Live Energy: US Faculty Co-Author an Electronic Textbook to Deliver the Most Up-to-date and Relevant Content in Energy and Sustainability

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Bugrahan Yalvac is an associate professor of science and engineering education in the Department of Teaching, Learning, and Culture at Texas A&M University, College Station. He received his Ph.D. in science education at the Pennsylvania State University in 2005. Prior to his current position, he worked as a learning scientist for the VaNTH Engineering Research Center at Northwestern University for three years. Yalvac's research is in STEM education, 21st century skills, and design and evaluation of learning environments informed by the How People Learn framework.

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Emily (Binks) Cantrell, Ph.D., is a Clinical Assistant Professor of Reading and Language Arts at Texas A&M University - College Station, where she teaches both undergraduate and graduate courses in reading and ESL, co-directs the Texas A&M Reading Clinic, and also serves as the adviser for the Aggie Storytelling Association. She has published widely and presents at international conferences on a regular basis, with her most recent publication entitled "Peter Effect in the Preparation of Reading Teachers" in Scientific Studies of Reading. She is actively involved with the International Dyslexia Association, serving as a reviewer of teacher preparation programs and founding/advising the local Brazos Valley chapter. Prior to returning to A&M (where she received all three of her degrees and obtained her Reading Specialist, Master Reading Teacher, and EC-6 Generalist Classroom Teacher certifications), Dr. Cantrell lived and worked at the University of Hull in England for several years as an Assistant Professor and Research Coordinator and also taught first grade in a small, rural school district in central Texas. Outside of her work at A&M, Dr. Cantrell is also a consultant for both the Neuhaus Education Center in Houston and the Region VI Education Service Center in Huntsville. In addition to delivering professional development seminars for Neuhaus and Region VI, she serves as the Knowledgeable and Skilled Teachers of Reading (KASTOR) coordinator for Neuhaus, in which she closely mentors new teachers throughout the greater Houston area. Dr. Cantrell is a firm believer that teachers are the most powerful tool in the education system and is passionate about increasing the quality of preparation and support teachers receive in order to meet the diverse needs of their students.

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Don is a professional project manager and a licensed software engineer. He provides project management consulting and mentoring to clients across Texas A&M University. He has contributed to the University's project management methodologies, frameworks, tools, and curriculum. Don was a published game developer, with over a dozen titles ranging from Orbiter in 1985 to Harpoon 3 Professional in 2012.

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Dr. Reza Toossi is a professor of mechanical and aerospace engineering at CSULB. He received his B.S. degree from the Sharif University of Technology in Tehran, Iran, and his M.S. and Ph.D. degrees from the University of California, Berkeley. He continued his Post Doctoral research studies in the Lawrence Berkeley Laboratory and joined the CSULB faculty in 1981. Dr. Toossi has worked both as a research scientist and a consultant on various projects related to aqueous aerosols and droplets in the atmosphere, nuclear safety, sensor design, air pollution modeling, flame propagation, fluid mechanics, and fiber optics.

Dr. Toossi has successfully managed over $6 M in research contracts from various private and Government agencies, holds two patents and has published a book on energy and in various peered and refereed journals. His current research interests are in hydrogen storage systems, combustion-generated soot emission, sorption refrigeration, hybrid-electric vehicle design, and renewable energy systems.

Dr. Toossi is a member of ASME, ASEE, SAE, SPIE, AAPT, and Tau Beta Pi, and the recipient of the 2001 CSULB Distinguished Faculty Teaching, 1995 CSULB Distinguished Faculty Scholarly and Creative Achievement, and 1994/1995 TRW Excellence in Teaching awards.

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Prof. Sukesh Aghara is an Associated Professor in the Chemical and Nuclear Engineering Department at University of Massachusetts Lowell. He is a NASA Administrator's Fellow at NASA Langley Research Center (LaRC). Dr. Aghara has over 12 years of experience in development and teaching of a variety of courses in nuclear engineering and chemical engineering discipline. He was responsible for conceptualization, development and implementation of the nuclear engineering concentration and the energy engineering minor at the Roy G. Perry College of Engineering.

He has served as PI/Director of the $5 million NSF CREST Center for Energy and Environmental Sustainability, the Director for Panther Pipeline Project, Scientific Lead for the Radiation Transport Group with NASA Center for Radiation Engineering and Science for Space Exploration (CRESSE). He has been a visiting scientist to NASA LaRC and Nuclear Science and Technology Division at Oak Ridge National Laboratory. He served as a member of the ANS delegation to India for nuclear collaboration and visited French Nuclear facilities as part of a US group of nuclear engineering professor.

His research expertise includes radiation shielding analysis and experimental design, applications of nuclear analytical techniques, nuclear energy, security and safeguards.

Mr. Timothy Allen Robinson, Penn State University
Dr. Dennie L. Smith, Texas A&M University

Professor in Teaching, Learning and Culture and Education Administration and Human Development

Dr. Mehmet C Ayar, The Scientific and Technological Council of Turkey (TUBITAK)

Dr. Mehmet C. Ayar is a scientific programs expert in the Scientific and Technological Research Council of Turkey (TUBITAK). He received his Ph.D. in Curriculum and Instruction with specialization in STEM education at Texas A&M University in 2012. His research is in ethnographic studies of science and engineering practice, curriculum development, design of learning environments, and robotics activities. Dr. Ayar worked for the Live Energy Project during his Ph.D. studies at Texas A&M University. Prior to his Ph.D. studies, he worked for three years as a science teacher at a private school in Turkey.

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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 three years on three objectives. One objective was 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, have authored 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 student data. The third objective was to explore and document the characteristics of the culture emerged as our professors co-authored the textbook. In our ethnographic analyses, we utilized the notion of community of practice. In this paper, we summarize and discuss the project accomplishments, student learning outcomes, and the collaboration among the professor co-authors. 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 have co-authored 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 the 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 the 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 at the time the project was initiated and their instructional contexts are summarized in Table 1. One of our professors accepted a position at another institution.

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 (2014).*

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 Hydrocarbon Resources
Chapter 2.5 Environmental Consequences of Fossil Fuel Use
Section 3. Nuclear Energy
Chapter 3.1 Nuclear Energy Technology
Chapter 3.2 Advanced Nuclear Reactors and Future of Nuclear Energy
Section 4. Renewable Energy
Chapter 4.1 Hydro Energy
Chapter 4.2 Geothermal Energy
Chapter 4.3 Solar Thermal Energy
Chapter 4.4 Solar Photovoltaic Energy
Chapter 4.5 Wind Energy
Chapter 4.6 Bio-Energy
Chapter 4.7 Transmission for Energy Sources

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.

liquid fuels. The primary concern with the use of agricultural crops for biomass purposes is the conflict with their use as food and fodder.

Agricultural residues[3]

Crop residues such as sugarcane bagasse, orange peels, husk, etc. can be used as a source of biomass. Currently, the world produces residue biomass that could be sustainably harvested and converted into nearly 47 QUAD per y of energy. The conversion of agricultural residues to energy is extremely useful since it reduces disposal and landfilling costs while making good use of the waste. Also, there is no adverse effect on the food or fodder supply.

Animal wastes[4]

Direct burning of animal dung had been used as a source of energy for centuries. However this is considered to be polluting. Dung has been effectively used to obtain energy often by converting it to biogas. It may also be used for gasification. The suitability of the technique to obtain energy depends on the moisture content and mineral composition of the animal waste. Dry manure is usually burnt directly while wet manure is used for biogas production.

Municipal Solid Waste[5]

Disposal of this waste is becoming an issue, yet it exists in large amounts. Hence, utilization of this waste as a source of energy would be of great value. Direct incineration can release pollutants such as Poly Aromatic Hydrocarbons (PAHs), Poly chlorinated Biphenyls (PCBs), dioxins, carbon monoxide, etc. However, it can be converted into a form called refuse derived fuel, which has high energy density and is less polluting on combustion. It can also be used effectively for co-firing and pyrolysis along with coal.

Landfill gas

Large amounts of organic matter are often disposed by the technique of land filling. This organic matter can decompose over time. As the decomposition occurs, gases such as methane are generated. If these gases get released into the atmosphere they can have adverse effects. On the other hand, a careful utilization of these gases can make available a useful source of power. Landfill gas (LFG) is typically made up of 50 percent methane (CH4) and 50 percent carbon dioxide (CO_2), with small amounts of non-methane organic compounds. The quality of this gas can be affected by a number of different factors such as the quantity of waste in the landfill, the decomposition rate, the type of waste, the moisture levels and the air temperature.

Photographs of various biomass feedstock are shown in Figure 2. Figure 3 shows the analysis of typical biomass species.

Figure 2

Various types of biomass. [Courtesy of Sarma Pisupati]

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Figure 1. A screenshot from the Live Energy iBook (2014)

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.

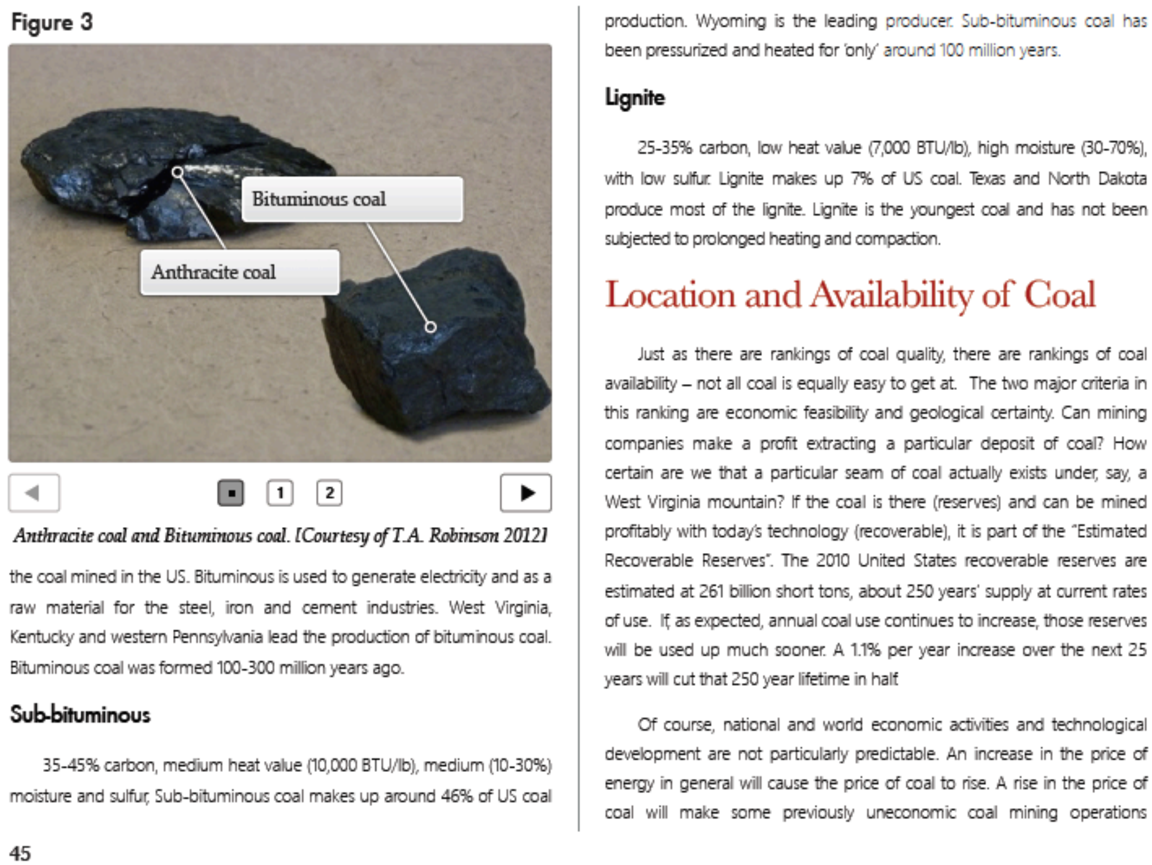

Figure 3

Anthracite coal and Bituminous coal. [Courtesy of T.A. Robinson 2012]

the coal mined in the US. Bituminous is used to generate electricity and as a raw material for the steel, iron and cement industries. West Virginia, Kentucky and western Pennsylvania lead the production of bituminous coal. Bituminous coal was formed 100-300 million years ago.

Sub-bituminous

35-45% carbon, medium heat value (10,000 BTU/lb), medium (10-30%) moisture and sulfur, Sub-bituminous coal makes up around 46% of US coal production. Wyoming is the leading producer. Sub-bituminous coal has been pressurized and heated for 'only' around 100 million years.

Lignite

25-35% carbon, low heat value (7,000 BTU/lb), high moisture (30-70%), with low sulfur. Lignite makes up 7% of US coal. Texas and North Dakota produce most of the lignite. Lignite is the youngest coal and has not been subjected to prolonged heating and compaction.

Location and Availability of Coal

Just as there are rankings of coal quality, there are rankings of coal availability – not all coal is equally easy to get at. The two major criteria in this ranking are economic feasibility and geological certainty. Can mining companies make a profit extracting a particular deposit of coal? How certain are we that a particular seam of coal actually exists under, say, a West Virginia mountain? If the coal is there (reserves) and can be mined profitably with today's technology (recoverable), it is part of the "Estimated Recoverable Reserves". The 2010 United States recoverable reserves are estimated at 261 billion short tons, about 250 years' supply at current rates of use. If, as expected, annual coal use continues to increase, those reserves will be used up much sooner. A 1.1% per year increase over the next 25 years will cut that 250 year lifetime in half

Of course, national and world economic activities and technological development are not particularly predictable. An increase in the price of energy in general will cause the price of coal to rise. A rise in the price of coal will make some previously uneconomic coal mining operations

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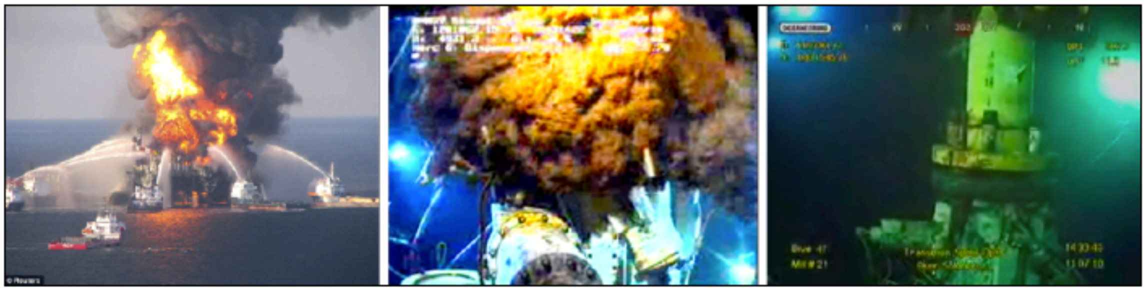
Figure 2. A screenshot from the Live Energy iBook (2014)

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 25



Burning drill rig following well blowout, view of oil flowing out of the subsea wellhead one mile below sea level, successful subsea cap that permanently stopped flow from the well. [Courtesy of U.S. Coast Guard]

In 1989 a drunken captain ran the Exxon Valdez tanker into an iceberg near Valdez, Alaska, spilling 45,000 barrels (Figure 27). The damage from this spill was more difficult to clean up than that from the Macondo well, even though the latter was a 100 times greater volume, at least in part due to colder temperature. While some fish and wildlife have recovered essentially to their status before the fill, others still have not (http://www.evostc.state.ak.us/recovery/status.cfm).

People cause most of the actual environmental damage from hydrocarbons through two mechanisms: air pollution, and consumer product wastes. Regarding air pollution, the gasoline and diesel burned in internal combustion engines in trains, trucks, and personal vehicles account for 66% of all carbon monoxide, 38% of all nitrogen oxide, 26% of all volatile organic compounds, and 30% of all carbon dioxide emitted into the atmosphere in the US.

Plastic and other petrochemical products provide inexpensive and virtually indestructible materials for many uses. Plastic provides airtight packaging often worth more than the contents inside it. After the contents are consumed, the packaging becomes solid waste that is not biodegradable and ends up as litter or in landfills (Figure 28). Like the aluminum used to package many beverages, plastic can be recycled, and many communities support recycling operations to reduce solid waste buildup in landfills. However, as a natural resource, aluminum is far scarcer than petroleum, and recycling aluminum is cost effective. In most regions, petroleum is cheaper and more energy efficient to use for petrochemical product development than recycled plastic.

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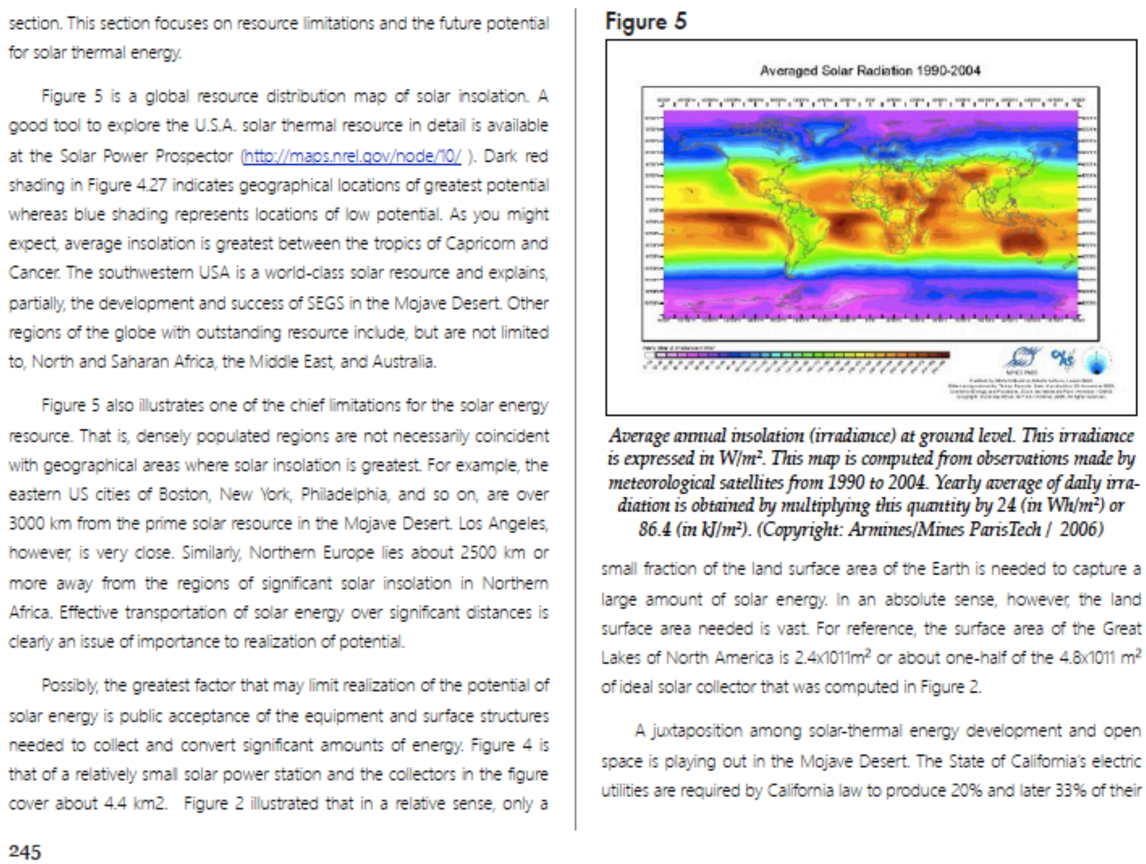
Figure 3. A screenshot from the Live Energy iBook (2014)

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



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 more away from the regions of significant solar insolation in Northern Africa. Effective transportation of solar energy over significant distances is clearly an issue of importance to realization of potential.

Possibly, the greatest factor that may limit realization of the potential of solar energy is public acceptance of the equipment and surface structures needed to collect and convert significant amounts of energy. Figure 4 is that of a relatively small solar power station and the collectors in the figure cover about 4.4 km2. Figure 2 illustrated that in a relative sense, only a

Figure 5

Average annual insolation (irradiance) at ground level. This irradiance is expressed in W/m². This map is computed from observations made by meteorological satellites from 1990 to 2004. Yearly average of daily irradiation is obtained by multiplying this quantity by 24 (in Wh/m²) or 86.4 (in kJ/m²). (Copyright: Armines/Mines ParisTech / 2006)

small fraction of the land surface area of the Earth is needed to capture a large amount of solar energy. In an absolute sense, however, the land surface area needed is vast. For reference, the surface area of the Great Lakes of North America is 2.4x1011m² or about one-half of the 4.8x1011 m² of ideal solar collector that was computed in Figure 2.

A juxtaposition among solar-thermal energy development and open space is playing out in the Mojave Desert. The State of California's electric utilities are required by California law to produce 20% and later 33% of their

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Figure 4. A screenshot from the Live Energy iBook (2014)

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 explored 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 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' new media skills (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. The interactive textbook was implemented in the participating campuses during 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 serves 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) were collected from different students. To reduce the impact of individual student differences, we collected control data as many as times as we could, so that we could investigate the individual student differences and take these differences into account during the final analysis.

Over the course of the project activities, we observed our professors' interactions and interviewed them one-to-one in order to explore the characteristics of the culture emerged as they co-authored the ebook. Because the project activities our professor accomplished were quite novel, exploring and documenting the characteristics of their interaction and the culture emerged are insightful for future research in engineering education. It is not common for university engineering faculty to co-author an e-book with dynamic content embedded, and more importantly, accomplish this with limited or no input from a commercial publisher.

Student Learning Outcomes

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 prototype iBook and its analog eBook pdf was used in four of the five collaborating universities in spring 2013. Use of the iBook and eBook prototypes enabled data collection suitable for comparing student content learning, life-long learning skills, attitudes, and experiences with use of the iBook and eBook platforms. Preliminary analysis of these data shows that there were no significant differences in growth between the control (traditional textbook) and experimental (e-textbook) groups. In fact, the only survey scores that resulted in statistically significant differences pre and post semester were that of the Energy and Sustainability Survey (see Table 5), although, again, the growth (albeit significant across the semester) was not significantly different between the control and experimental groups. In a further analysis, we looked specifically at those students who were able to view the e-book via the iBook platform (thus, with the capability to use all of the interactive features). The iBook users followed the same patterns as the control and experimental (all users) groups on the Energy & Sustainability Survey as well as the Lifelong Learning Survey. However, unlike the control and experimental (all users) groups, the iBook users did have significant growth across the semester on the Engineering Attitude Survey. Unfortunately, the growth was negative. It is important to note that over half of the iBook users were education majors at one of the universities in the study (who had received iPads as part of their education program), so these results could be biased.

Table 5. *Pre and Post Test Survey Means and Standard Deviations of Control and Experimental Groups.*

Instrument	Control Pre-Test [m(sd)] (n=480)	Control Post-Test [m(sd)] (n=480)	Experimental (all users) Pre-Test [m(sd)] (n=316)	Experimental (all users) Post-Test [m(sd)] (n=316)	Experimental (iBook users only) Pre-Test [m(sd)] (n=76)	Experimental (iBook users only) Post-Test [m(sd)] (n=76)
Energy & Sustainability Survey (1-never – 5-	2.16 (0.98)**	2.64 (1.11)**	2.17 (0.37)**	2.46 (0.39)**	2.12 (0.39)**	2.55 (0.53)**

always/daily)						
Lifelong Learning Survey (1-never – 5-always/daily)	3.54 (1.07)	3.61 (1.06)	3.48 (0.50)	3.50 (0.43)	3.46 (0.53)	3.44 (0.46)
Engineering Attitude Survey (1-most positive – 5-most negative)	2.27 (0.63)	2.23 (0.65)	2.46 (0.49)	2.47 (0.45)	2.58 (0.55)*	2.51 (0.49)*

*Significant difference pre v. post test ($p<.005$).
**Significant difference pre v. post test ($p<.001$) (*negative* growth).

Over time, the faculty collaboration process has improved and provides a positive example of a successful virtual collaboration. Successful on time delivery of the online textbook has demonstrated the effectiveness of the online collaboration approach, along with its evolution over time in response to formative research observations. Finally, adoption of the online textbook and its influence on the introduction of new ES courses is expected to further endorse its value and the inherent value of online collaboration and collaborative textbook development.

Observations about student learning varied depending on the measure. The comparison of student questionnaire responses before and after the iBook and eBook introductions suggest that while the impact on content learning and attitudes about engineering were essentially the same, students' perceptions of the e-book were fairly neutral, slightly favorable, with little deviation. Technological difficulties did not appear to be a major issue. However, over half of the students viewed the book in PDF rather than via iBooks, so they therefore may not have been able to utilize all of the interactive features. We thus decided to compare the perceptions of those who used iBook versus those who did not (e.g., just used the PDF). Analyses revealed that those who used iBook had statistically significantly higher perceptions of the e-book on all items as compared to those who did not use iBook (see Table 6). There was no significant difference in technological problems (see Figure 5). It appears that interactive features of the iBook that are not available in the PDF form play a measureable role in students' perceptions of the eBook.

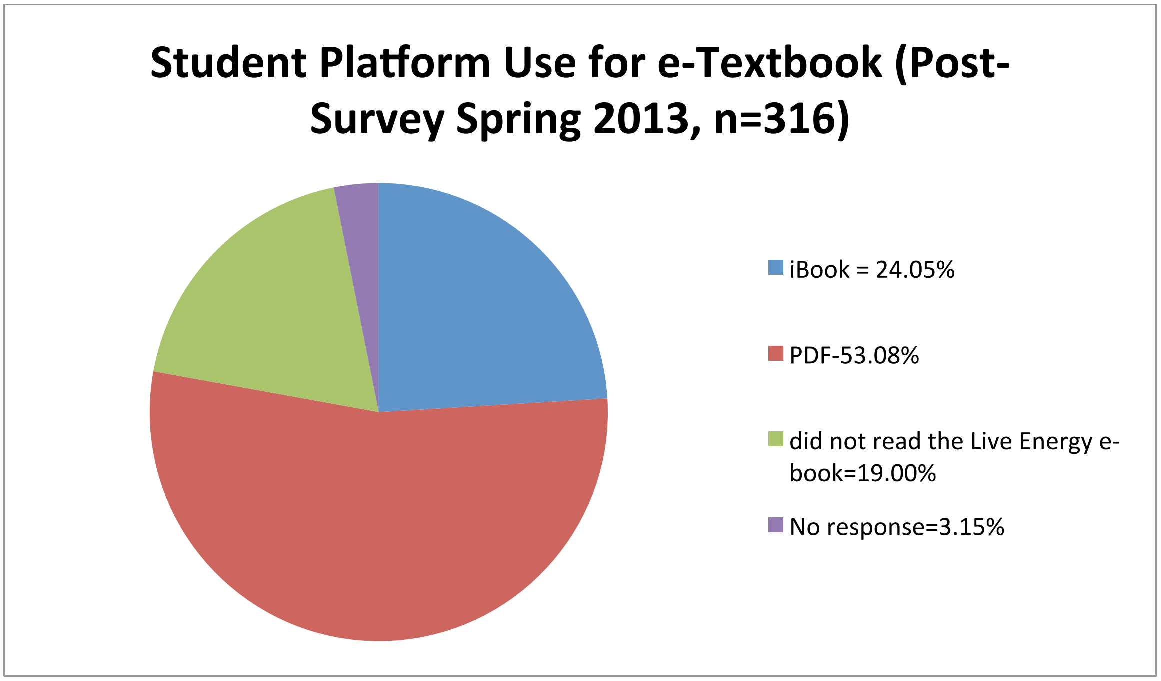
Table 6. *Student Perceptions of e-Textbook (Post-Survey Spring 2013).*

Item	Mean (Standard Deviation) for All Participants (n=316)	Mean (Standard Deviation) for iBook Users (n=76)	Mean (Standard Deviation) for non-iBook users (n=240)
Please rate your overall experience with the Live Energy e-book in this course this semester.	3.34 (0.85)	3.64 (1.07)**	3.24 (0.74)**

(1-strongly disliked, 3-neutral, 5-strongly liked)			
I prefer the Live Energy e-book to a more traditional textbook. *(1-strongly disagree, 3-neutral, 5-strongly agree)*	3.21 (1.09)	3.63 (1.19)***	3.07 (1.02)***
My experience with the Live Energy e-book was better than my experience with other e-books I have used. *(1-strongly disagree, 3-neutral, 5-strongly agree)*	3.28 (0.82)	3.53 (0.97)**	3.20 (0.75)**
I experienced technological difficulties with the Live Energy e-book. *(1-never, 2-rarely, 3-occasionally, 4-often, 5-most of the time)*	2.23 (1.02)	2.30 (1.03)	2.20 (1.01)
I believe my learning in this course was enhanced because of the Live Energy e-book. *(1-strongly disagree, 3-neutral, 5-strongly agree)*	3.26 (0.85)	3.49 (0.97)*	3.19 (0.79)*

*Statistically significant difference between groups (ibook v. non-ibook users) at p<.01.
**Statistically significant difference between groups (ibook v. non-ibook users) at p<.005.
*** Statistically significant difference between groups (ibook v. non-ibook users) at p<.001.

Figure 5.



Virtual Community of Practice

An interesting aspect of the Live-Energy project is that the entire effort has been conducted through virtual meetings. The project team consists of professors who have never met face-to-face. The project manager set up online collaborative environments starting with writing the NSF CCLI proposal and continuing even today with teleconferences focused on finding a publisher to commercialize the eBook.

To explore the professors' experiences in coauthoring the eBook and the culture emerged through their participation, we conducted a qualitative case study[16, 17]. We recorded the weekly project meetings where the professors interact and perform most of their project communication and decide on their individual as well as group tasks. We analyzed the selected meetings' transcriptions. We also talked to professors one-to-one and ask them open-ended questions about their experiences with the project activities. The interview transcriptions were analyzed and merged with the weekly meeting analyses' findings. We sought to answer the extent to which the culture of the five engineering professors coauthoring an eBook on energy and its sustainability topics could be characterized as a community of practice [18,19]. The design of this qualitative case study is reported elsewhere[20]. Here we provide a summary of the findings.

Our five professor participants developed a joint enterprise, shared language, and individual identities as they participated in weekly meetings. The virtual collegial participation in the weekly meetings became the cultural norm that each professor became accustomed to and that bound them together as a team.

We observed that the norms of the professors' participation in the weekly meetings were similar to the norms of other academic settings. Professors respected other's opinions and provided constructive feedback to each other's ideas. In turn, they were encouraged to contribute and discuss the technical, social, and epistemic aspects of the eBook.

The pre-defined goal early in the project was to co-author an online textbook on energy sustainability. Over time, this joint enterprise evolved. Professors decided to publish the book on an eBook reader (e.g., Kindle or iPad) that would be more convenient to read. Most recently, iBook Author was used to publish the book. A team of technology experts designed the iBook and the professors provided the content. Another goal that emerged was to sustain the book after the project funding ended. For this purpose, our team is negotiating with publishers to help sustain the authorship and the dynamic characteristics of the eBook content.

As a group, the professors became accustomed to using several technological tools and methods in the community. These common tools and methods helped to develop a shared repertoire and a common language. Among these tools and methods were the content questionnaire organization and administration techniques, the unique communication technique in Adobe Connect, and engineering problem solving techniques.

As they continued to write a draft for the eBook, the professors had difficulties with the technical and social dimensions of coauthoring practice. We conceive of these difficulties as the resistance on their way to reach their goal. Their mutual interaction through the Adobe Connect was a way to resolve these difficulties because different ideas, comments, and experience were shared and negotiated to do so. In addition, the professors had problems or concerns in regard to administering and collecting student questionnaires because each institution had different technologies and techniques. Ultimately, a technique for administration and collection of the questionnaire emerged from the community naturally as they shared and negotiated their ideas and experience. Recently, all student surveys and questioners were administered online and the data were collected electronically without any paper copy.

The professors brought their engineering problem solving expertise into the project activities. The content of the eBook included chapters devoted to a variety of energy-related topics (e.g., coal, hydro, solar, wind, and nuclear) and sustainability. Thus, an early and primary concern for the professors was consistency of treatment of the topics within the chapters they were expected to write. Their solution was to apply a common scientific problem solving process to the task. They first identified the problem, which was attributed to the content of each chapter and technical aspects (template, formatting, figures or formulas). The second step was to discuss possible solutions (e.g., preparing a template that every faculty would use to write their chapter), and finally, to choose the best among the possible solutions in order to proceed.

The professors' individual identities developed over the course of the project and was most observable in obtaining of IRB forms and administration of the surveys to students in five different institutions by professors with different frames of reference regarding their individual institutions, their own students, and their experience backgrounds as researchers. We interpreted that one of the professors' individual identity influenced her pedagogical practice. She treated her students as reliable and honest when they were asked to complete the questionnaires and did not want to administer the questionnaires in class and thus limit the time to complete them.

Another professor's individual identity was associated with her experience as a scientific researcher. From her perspective safety of data coming from the students was a credential to perform scientific research. She viewed such safety as essential to establishing reliability and validity of the data collection instruments and ensuring credibility of the study.

Overall this study showed that a virtual community of practice was emerged as our professor participants performed their project activities. We were able to capture and document the co-authors' evolved goals, joint enterprise, shared language, and individual identities[18,19]. Portrayal of these "community of practice" elements explains that our professors' interactions were sufficiently genuine and authentic to develop and operationalize new practices, norms, and techniques within the context.

Conclusions

This project included three research studies: one study looked at the collaboration experience among the professors in creating an eBook; another study analyzed impacts of the eBook on student learning; and the third study related to the experience of developing the eBook entirely with virtual meetings by teleconference and the use of online collaborative environments.

The one on faculty collaboration should address the following points:

- Study approach
- Collaboration approach
- Success demonstrated by book product

To analyze the impacts of the e-textbook on student learning, we used four surveys to assess students both prior to using the e-textbook and after using the e-textbook for one full semester: (1) a researcher-developed questionnaire containing 20 multiple-choice items designed to assess content understanding, (2) Wielkiewicz and Sinner's Life-Long Learning (LLL) scale to assess life-long learning skills through 16 items with a five-point Likert scale, (3) the Engineering Attitude Survey (EAS) developed by Robinson et al. to assess attitudes towards engineering through 25 items with a six-point Likert scale, and (4) a researcher-developed six item survey with a five-point Likert scale to assess new media skills. According to our baseline data from the pre and post semester survey results (Spring 2011-Spring 2012), instruction ***without*** the e-textbook did not result in significant change in students' content understanding, skills, or attitudes pertaining to energy and engineering; we had hoped that after implementation of the e-textbook that this lack of growth would change. From the baseline data, we also found there were no institutional differences, which provided some evidence that the students' respective universities was not a significant effect on their survey performance. With our post intervention data, we found most measures still showed no significant growth in students' content understanding, skills, and attitudes from the beginning to the end of the semester, even ***with*** the implementation of the e-textbook. The only survey scores that resulted in statistically significant differences pre and post semester were that of the Energy and Sustainability Survey, although the growth (albeit significant across the semester) was not significantly different between the control and experimental groups. When comparing the perceptions of those who used iBook versus those who did not (e.g., just used the PDF), analyses revealed that those who used iBook had statistically significantly higher perceptions of the e-book on all items as compared to those who did not use iBook. It appears that interactive features of the iBook that are not available in the PDF form play a measureable role in students' perceptions of the e-textbook. Interestingly, iBook users, who represented all of the education students who took the course and who also represented a large fraction of the students who used the iBook, did have significant negative growth across the semester on the Engineering Attitude Survey. The e-textbook holds an advantage over traditional textbooks that is particularly important in the engineering courses that involve dynamic content in that university faculty and curriculum developers can create online and dynamic course materials that can be updated easily and frequently as needed.

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 addressing similar learning outcomes.

The qualitative research on the interaction among the Live-Energy project team has shown that our professor participants developed a joint enterprise, a shared language, and individual identities, all of which are characteristics of a community of practice. Our professors were able to accomplish not only their mutual goal over the course of the project activities but also acquire new skills and knowledge to perform their tasks.

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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) O_3, beneficial, detrimental
b) O_3, detrimental, beneficial
c) O_3, detrimental, detrimental
d) O_2, beneficial, detrimental
e) O_2, detrimental, beneficial

11- The primary source of man-made SO_2 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.