AC 2012-3161: A HOLISTIC VIEW ON HISTORY, DEVELOPMENT, ASSESSMENT, AND FUTURE OF AN OPEN COURSEWARE IN NUMERICAL METHODS

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Autar Kaw is a professor of mechanical engineering and Jerome Krivanek Distinguished Teacher at the University of South Florida, USA. He holds a Ph.D. in engineering mechanics from Clemson University. His main scholarly interests are in engineering education research methods, open courseware development, bascule bridge design, body armor, and micromechanics of composite materials. With major funding from the U.S. National Science Foundation, he is the lead developer of award-winning online resources for an undergraduate course in numerical methods (http://numericalmethods.eng.usf.edu). He is the recipient of the 2011 ASEE Outstanding Teaching Award and the 2004 U.S. Florida Professor of the Year Award from the Council for Advancement and Support of Education (CASE) and the Carnegie Foundation for the Advancement of Teaching (CFAT). He has authored several textbooks on subjects such as composite materials, numerical methods, matrix algebra, and computer programming.

Dr. Ali Yalcin, University of South Florida

Ali Yalcin is an Associate Professor at the Industrial and Management Systems Engineering Department. His research interests include systems modeling, analysis and control, production planning and control, industrial information systems, data analysis and decision support in healthcare, and engineering education research. He teaches courses in the areas of systems modeling and performance analysis, information systems design, production planning, facilities design, and systems simulation. He is also the co-author of the Design of Industrial Information Systems textbook which was awarded the 2007 IIE/Joint Publishers Book-of-the-Year Award.

Dr. Gwen Lee-Thomas, Old Dominion University and Quality Measures, LLC

Gwen Lee-Thomas, Ph.D., is currently serving as the Assistant to the President and Provost for Special Projects at Old Dominion University and CEO of Quality Measures, LLC. Lee-Thomas has been an external consultant for more than 13 years, serving businesses as well as two- and four-year private and public colleges and universities in the states of Washington, California, Florida, Indiana, Illinois, Nebraska and Virginia in diversity, STEM education, organizational culture, and leadership strategies. Gwen has conducted more than 30 workshops and presentations on cultural, racial, and generational diversity; assessment, evaluation, and accreditation; teaching and learning; and leadership.

Lee-Thomas teaches organization administration and culture and the project management capstone course as an Adjunct at Old Dominion University in the graduate program of the Darden College of Education. Prior to ODU, she was the Executive Assistant to the President from 2004 2005 and Director of Assessment from 1998 through 2004 at Rose-Hulman Institute of Technology, a small private STEM college in Indiana. She has also served as an editorial associate of a literary journal and office manager of a multimillion dollar construction company. Additional teaching experiences have included Career Switchers of the U.S. Department of Education and the Diversity Instituteboth of which are housed at Old Dominion University.

Lee-Thomas's leadership service has included State Board Chair of the Indiana Minority Health Coalition, which is a legislated grassroots organization that provides education, advocacy, and research to eliminate health disparities among minority populations in the state of Indiana; and Commissioner on the Indiana Commission for Higher Education appointed by the late Governor Frank O'Bannon.

Other service has included serving on the community relations board for the U.S. Penitentiary of Federal Bureau of Prisons, the United Way Grants Sub-Committee of Vigo County, and Academic Business Council of the Greater Terre Haute Chamber of Commerce in Indiana.

Dr. Duc T. Nguyen, Old Dominion University

Duc T. Nguyen (http://eng.odu.edu/cee/directory/dnguyen.shtml) has been a civil engineering faculty member at Old Dominion University (ODU) since 1985. His teaching activities (including his four textbooks, published in 1999, 2002, 2006, and 2010, respectively), research works with more than 150 published articles (in referred journals, conference proceedings, and technical reports), and funded projects (approximately $3.5 million funded projects, from various government research laboratories, industrial sectors, and universities) in numerical methods, large-scale parallel algorithms and software developments, finite element analysis and optimal design, and linear/nonlinear equation and Eigen-solutions have led to several international (1989 Cray Research, Inc. GigaFlops Award), national (NASA Langley Research Center Tech Brief Award, in 1993; Recipient of NASA-ASEE Summer Faculty Fellowship Awards [11 summers]), and regional awards (A. Rufus Tonelson Distinguished Faculty Award, in 2001; ODU Shining Star Award, in 2010; and ASCE Faculty of the Year Award, in 1990).

Nguyen has been added to the ISIHighly Cited.com's list of most highly cited engineers/researchers. Individuals on the list are the most highly cited within each category (such as engineering, life science, medicine, physical sciences, and social sciences) for the period 1981-1999, and comprise less than one-half of one percent of all publishing researchers in the world.

As a Senior Investigator of the (already completed) NSF educational grant (Aug. 2004 Aug. 2007) and two on-going STEM educational grants, as a PI (Feb. 2009 July 2011) and Co-PI (June 2008 Dec. 2012), respectively, Nguyen's team has developed the Stiffness Matrix Method (SMM) modules on the internet for teaching purposes, which includes theoretical, computer simulation, and computer self-assessment test (with automated grading test scores, delivered to students by emails). More details can be found at http://www.lions.odu.edu/˜amoha006. Preliminary results for Game-Based Learning (GBL) for reordering, and symbolic factorization phases of Simultaneous Linear Equations (SLE) can be viewed/played at http://www.lions.odu.edu/˜amoha006/Fillinterms/FILLINTERMS.html, and also at http://www.lions.odu.edu/˜skadi002 (then SELECT/click CEE-305, and view the YOUTUBE Lectures #23, #25).

Practical/large-scale applications of parallel-sparse matrix computation in computational biology, finite element numerical modeling of oceans, etc. have also been considered as areas of interests by Nguyen's Multidisciplinary Parallel-Vector Computation Institute's research activities in the past recent years.

Dr. Melinda R. Hess
Dr. James A. Eison, University of South Florida
Prof. Ram Pendyala, Arizona State University

Ram Pendyala is a professor in the School of Sustainable Engineering and the Built Environment at Arizona State University. He specializes in transportation systems engineering and has published extensively on topics related to the planning, operation, and design of various modes of transportation. His professional activities include service on several journal editorial boards, leadership of committees for the Transportation Research Board and the American Society of Civil Engineers, and organization of international conferences related to sustainable transport development. He is also involved in the implementation of new pedagogical techniques and web-based resources for instruction in courses on numerical methods for engineers. He has his Ph.D. in civil engineering from the University of California, Davis.

Prof. Glen Howard Besterfield, University of South Florida

Glen Besterfield has been a faculty member of the Department of Mechanical Engineering at USF for 23 years. He received his B.S. degree from the Missouri University of Science and Technology, M.S. degree from Purdue University, and his Ph.D. from Northwestern University, all in mechanical engineering.

During his tenure in mechanical engineering at USF, he performed research in the areas of computational mechanics and numerical methods, bascule bridges, and rehabilitation engineering, all of which has been funded via NSF, AFOSR, and the Florida Department of Transportation, among others. Further, Besterfield has also co-written a book entitled "Total Quality Management" in the 3rd Edition published by Prentice-Hall.

In 2005, Besterfield assumed the position of Associate Dean for Undergraduate Studies at USF. In this role, Besterfield supervised many different units and initiatives: retention initiatives and accountability; academic enrichment center for student athletes; university-wide tutoring and earning services; freshman and transfer student orientation; all academic advising, including the transitional advising center; university experience, college preparatory and academic support courses; first generation access programs; pre-collegiate programs; and tracking the academic progress of students.

In early 2010, Besterfield was appointed the Center Director and Executive Academic Director for INTO USF. As Center Director, he supervises admissions, immigration, academic credential evaluations, student support, financial operations, business operations, and marketing. In his role as Executive Academic Director, he supervises the academic programs such as Academic English, General English, and Pathways, along with the English faculty.

Dr. Corina M. Owens, Battelle Memorial Institute

A Holistic View on History, Development, Assessment, and Future of an Open Courseware in Numerical Methods

History

In 1990, the first author of this paper thought of developing MS-DOS based simulations and textbook chapters for a course in Numerical Methods. He would use Quickbasic[1] to develop the simulations and WordPerfect[2] to write the textbook. He would distribute these by US mail to various Numerical Methods instructors via 1.44MB floppy disks. This idea was pitched in a proposal to the newly established (1988) NSF Instrumentation and Laboratory Improvement (ILI) program[3] in 1990. The proposal received good reviews and but was not funded, primarily because the emphasis of the ILI program then was on hardware-oriented laboratory improvement. A resubmission of the proposal in 1991 was not funded either.

Shelving the idea for 9 years, in 2000, the first author along with the eighth author (a fellow mechanical engineering professor with a background in finite element methods and statistical analysis) applied again to get the idea funded. This time we applied to the Course, Curriculum and Innovation (CCLI) program of NSF, a program that had unfolded from the ILI program in 1999. The CCLI program "gave increased priority to testing the effectiveness of materials and practices in terms of gains in student learning"[4]. By Year 2000, much had also changed in the computational world – internet was being embraced as a means to provide information, computational packages such as Mathcad[5] were being used in engineering curriculums, Microsoft Office[6] had made keen advances in word processing and presentation software, and the Acrobat Reader[7] made reading documents accessible free-of-charge and on multiple platforms. All these advances were incorporated in the revised proposal. Again, the proposal was rejected but mainly for the lack of an assessment expert from the education field.

In April 2001, MIT announced [8] its open courseware initiative[9] where they would publish online course materials such as course syllabus, lecture notes, digital audiovisual lectures, assignments and examinations. In 2002, they published their first set of 50 courses. More than 2,000 courses have since been published. Combined with the acceptance of such ideas of open courseware and teaming with the sixth author from the College of Education at USF, a revised proposal to the NSF CCLI program was funded in 2001[10]. Since then we have received two expansion CCLI grants[11,12] and one more CCLI prototype grant[13] for the development, assessment, refinement and revision of the comprehensive open courseware for Numerical Methods. We call these resources: Holistic Numerical Methods (HNM).

Development

The topics (Figure 1) covered in the developed Numerical Methods open courseware[14] include

1. Introduction to Scientific Computing,
2. Differentiation,
3. Nonlinear Equations,
4. Simultaneous Linear Equations,
5. Interpolation,
6. Regression,
7. Integration,
8. Ordinary Differential Equations,

9. Partial Differential Equations,
10. Optimization, and
11. Fast Fourier Transforms.

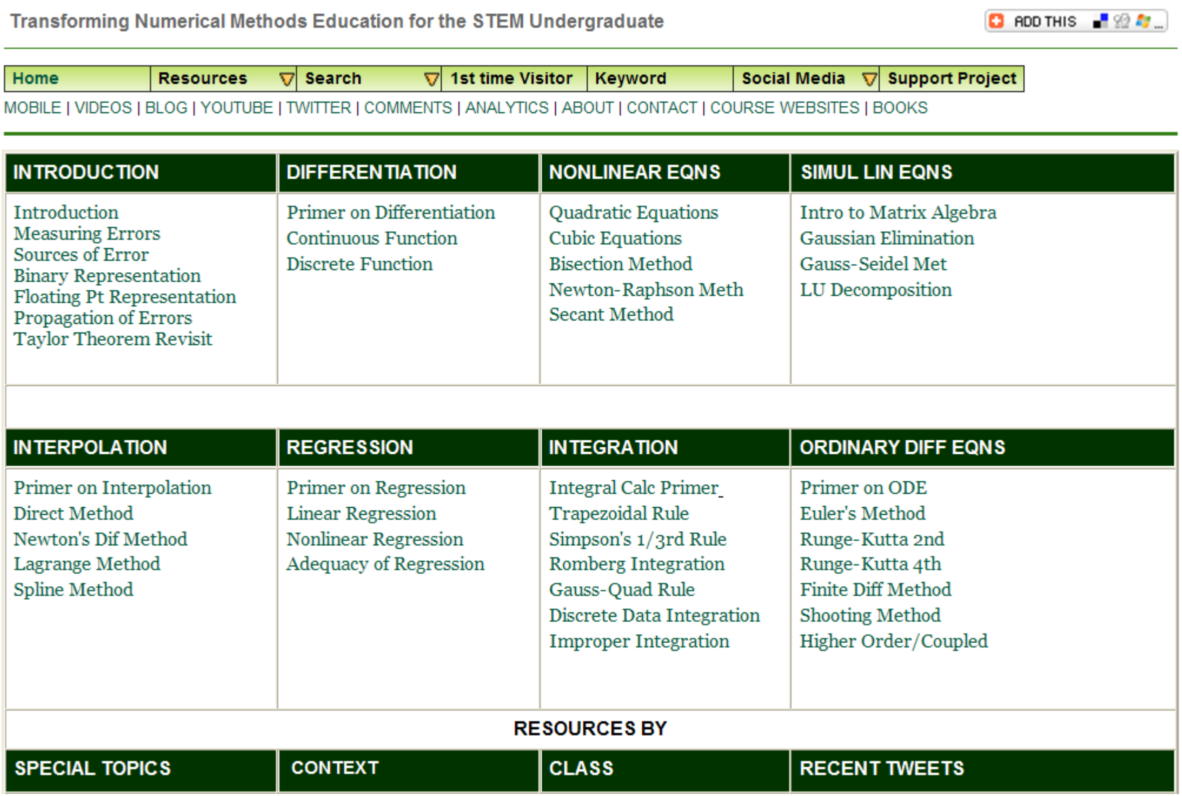

Figure 1: Home page of the Numerical Methods Open Courseware

The open courseware available at http://numericalmethods.eng.usf.edu consists of resources that are available in multiple-context and modes of access. The context items include

1. primers for pre-requisite knowledge,
2. textbook chapters,
3. digital audiovisual lectures,
4. presentations,
5. worksheets,
6. real-life applications, and
7. multiple-choice quizzes.

1. Primers for Pre-requisite Knowledge: The pre-requisite courses to a typical Numerical Methods course include the Calculus series, Ordinary Differential Equations and Programming. To make it simpler and specific for students to review the pre-requisite information, short primers have been developed for topics such as quadratic equations, Taylor series, differential calculus, integral calculus, and ordinary differential equations. These include multiple-choice questions and related audiovisual lectures.
2. Textbook Chapters: Dividing each of the 11 topics into subtopics for modular purposes, a textbook chapter has been written for each subtopic. Because of the modular nature of the HNM resources, using self-publishing[15] and semi-automated compilation programs, we have

developed customized textbooks for various programs. This has reduced the weight and cost of the textbook.

3. Digital Audiovisual Lectures: More than 300 modular digital audiovisual lectures[16, 17] (Figure 2), spanning a comprehensive course in Numerical Methods, have been uploaded to YouTube[18]. These audiovisual lectures work seamlessly with mobile devices such as smartphones, notebooks and tablets.

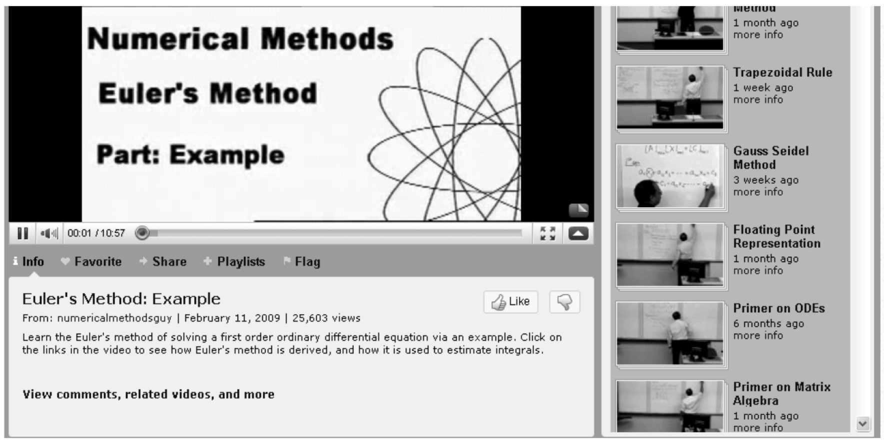

Figure 2. Home page of the Numerical Methods YouTube site.

4. Presentations: PowerPoint presentations have been developed for all topics. The examples in the presentations are based on one's major of choice so that instructors and students can quickly relate to the topic at hand.
5. Worksheets: The worksheets illustrating various numerical methods are developed in four popular computational systems – Mathcad[5], Mathematica[19], Maple[20], and MATLAB[21]. These are not simulations as we wanted to recreate hand-written solutions of numerical methods examples. But why develop the worksheets in four separate systems?
   - First, for continuity, cost, and pedagogy, a college may select and employ only one of these packages across their curriculum.
   - Second, there is no additional cost involved if a university already has a site license to just one of the four computational systems.
   - Third, given a choice, students are typically reluctant to learn a second computational system if they already know one.
   - Fourth, those motivated can use an alternate computational system to gain greater proficiency in it.
6. Real-Life Applications: Typically, when a Numerical Methods course is taught, instructors either focus on the methods while paying little attention to showing applications in the STEM majors or put most of the emphasis on solving STEM problems via computational systems while spending little time on the algorithms of numerical methods. The open courseware allows users to do both by choosing specific real-life examples to illustrate numerical methods applications and procedures from each of the engineering disciplines (other STEM disciplines choose General Engineering applications). For example, at USF, throughout the Numerical Methods course, we interweaved a single problem of shrink-fitting procedure of a bascule bridge (Figure 3)[22].

The real-life examples from different engineering majors also provide the critical cross-disciplinary opportunity for students and instructors to see how others use numerical methods.

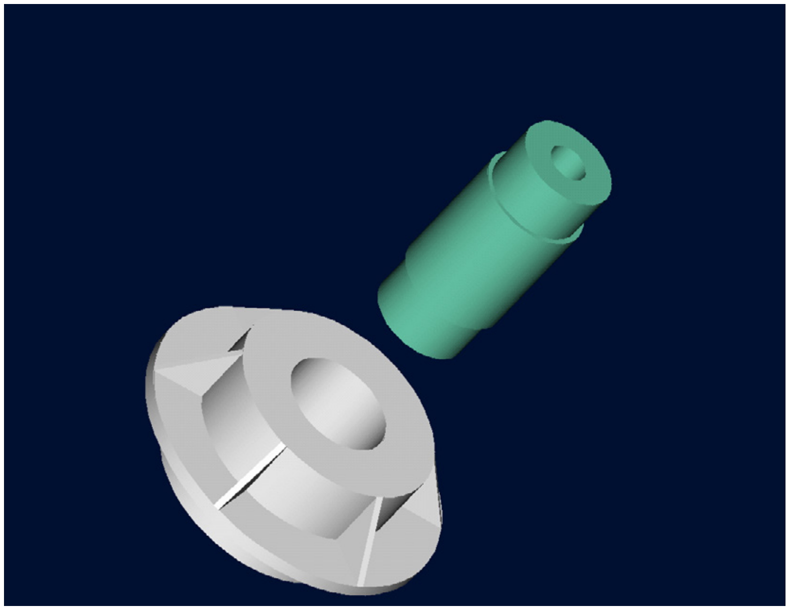

Figure 3. Real-life application of a trunnion being shrink-fitted into a hub to form the fulcrum of a bascule bridge assembly

7. Multiple-Choice Quizzes: Each sub-topic is followed by a 6-question multiple-choice quiz (Figure 4). The quizzes mostly follow the first four levels of Bloom's taxonomy[23]. The quizzes are automatically graded, and the feedback is instant. A student can take the quiz multiple times, but the questions stay the same. We are currently looking at replacing some of the questions in each quiz with algorithmic solutions which will allow random values of input variables.

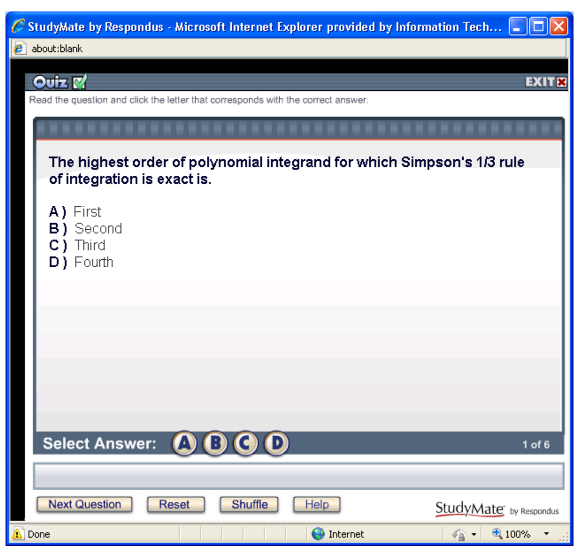

Figure 4. An example of multiple-choice quiz for self-assessment.

The access modes include resources in original software format, Acrobat reader, etc. For example, a multiple-choice quiz resource is available in four formats - MS Word, Acrobat PDF, HTML and Flash[24]. These access modes are essential in reaching a broad audience who has different levels of access to the internet and software, and to encourage re-use and re-distribution as per a Creative Commons License[25].

Implementation

The HNM resources have been adapted and implemented successfully at the University of South Florida, Old Dominion University, Arizona State University, the Milwaukee School of Engineering, and Mississippi Valley State University.. With philosophies of open dissemination and pedagogical neutrality, an additional 30 institutions and thousands of individual users have adopted the HNM resources in an *a la carte* fashion. Implementation has been done not only in STEM Numerical Methods courses, but also in other courses such as Finite Element Methods, Political Science, Linear Algebra, Psychometric Studies, and Mathematics for Economics and Business.

Assessment

The current project courseware and assessment of its impact was evaluated via a variety of satisfaction assessment and examination instruments and transparent analytics tools. Only a brief summary of the important results is provided here as detailed data and *statistical* interpretation are provided elsewhere in Refs.[26-32].

1. Quantitative Assessment Based on Bloom's Taxonomy: All students were given a multiple-choice final examination. The examination questions were not exactly the same at all four institutions because the syllabus and approach in the course differed at each institution. However, more than 50% of the questions were common on these examinations and covered both the lower-three and higher-three levels outlined by Bloom and colleagues in their classic taxonomy in the cognitive domain[23].

Statistical procedures to measure changes in instructional effectiveness from semester to semester were computed. A two-tailed t-test comparing the final examination grade of students between the two treatments of before and after implementation of the HNM resources are given in Table 1.

2. Concept Test: A concept test was used as an assessment tool to measure student learning and its improvement during the course. The concept test comprised of 16-multiple-choice questions (two from each of the eight topics covered at USF) and was given in the beginning and end of the class for three semesters at USF.

The basis of the distractors in the multiple-choice test was classroom questioning, homework assignments, and tests. This "informal approach" is the reason why we call our test a "concept test" and not a "concept inventory". Nonetheless, the concept test also does not fall in the category of a "diagnostic test" either. Our focus lied in finding how well the students understand the fundamental background concepts of numerical methods, and how much they gained in the understanding of these concepts by the end of the semester.

The improvement in students' performance between the pre-test and the post-test is summarized in Table 2. A paired t-test with $p<0.001$ indicated significant difference between the mean number of correct answers in the pre- and post-concept tests.

Table 1. Comparison of final examination results (maximum final exam score is 100) before formal implementation and after full implementation (N=number of students taking the final examination, μ=average final examination score, σ=standard deviation of final examination scores).

University	Semester before formal implementation	Semester after full implementation	Statistically Significant Improvement
USF	N=41, μ=56.4, σ=13.4	N=62, μ=69.0, σ=12.0	Yes (t(101)=4.97, p<0.01)
ODU[a]	N=51, μ=61.9, σ=8.9	N=58, μ=70.0, σ=9.3	Yes (t(107)=1.98, p<0.01)
ASU[b]		N=71, μ=70.6, σ=12.0	N/A
MVSU	N=3, μ=30.0, σ=16.6	N=5, μ=43.6, σ=16.9	Yes (by observation; small sample size)

A method to quantify student learning is to calculate the Hake's gain index[33], which is the defined as follows

$$g = \frac{\mu_{post} - \mu_{pre}}{100 - \mu_{pre}} \quad (1)$$

where

μ_{pre} = mean percentage score of the pre-test,

μ_{post} = mean percentage score of the post-test.

The Hake's gain index in Equation (1) ranges from 0 to 1, where 0 is a measure of no gain and 1 is a measure of maximum possible gain. The Hake's gain index for the three semesters was 0.36, 0.42, and 0.41, respectively, indicating increased student learning of the basic concepts.

The analysis discussed in detail in Ref[32] showed that certain subgroups' performance in the pre- and post-concepts test is significantly better than others. For example, students with prerequisite GPA≥3.0 perform better than those with prerequisite GPA<3.0, and non-adult students perform better than adult students do. The latter may be attributed to adult students having a larger time gap between taking the Numerical Methods course and its pre-requisites.

[a] Because of the philosophy of open dissemination, students had informal access to most of the HNM resources in Fall 2008 (baseline semester) at ODU before formal implementation; the post-formal implementation results are for Fall 2011.

[b] ASU already was using the textbook resources before becoming a grant partner and hence we do not have pre-implementation results. However, ASU uses almost (88% questions are identical) the same examination as USF, and their average and standard deviation results are comparable to that of USF.

Table 2. Student performance in pre- and post-concept test over three semesters at USF

Semester	Average Number of Correct Answers in Pre-test (mean/st.dev.)	Average Number of Correct Answers in Post-test (mean/st.dev.)	Hake's Gain Index
Spring 2008	8.2/2.4	11.0/2.7	0.36
Spring 2009	8.3/3.5	11.6/3.9	0.43
Spring 2010	9.2/2.6	12.0/2.2	0.41

3. Digital Audiovisual Content Assessment: To assess the effectiveness of lecture videos, a pilot study[29] was conducted at USF for a single instructional unit (Nonlinear Equations) over separate administrations (2002-06) to study four instructional delivery modalities:

Modality a: Traditional lecture (traditional face-to-face mode without benefit of web-based materials)

Modality b: Web-enhanced lecture (face-to-face mode with active learning via multiple-choice questions and small calculation questions, and benefit of supplementary web-based content)

Modality c: Web-based self-study (learning only via primary content available on the web)

Modality d: Combined web-based self-study and classroom discussion (learning via primary content available on the web outside the classroom, and followed by Q&A classroom discussion)

Videotaped topics were made available as part of the web-based content for Modalities c and d. To compare the delivery modalities, student achievement on a multiple-choice examination (part of the final examination) and a student satisfaction survey were used. We found that the use of web-based modules provides students with greater satisfaction and an enhanced likelihood to succeed in the course. Students in the Modality b cohort tended to have more favorable survey ratings as compared to the other three groups of students (Table 3) and students in the Modality b and Modality d cohorts performed consistently better on achievement measures (Table 4).

Table 3. Student satisfaction level average (maximum of 7 on scale of 1-truly inadequate to 7-truly outstanding) for different instructional delivery modalities (N=number of students).

	MODALITY			
	Modality a: Traditional Lecture (N=42)	**Modality b: Web-Enhanced Lecture (N=27)**	**Modality c: Web-Based Self Study (N=49)**	**Modality d: Combined Self Study & Class Discussion (N=56)**
Satisfaction Level Average (Standard Deviation)	4.48 (0.174)	5.80 (0.135)	4.26 (0.208)	4.66 (0.226)

Table 4. Final examination averages (maximum of 4) for different instructional delivery modalities (N=number of students).

	MODALITY			
	Modality #a: Traditional Lecture (N=42)	**Modality#b: Web-Enhanced Lecture (N=27)**	**Modality#c: Web-Based Self Study (N=49)**	**Modality#d: Combined Self Study & Class Discussion (N=56)**
Final Examination Average (Standard Deviation)	2.14 (0.814)	2.51 (1.12)	2.27 (0.953)	2.68 (1.01)

Most respondents considered use of a distance learning modality as positive, tending to cite availability of a variety of resources and flexibility as strengths of the web-based materials. Complete *statistical analysis details* and qualitative data of this assessment are available in Ref. [29].

4. Summative Course Rating: Students assessed the HNM resources using a summative rating[26] based on five critical factors – a) content, b) learning, c) delivery support, d) usability, and e) technology. For each factor, questions asked are based on technology standards and are rated on a 0-4 (Absent to Excellent) Likert scale. Average reported ratings over several semesters at USF, ASU and MSOE are given in Table 5.

Table 5. Summative open courseware rating (0-absent to 4-excellent)

SEMESTER	**USF**	**ASU**	**MSOE**
Spr 05	3.1		
Fall 05			2.5
Fall 06			2.3
Spr 07	3.1		
Fall 07			2.5
Spr 08	3.1		
Spr 09	3.1	3.2	
Fall 09			
Spr 10	3.3		

In response to qualitative questions, students liked the videos, simple "no frills" navigation, the multiple-choice tests, and access to additional examples from other engineering majors. Complete *statistical analysis details* and qualitative data of this assessment are available in Ref. [26].

5. External Evaluators: The online-developed modules were evaluated by four independent Numerical Methods instructors (Table 6). These instructors each teach a course in Numerical Methods in their respective institutions, and their years of teaching experience range from 3 to 35 years (average=19 years). They teach courses to variety of engineering majors and use different

computational software systems. The feedback received from these evaluators was incorporated in the HNM resources.

Table 6. External evaluation average rating (1-truly inadequate to 7-truly outstanding) results of HNM resources.

The HNM resources were helpful		
	as a supplement	5.7
	for class presentations	5.7
	for problem assignments	5.3
	in developing higher order thinking and problem solving skills	4.7
	for relevance to engineering major	5.7

In answers to qualitative questions, the reviewers found the HNM resources to be effective without being overwhelming. The level of presentation and choice of real-world problems were found to be very appropriate. The holistic approach was highly appreciated, as was the flexibility to choose among the sub-modules. Complete *statistical analysis details* and qualitative data are available in Ref.[26].

6. Analytics: Google analytics[34] were used to analyze the visits to the open courseware by the general user. "Google Analytics shows you how people found your site, how they explored it, and how you can enhance their visitor experience" – Google Analytics. The site has been tracked since April 2008, and it has played a key role in modifying and improving the access to the users worldwide. The following items provided by Google Analytics (Figure 5) were used in the process.

a) Top content topics: This gives the web links that are most popular with the users. The top content showed that web pages that collated all the resources for a particular numerical method on a single page were the most popular. Using this analytic result, we developed individual web pages for all the numerical methods and linked them from the home page of the open courseware.

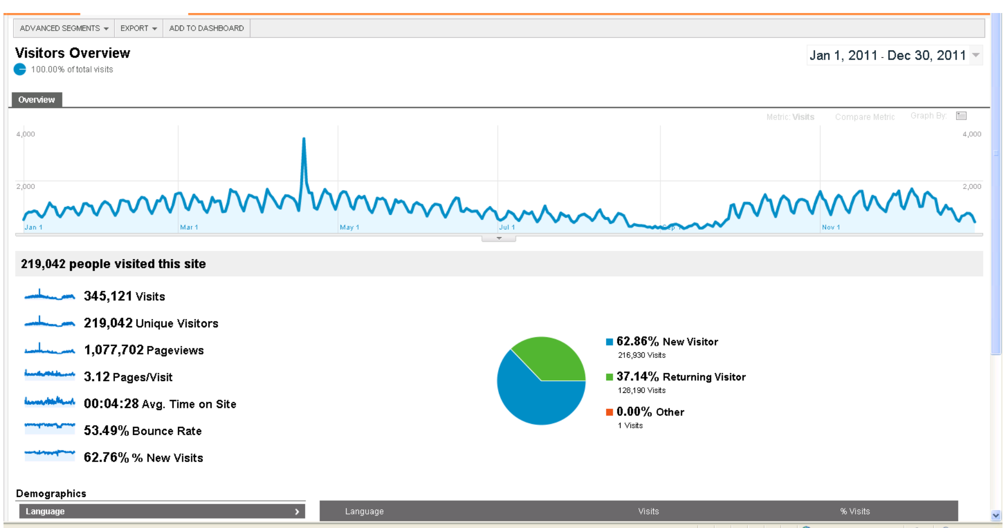

Figure 5 Google analytics report on site visitors in 2011.

b) Referring sites: This information allows finding the sites that refer to the open courseware. So far, other than search engines and direct hits, Wikipedia is the largest referring site. But what is most important is to be able to readily find institutional (.edu) sites and educational blogs that refer to the open courseware. This gives a fair idea of how and which universities are using the HNM resources, and helps us target the commercial dissemination of textbooks for self-sustaining the project.
c) Traffic Sources: The traffic sources are tracked by three categories – search engines, referring sites and direct traffic. Table 7 shows these categories by numbers for 2009 and 2011.

Table 7 Visits by traffic sources

Traffic Source	2009	2011	Change
Search Engines	124,585 (55%)	170,946 (50%)	37%
Referring Sites	60,255 (26%)	82,734 (24%)	37%
Direct Traffic	43,918 (19%)	91,440 (26%)	108%

The visits from each of the traffic sources are increasing and the direct traffic has increased by 108%, a testimony that the open courseware is being recognized as a definite source for numerical methods. In fact, for the search phrase of "numerical methods" the open courseware is ranked[c] #2 on all major search engines - Google™, Yahoo™, and Bing™ (after Wikipedia).
d) Search words: This is a set of popular search words used that send users to the open courseware. Again, these search words have been used to develop an alphabetically ordered keyword web page. This directs the users quickly to the relevant information.
e) Site Usage: Five parameters are tracked in this category and are shown in Table 8 for the 2009 and 2011.

Table 8 Change in yearly site usage

Factor	2009	2011	Change
Visits	228,758	345,121	51%
Page Views	679,262	1,077,702	58%
Pages/Visit	2.97	3.12	5%
Bounce Rate	58%	54%	-7%
Average Time	00:04:09	00:04:28	8%

From 2009 to 2011, the visits to the open courseware and page views have increased by more than 50%. The bounce rate, a measure of percentage of users leaving the open courseware for another rather than go to other pages of the open courseware, has also decreased by 7%. Users are spending 8% more time on the open courseware, although a long time is not necessarily better for a reference site.

[c] The searches were conducted on December 30, 2011.

Future of the Open Courseware
The authors are currently seeking support to adapt, implement and assess the open courseware in nine other universities, and conduct national workshops to train faculty in the use and improving of awareness of the open courseware.

The overarching question we want to answer is: "To what extent would the expansion of open courseware to the diverse institutions enhance student learning (cognitive and affective), ownership of learning, and ability to demonstrate greater competence in Numerical Methods-type courses that are critical to successful completion of STEM programs?" We also plan to create several new instructional materials to improve student learning and develop assessment tools to measure these learning gains as follows.

1. Concept Inventory: Ever since the Force Concept Inventory[35] explored the student's understanding of a first course in College Physics, concept inventories[36-38] have become a favored assessment tool in identifying students' conceptual misunderstandings and inadequacies, and in measuring student-learning gains. We are planning to develop a Concept Inventory for the course using a rigorous and well-established methodology based on Delphi methodology [39].

2. Simulations: The worksheets written in the four computational systems for the open courseware are not written to develop simulations of various numerical methods but to emulate the step-by-step procedure of the numerical methods. To develop simulations in a stable and professional environment, we have developed prototype Wolfram demonstrations[40] to simulate graphically (Figure 6) various numerical methods, and related concepts of convergence and pitfalls. These demonstrations are used in class to illustrate the workings of a numerical method and students are encouraged to use them at home while reviewing the course material. The ultimate goal of these simulations is to embed them into ebooks along with digital audiovisual lectures and interactive quizzes to develop the next generation ebooks that are free.

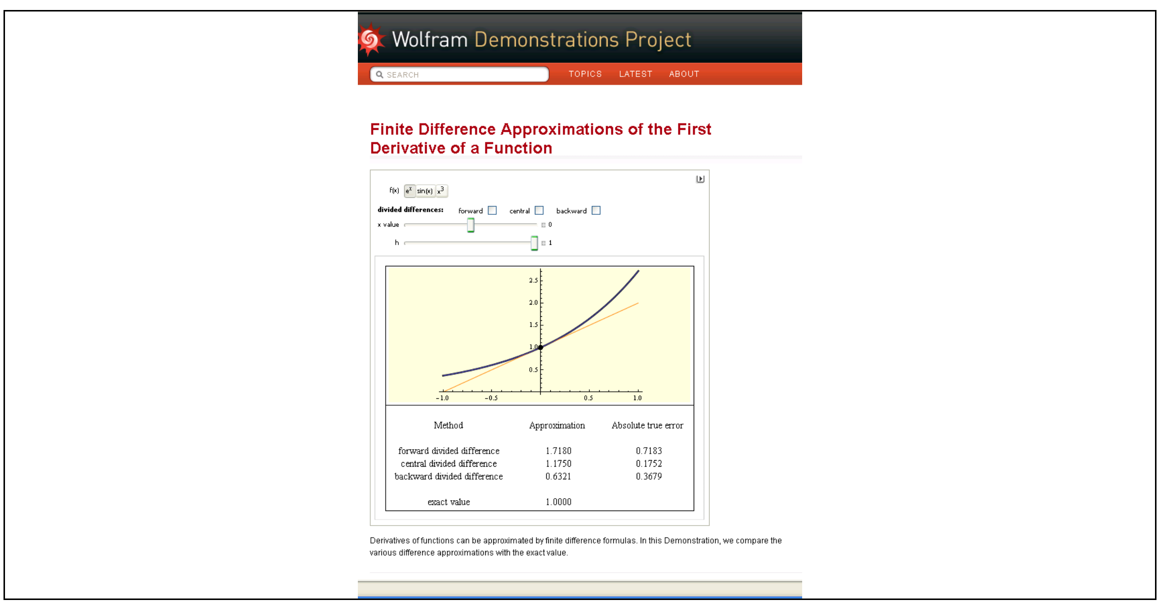

Figure 6. An example of a Wolfram Demo illustrating the approximation of the first derivative of a function.

3. Unlimited Attempts Self-Assessment Quizzes (UASQs): Self-assessment with unlimited attempts to solve problems allows students to become actively engaged with the information and their learning[41]. As a prototype, we implemented in the course-management system of Blackboard[42], three “unlimited-attempts self-assessment quizzes” (UASQ) for the topic of Simultaneous Linear Equations (SLE). Each of the 3 quizzes (Figure 7) had 6-7 questions that were of algorithmic form, which allows the instructor to choose some or all input variables to take values within a pre-determined range, and develop a formula for the correct answer.

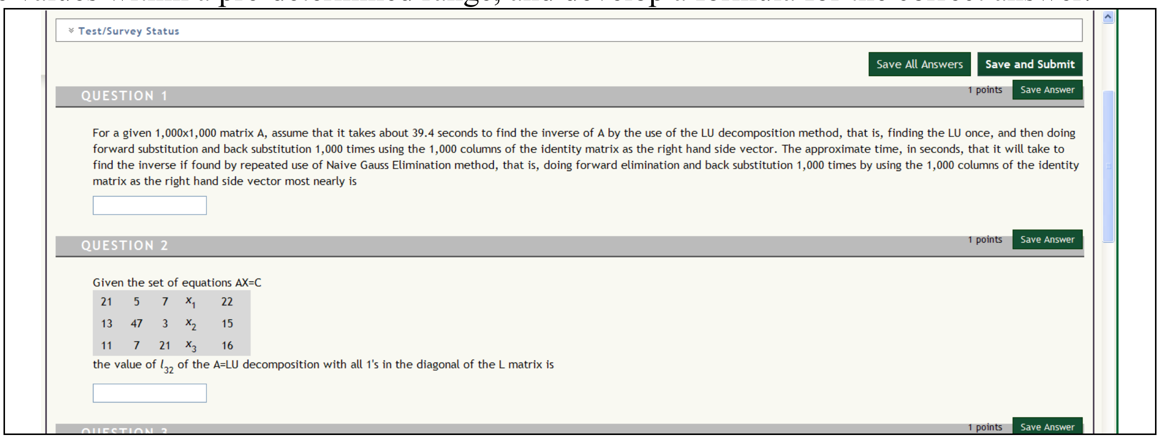

Figure 7. Unlimited self-assessment algorithmic quizzes.

When a student took the quiz, the system randomly chose the values of the selected variables, and answered the question by filling in the answer field. The student’s answer was checked against the correct value. Feedback, including the answer and its correctness, was provided immediately.

A limited amount of time (10 days from the start of the first sub-topic), but unlimited attempts to complete all three quizzes, was given. The number of attempts, the time taken, and the score for each attempt were recorded automatically by Blackboard.

To measure the effectiveness of the UASQs, the following treatments were used. For the topic of Simultaneous Linear Equations (SLE), in 2009, homework problems were assigned from the book but not collected for a grade, while in 2010, we assigned and graded (3% of overall grade) the UASQs. Under the two treatments, the scores of the SLE questions on the final examination were compiled and the results are shown in Table 9.

While the first row in Table 9 shows a notable improvement in the performance of all students in the SLE questions, we were prescriptively curious if this improvement is more pronounced for particular subgroups based on pre-requisite GPA. The high p-values indicate that the observed differences are very likely attributable to chance for the subgroup of students with pre-requisite GPA between 0.00-2.50 and 3.50-4.00. However, for the subgroup of students with pre-requisite GPA between 2.50 and 3.50 (corresponding to 62% of the entire sample), UASQs had a significant positive impact in student learning of the material related to SLEs.

Table 9. SLE final examination score (maximum score is 4) before and after implementation of UASOQs (N=number of students taking the exam, μ=average score, σ^2=variance in exam scores, p=p-value).

Pre-requisite GPA	UASQs	SLE Final Examination Scores	
All participants	Before	N=110, μ=2.7, σ^2=0.9	p=0.11
	After	N=134, μ=2.9, σ^2=0.9	
0.00-2.49	Before	N=16, μ=2.7, σ^2=0.7	p=0.57
	After	N=22, μ=2.6, σ^2=0.7	
2.50-3.50	Before	N=79, μ=2.6, σ^2=1.0	**p=0.03**
	After	N=83, μ=2.9, σ^2=1.0	
3.51-4.00	Before	N=15, μ=3.2, σ^2=0.5	p=0.44
	After	N=29, μ=3.0, σ^2=0.7	

The statistical results of the UASQ prototype study also revealed that overall students' learning styles, self-efficacy, pre-requisite grades, number of attempts, and time duration with UASQs did not have a significant relationship to the students' UASQ scores. This is possibly a positive outcome of the UASQ environment because regardless of the students pre-course disposition, they can be successful with demonstrating knowledge of SLE if they have unlimited access and time with UASQs.

Focus groups and surveys exploring the experience with the UASQs also were conducted. Overall, the students indicated that they really enjoyed working with UASQs for several reasons.

- UASQs had no time limit and, hence, there was no stress or pressure to complete the problems. This allowed the students to think through what they needed to do to complete the problem.
- UASQs were helpful in preparing the students for their exams, and the structure directed their study. They felt that they studied more than they would have without UASQs, and they enjoyed getting the immediate feedback to help with "the little things".
- UASQs helped them identify immediately what they did and did not know. This was considered important to them because when they did the UASQs they knew right away what they got right and wrong. In the traditional homework assignments, "you don't really know what you've gotten right or wrong until much later."

Based on the above observations, we are planning to develop and assess the effectiveness of these unlimited assessment quizzes for all topics of a typical course in Numerical Methods.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant Nos 0717624, 0836981, 0836916, 0836805, and the Research for Undergraduates Program in the University of South Florida (USF) College of Engineering. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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