wildlife, and caused a ban on fishing in contaminated water. Interestingly, the crude oil that spilled from the well quickly dissipated in the environment leaving little damage lasting longer than about 6 months, but hundreds of thousands of jobs were lost as a result of the incident. New more stringent regulations were developed to reduce the risk of another deep water well blow out, and slowly deep water drilling and development resumed as before in the Gulf of Mexico. It is now unclear when, if ever, petroleum development will be resumed on either the east or the west coast.

Crude oil tankers have spilled significant oil quantities in highly environmentally sensitive locations. The reasons for these either were directly due to human error or exacerbated by the same. In 1979 bad weather caused the Amoco Cadiz (Figure 2.41) to run aground along the Normandy coast of France. After that, due to bad decisions and delayed

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Figure 3. A screenshot from the Live Energy iBook version 0.9.4.4

Our Live Energy iBook included events that are recent, for example, the oil spill in the Gulf of Mexico in 2010.

solar steam generator is backed up using natural gas that is burned to create steam on cloudy days, to meet peak energy demands, and for nighttime electricity generation. SEGS power plants have operated such that 75%, or more of the electricity generated is a result of sunlight (Price and Carpenter, 1999). It is said that currently SEGS only produces "a few percent" of their electricity from burning natural gas (NREL, 2011). Accordingly, it can be claimed that SEGS is a hybrid solar-fossil fuel power plant. Moreover, sunlight and natural gas complement each other due to availability in North America and cleanliness of both energy sources.

Figure 4

Areal view of SEGS III to VII in the Mojave Desert CA. Power generation equipment in the center is surrounded by rows of parabolic trough collectors. (Copyright Alan Radecki, licensed under CCSA 3.0 http://creativecommons.org/licenses/by-sa/3.0/deed.en)

Future Potential

The statistics that solar energy provides only 0.1% of U.S.A. primary energy but that the vastness of solar energy incident upon the Earth exceeds world energy needs by 7600 times were intended to strike a large contrast. The future potential for solar thermal energy is great, but natural variability of solar insolation, technology limitations, environmental considerations, and cost are roadblocks to significant implementation. Existing and emerging technology are discussed in some depth in the next section. This section focuses on resource limitations and the future potential for solar thermal energy.

Figure 5 is a global resource distribution map of solar insolation. A good tool to explore the U.S.A. solar thermal resource in detail is available at the Solar Power Prospector (http://maps.nrel.gov/node/10/). Dark red shading in Figure 4.27 indicates geographical locations of greatest potential whereas blue shading represents locations of low potential. As you might expect, average insolation is greatest between the tropics of Capricorn and Cancer. The southwestern USA is a world-class solar resource and explains, partially, the development and success of SEGS in the Mojave Desert. Other regions of the globe with outstanding resource include, but are not limited to, North and Saharan Africa, the Middle East, and Australia.

Figure 5 also illustrates one of the chief limitations for the solar energy resource. That is, densely populated regions are not necessarily coincident with geographical areas where solar insolation is greatest. For example, the eastern US cities of Boston, New York, Philadelphia, and so on, are over 3000 km from the prime solar resource in the Mojave Desert. Los Angeles, however, is very close. Similarly, Northern Europe lies about 2500 km or

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Figure 4. A screenshot from the Live Energy iBook version 0.9.4.4

Hyperlinks embedded in the text provide easy access to the information on the Internet. If the reader has an Internet connection, she can read the materials online by a simple click on the link embedded in the book.

The first release of the electronic textbook is in Apple's iBook format[3]. The iBook format only works on Apple's iPad. This format was selected based on a combination of factors--mostly the lowest cost of development (due to the iBook Author software), advanced reader interactivity (iBook reader software), and an effective market share[4]. We are also offering the textbook as a PDF due to the need to address the student population who do not have iPads and because the iBook Author tool will generate a "flat" version of the book with minimal additional editing/development effort.

Interestingly, the PDF and iBook represent two extremes in electronic textbook formats. Our informal discussions with students indicate that the iBook format's capability for annotation, sharing, embedded glossary, search, and highlighting are features that the students desire and yet have not had. There is at least one large university level study underway that we are watching for guidance in our selection of features and formats, the Internet 2 eText study with 20+ universities[5].

The Nook and Kindle are the other two mostly used electronic textbooks[6,7]. Both the Kindle and Nook reader software is available on Macintosh, iPad, Windows, Android and other lesser platforms in addition to the proprietary Amazon and Nook tablets. Kindle and Nook do not offer adequate interactivity at this time, even though the vendors are slowly attempting to add competitive features to Apple's. Amazon's KF8 format[6] was released with the latest generation color Fire tablets, however the reading experience is only slightly better than a flat PDF on most platforms, are nowhere near as interactive as the iBook, and there are no authoring tools at the level of the incompatible iBook Author tool.

Finally, it is technically possible to use game specific software development tools to build an electronic textbook that would be massively interactive featuring mini-games, puzzles, SCORM compliant data collection, leader boards, and the expected assortment of videos, animations, and interactive models.

Research Design

To assess the pedagogical impact of the newly developed online and dynamic textbook on student learning outcomes, we designed an iterative educational research study. Informed by the previous grant work,[8,9,10] we have planned to explore the following student learning outcomes: (a) content understanding, (b) attitudes towards engineering, (c) life-long learning skills, and (d) skills to locate resources pertaining to energy and its sustainability resources.

To assess students' content understanding, we developed a content questionnaire with 20 multiple-choice items. The items we used in the questionnaire were originally developed by Faculty 4 and have already been used in assessing students' content understanding. This supported the initial content validity of the items. After choosing 20 items from a pool of 51 items, our faculty participants and learning scientists reviewed the items one by one. We modified a few of them either by changing the verbiage in the questions or re-writing some better multiple-choice alternatives. The most recent version of the content questionnaire items are presented in Appendix A.

To assess students' life-long learning skills, we searched the literature for a valid and reliable life-long learning scale[11,12,13]. After a thorough review, we have chosen Wielkiewicz and Sinner's Life-Long Learning (LLL) scale[12] which best matches our student population's characteristics. The LLL scale included 16 items with a five-point scale.

To assess students' attitudes towards the engineering, we followed the same procedure above and located the Engineering Attitude Survey (EAS) developed by Robinson et al.[14,15] The EAS included 25 items with a six-point scale.

To assess students' skills to use new media (e.g., Facebook, Twitter, Wikipedia, blogs, etc.), we designed another scale including six items with a five-point-scale. The six items in this scale complemented the LLL scale items. However, we grouped the items of this measure separate from the LLL scale items, because we wanted to keep the LLL scale items as a whole for the analysis. The scale items are presented in Appendix B and titled "Energy and Sustainability Survey Items."

Our project activities are still in progress. Our faculty members have finished drafting the first version of the textbook (version 0.9.4.4). Individual faculty members have reviewed each other's chapters, and the book has been edited for coherency among the chapters. The figures, tables, images, references, etc. are presented similarly for aesthetic purposes. We anticipate using the textbook in the participating campuses in Spring 2013.

In Spring 2011, Fall 2011, Spring 2012, and Fall 2012, we collected data from students in the five campuses without the use of the online textbook. This data will serve as the control data. Our study design is a quasi-experimental quantitative research without randomizing the groups. Our sampling strategy was convenience sampling for both control and experimental groups. Even though this is not a preferred method to assign groups in ideal experimental studies, in educational studies where subject assignment is limited by the courses offered, convenience sampling strategy is often accepted. It is worthwhile to mention that our control data (without the online textbook instruction) and the experimental data (with the online textbook instruction) will have been collected from different students. To reduce the impact of individual student differences, we collect control data as many as times as we could, so that we can investigate the individual student differences and take these differences into account during the final analysis. The individual student differences between semesters in each campus will be treated as covariances in the final analyses and their effect (if significant) will be subtracted from the final analysis results.

Findings

The pre and post responses of the students on the research instruments revealed that instruction without the online textbooks did not result in much change in students' content understanding and their skills and attitudes pertaining to energy and engineering. Findings also showed no institutional differences. We used the collected control data to evaluate the effectiveness of the content questionnaire items. Item analysis revealed a need to redesign six items that had marginal difficulty powers or insufficient discrimination of the upper and lower student groups. The revised items were used in the Fall 2011 and subsequent semesters. The revised content questionnaire is given in Appendix A.

In our first data collection phase, the content questionnaire was printed on paper using Gravic Remark Office OMR software that enabled automated scoring. In the Fall 2011 and pre-survey of Spring 2012, the four surveys were administered online on Survey Monkey. In the post-survey of Spring 2012 and pre- and post-surveys of Fall 2012, the surveys were administered online via Qualtrics. All instruments were administered twice during the semester, once early in the semester and once after the semester was completed. Data from students who completed both pre and post surveys and the content questionnaires were used in the analysis. A total of 483 participants were matched for participation in both pre-and post-tests in Spring 2011, Fall 2011, Spring 2012, and Fall 2012 data. Any students who did not complete any of the pre or post research instruments were excluded from the analysis.

Table 3 reports the means (m) and standard deviations (sd) of the scores on the pre-and post-instruments from the data collected in Spring 2011 (n=153), Fall 2011 (n=54), Spring 2012

(n=273), and Fall 2012 (n=3). Table 4 reports the correlations among the measures for the same data set. Because of the marginal group size differences across the campuses, we used both parametric and non-parametric tests to analyze the relations between the measures. Both test results revealed no institutional differences on gain scores in any of the measures. For the Energy & Sustainability Survey Items (which were created by authors and not yet standardized), a high internal consistency reliability was found at Cronbach's alpha=0.8443. Further, moderate correlations were found between some of the survey sub-tests and the content questionnaire (Table 4).

Table 3. *Means (m) and standard deviations (sd) of the participants' pretest and posttest scores for each instrument (N=483).*

Instruments	Pre-test [m (sd)]	Post-test [m (sd)]
Content Questionnaire *(0-none correct – 20-all correct)*	7.48 *(2.41)*	7.63 *(2.19)*
Energy & Sustainability Survey *(0-never – 4-always/daily)*	1.158 *(.9821)*	1.6406 *(1.107)*
Lifelong Learning Survey *(0-never – 4-always/daily)*	2.5389 *(1.0749)*	2.6078 *(1.0601)*
Engineering Attitude Survey *(0-most negative – 5-most positive)*	3.2725 *(1.2388)*	3.2306 *(1.2453)*

Table 4. *Correlations among the measures (N=483).*

Correlations	Pre-test (Pearson's r)	Post-test (Pearson's r)
Content Questionnaire – Energy & Sustainability	0.3712	0.2416
Content Questionnaire – Lifelong Learning	0.3848	0.0405
Content Questionnaire – Engineering Attitude	0.298	0.4227
Energy & Sustainability – Lifelong Learning	0.3969	0.416
Energy & Sustainability – Engineering Attitude	0.3165	-0.0675
Lifelong Learning – Engineering Attitude	0.3063	0.264

The designed Live Energy electronic textbook will be in use in Spring 2013. We will continue administering the same instruments in the Spring 2013 semester from the participating institutions. After 2013 Spring semester, we will have the data from both the control and the experimental groups. We will be able to investigate any impact of the Live Energy electronic textbook on students' learning outcomes after the Spring 2013 semester is completed.

Conclusions

Our findings showed that the student learning outcomes were not significantly improved when traditional textbooks were used in teaching energy and its sustainability in each of the participating campuses. Results also showed no institutional differences. These are promising findings for us because when the online textbook is used, any significant improvement of student learning outcomes over the course of a semester will show favorable results for our project goals.

Our iterative research design informs the similar educational efforts aimed to help improve the student learning experiences in higher education. Particularly in the engineering courses that involve dynamic content, university faculty and curriculum developers can create online and dynamic course materials that can be updated easily and frequently as needed. The work

presented in this paper and the instruments described will also guide any systematic evaluation of a pedagogical novelty on similar student learning outcomes.

Acknowledgement

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References

1. Bransford, J. D., Brown, A. L., & Cocking, R. R., (2000). *How people learn: Brain, mind, experience, and school.* Washington DC: National Academy Press.

2. National Academy of Engineering (2004). *The engineer of 2020: Visions of engineering in the new century*. Washington, DC: National Academy Press.

3. Apple's iBook (2013). iBook is an (R) Apple Inc. Retrieved from https://www.apple.com/apps/ibooks/ on Jan 7, 2013.

4. Apple's iBook Author (2013). iBook Author is ® Apple Inc. Retrieved from http://www.apple.com/ibooks-author/ on Jan 7, 2013.

5. Burton, M., Maas, B., & Osborne, N. (2012). *Internet2 eText Pilot-Background and Preliminary Results*, A presentation at the 2012 Internet2 Member Meeting, Arlignton, Virginia, April 22-25, 2012. Retrived from http://events.internet2.edu/2012/spring-mm/agenda.cfm?go=session&id=10002255 on Jan 7, 2013.

6. Kindle Reader (2013) Kindle is ® Amazon.com, Inc. Retrived from https://kindle.amazon.com/ on Jan 7, 2013.

7. Nook Reader (2013) Nook is ® Barnes and Noble, Inc. Retrived from http://www.barnesandnoble.com/ on Jan 7, 2013.

8. Yalvac, B., Ehlig-Economides, C., Brooks, L. A., & Smith, D., (2009). An international, interdisciplinary, and dynamic approach to teaching energy utilization and sustainability, Proceedings of the *International Symposium on Engineering Education and Educational Technologies (EEET)*, July, 2009, Orlando, FL.

9. Yalvac, B., Brooks, L. A., & Ehlig-Economides, C., (2008). Research on the evolution of college instructors' perspectives of teaching and learning, Proceedings of the *American Society for Engineering Education (ASEE) Annual Conference and Exposition*, June, 2008, Pittsburgh, PA.

10. Brooks, L. A., Yalvac, B., Economides, C. E., Ferguson, J., & Cryer, J., (2009). The influence of apprenticeships of observation on STEM recitation instructors' practices and epistemological flexibility. Poster presentation at the annual meeting of the American Educational Research Association (AERA), April, 2009, San Diego, CA.

11. Kirby, J.R., Knapper, C., Lamon, P., & Egnatoff, W.J., (2010). Development of a scale to measure lifelong learning, *International Journal of Lifelong Education, 29*,(3), 291-302.

12. Deakin-Cric, R., Broadfoot, P., & Claxton, G. (2004). Developing an effective lifelong learning inventory: the ELLI project. *Assessment in Education, 11*(3), 247-272.

13. Wielkiewicz, R. M., & Sinner, A. S., (2010). A Life-Long Learning Scale for student development research and evaluation, *Personal communication held on August 2010.*

14. Robinson, M., Fadali, M. S., Carr, J., & Maddux, C., (1999). Engineering principles for high school students, Paper presentation at the 29th Annual Frontiers in Education Conference, Nov 10-13, 1999, San Juan, Puerto Rico.

15. Fadali, M. S., Henderson, N., Johnson, J., Mortensen, J., & McGough, J., (2001). On-line engineering mathematics testing and assessment, Paper presentation at the 31st Annual Frontiers in Education Conference, 2001, Oct 10-13, 2001, Reno, NV.

Appendix A- The content questionnaire

1- Per capita energy consumption in a modern technological society is roughly 10 times that before the Industrial Revolution.
a) True
b) False

2- How much does the energy content of the wind change if wind speed suddenly doubles?
a) About one-half
b) About the same
c) About twice as much
d) About four times as much
e) About eight times as much

3- What percentage of the US's consumable electrical capacity comes from wind?
a) Less than 1%
b) About 2%
c) About 5%
d) About 15%
e) About 50%

4- Today, which renewable energy source provides the US with the most energy?
a) Fossil
b) Wind
c) Solar
d) Hydroelectric
e) Nuclear

5- Roughly, what percentage of energy from burning coal is converted to electricity?
a) 10-20%
b) 30-40%
c) 50-60%
d) 70-80%
e) 90-100%

6- During photosynthesis a plant
a) Converts energy
b) Absorbs energy
c) Gives off energy
d) Transmits energy
e) Reflects energy

7- Which energy source is currently used most by the United States?
a) Coal
b) Petroleum
c) Natural Gas

8- Gasoline is a product of refining
a) Coal
b) Petroleum crude oil
c) Natural gas
d) Propane
e) Ethanol

9- The three countries with the largest conventional petroleum reserves in the world currently are
a) Saudi Arabia, United States, and Russia
b) Saudi Arabia, Venezuela, and the United Arab Emirates
c) Saudi Arabia, Iran, and Iraq
d) Iran, Iraq, and Kuwait
e) United States, China, and Russia

10- Ozone has the chemical formula ___, is generally ___ in the lower atmosphere, and is ___ in the stratosphere.
a) O3, beneficial, detrimental
b) O3, detrimental, beneficial
c) O3, detrimental, detrimental
d) O2, beneficial, detrimental
e) O2, detrimental, beneficial

11- The primary source of man-made SO2 is _____; it harms people, animals, vegetation, and material through the formation of _____.
a) Gasoline burning, nitric acid
b) Hot springs, sulfuric acid
c) Coal burning, sulfuric acid
d) Coal burning, hydrocarbons
e) Automobiles, smog

12- The source of geothermal energy is
a) Radioactive decay of elements below the earth's crust
b) Heat still left from the time when the earth was formed
c) Chemical reactions among gases trapped below the earth
d) Underground nuclear explosions
e) Both a and b

13- Albedo is
a) The fraction of incident light that is absorbed by earth
b) The fraction of incident light that is reflected by earth
c) The fraction of incident light that is transmitted through the atmosphere and reaches earth
d) An organism exhibiting deficient pigmentation

14- The most common material used in PV modules today is
a) Single crystalline silicon
b) Polycrystalline silicon
c) Amorphous silicon
d) Cadmium telluride
e) Gallium arsenide

15- What is the fuel used in most present-day nuclear power plants?
a) Coal
b) Uranium-238
c) Uranium-235
d) Platinum-196
e) Plutonium-239

16- Alpha particles are
a) The same as nuclei of helium
b) The same as electrons
c) Electromagnetic radiation with no electric charge and no mass
d) The same as protons
e) None of the above

17- Baseload power plants are used
a) Primarily during the nighttime
b) Primarily during the daytime
c) Day and night
d) During peak times
e) During emergencies

18- Which of the following can be said about fuel cells?
a) Fuel cell is a well-developed technology with necessary infrastructure already in place.
b) Fuel cell vehicles can go thousands of miles between each charging.
c) Fuel cells are relatively cheap to manufacture.
d) Fuel cell efficiency can be higher than that dictated by the Carnot efficiency.
e) All of the above

19- The United States has a Gross Domestic Product (GDP) or Gross Domestic Income (GDI) in the order of
a) 10 billion dollars
b) 100 billion dollars
c) 1 trillion dollars
d) 10 trillion dollars
e) 100 trillion dollars

20- Sustainability implies
a) Using natural resources as slowly as possible
b) Using only as much as is replaced by natural processes
c) Not introducing new technology too quickly
d) Discovering new resources to allow maximum economic growth
e) All of the above

Appendix B- Energy and Sustainability Survey Items

Note: These items were written by the authors to complement the Life-Long Learning Scale. Students were asked to rate their responses on a 5-point scale (i.e., never, rarely, sometimes, often, and always/daily).

1. I read about energy on the Internet.
2. I listen to stories about energy on TV.
3. I listen to podcasts about energy.
4. I read about energy in printed media (books, newspapers, magazines, journals, etc.).
5. I discuss energy with my peers and friends.
6. I am active in a social networking group (Twitter, Facebook, Second Life, etc.) on energy.
7. I read about sustainability on the Internet.
8. I listen to stories about sustainability on TV.
9. I listen to podcasts about sustainability.
10. I read about sustainability in printed media.
11. I discuss sustainability with my peers and friends.
12. I am active in a social networking group on sustainability.