



Comparative Assessment of Student Performance on Exams when Using On-line Homework Tools in an Undergraduate Engineering Mechanics Course

Dr. Monique H. Head, Morgan State University

Dr. Monique Head is an assistant professor in the Department of Civil Engineering at Morgan State University in Baltimore, Md. She earned her bachelor and master of civil engineering degrees from the University of Delaware in 2000 and 2002, respectively, and her doctorate in structural engineering from the Georgia Institute of Technology in May 2007. Her research and teaching interests include experimental testing, detailed analytical modeling using state-of-the-art software to study the responses of bridges, structural dynamics, bridge engineering, performance-based bridge design using AFRP composite materials, reinforced concrete design, seismic retrofitting of bridges, and engineering education. Dr. Head is a member of several national professional organizations, and enjoys facilitating engineering outreach activities for K-12 students to stimulate an excitement for science, technology, engineering and mathematics (STEM).

Dr. Oludare Adegbola Owolabi PE, Morgan State University

Dr. Oludare Owolabi, a professional engineer in Maryland, joined the Morgan State University faculty in 2010. He is the assistant director of the Center for Advanced Transportation and Infrastructure Engineering Research (CATIER) at Morgan State University and the director of the Civil Engineering Undergraduate Laboratory. He has over eighteen years of experience in practicing, teaching and research in civil engineering. His academic background and professional skills allows him to teach a range of courses across three different departments in the school of engineering. This is a rare and uncommon achievement. Within his short time at Morgan, he has made contributions in teaching both undergraduate and graduate courses. He has been uniquely credited for his inspirational mentoring activities and educating underrepresented minority students. Through his teaching and mentoring at Morgan State University he plays a critical role in educating the next generation of underrepresented minority students, especially African-American civil engineering students. He is also considered to be a paradigm of a modern engineer. He combines practical experience with advanced numerical analysis tools and knowledge of material constitutive relations. This is essential to address the challenges of advanced geotechnical and transportation research and development. He is an expert in advanced modeling and computational mechanics. His major areas of research interest centers on pavement engineering, sustainable infrastructure development, soil mechanics, physical and numerical modeling of soil structures, computational geo-mechanics, constitutive modeling, pavement design, characterization and prediction of behavior of pavement materials, linear and non-linear finite element applications in geotechnical engineering, geo-structural systems analysis, structural mechanics, sustainable infrastructure development, and material model development. He had been actively involved in planning, designing, supervising, and constructing many civil engineering projects, such as roads, storm drain systems, a \$70 million water supply scheme which is comprised of treatment works, hydraulic mains, access roads, and auxiliary civil works. He had developed and optimized many highway design schemes and models. For example, his portfolio includes a cost-effective pavement design procedure based on a mechanistic approach, in contrast to popular empirical procedures. In addition, he had been equally engaged in the study of capacity loss and maintenance implications of local and state roads (a World Bank-sponsored project). He was the project manager of the design team that carried out numerical analyses to assess the impact of the new shaft and tunnel stub construction on existing London Underground Limited (LUL) structures as per the proposed alternative 3 design of the Green park Station Step access (SFA) Project in U. K. He was also the project manager of Category III design check for the Tottenham Court Road Tunnel Underground Station upgrade Project in UK.

Dr. Petronella A James, Morgan State University

Comparative Assessment of Student Performance on Exams when Using Online Homework Tools in an Undergraduate Engineering Mechanics Course

Civil Engineering Division

Abstract

Engineering mechanics courses are vital to the core competencies of engineering students. The objective of this study is to analyze student success in an engineering mechanics course using *MasteringEngineering*® to complete online (electronic) homework as opposed to traditional (written) homework. For this study, 2 different civil engineering instructors compare student data for this engineering mechanics course taught during the spring 2012 semester and summer 2012 mini-mester (3 sessions), thereby sampling a total of 56 students. The instruments used to measure effectiveness were homework assignments and final exam grades, and their effect on the final grades for the course. The homework assignments for this study focused on 2 main topics: 1) structural analysis of trusses, and 2) construction of shear and moment diagrams. The results show that an online instructional tool that supports the facilitation of online (electronic) homework, was used compared to traditional (written) homework, final exam grades on these 2 main topics within engineering mechanics improved by 8.8% and 17.4% for Professor A and B's classes, respectively, and thusly improved final grades by 8.4% and 1.8% for Professor A and B's classes, respectively. In addition to aiding student success, *MasteringEngineering*® proved to be user-friendly for the instructors while providing useful data on how a problem aligned with ABET learning outcomes for assessment, how much time students spent on problems, and how many attempts it took the student to input the correct answer (multiple attempts allowed in this study), which helped the instructors identify topics that seemed to still trouble students for deeper learning and understanding of engineering mechanics concepts. Lastly, this paper reveals some of the student and instructor benefits and challenges experienced when using *MasteringEngineering*® in an undergraduate engineering mechanics course at a Historically Black College and University (HBCU).

Background

Some instructors have used online homework tools as a way to integrate technology into the classroom.¹⁻⁴ *MasteringEngineering*®, a Pearson product, was used for the first time in the Department of Civil Engineering at a Historically Black College and University (HBCU) to promote student success in an engineering mechanics course, CEGR 304. The class compositions for CEGR 304 is unique is that it is the statics course required for non-civil engineering majors, comprised mainly of electrical, computer and industrial engineering students who need this course to graduate. Given the unfortunate reputation of the course, many of these students wait until their senior year to take the course. As a means to motivate student learning and redirect the attitude for the course, the instructors decided to take a different approach by using *MasteringEngineering*®, which served several purposes: 1) to excite learning using technology for which students gravitate to and like, 2) to reduce time- and labor-intensive homework grading given the automate grading feature, 3) to improve turnaround time for homework feedback, and 3) to provide the students with individualized tutoring given the hints that are available when completing the online homework once a student purchases an access code. The access code enables students to complete their homework assignments online while having

multiple attempts and opportunities for hints as a form of individualized tutoring. Once a student purchase the code, the information they input when registering is automatically populated into the *MasteringEngineering*® "Roster" for the course. Furthermore, given the popularity of E-books, this also enabled the opportunity for students to also purchase online access to the textbook for their convenience and easy access. While these were the initial reasons for using *MasteringEngineering*®, several additional benefits and lessons learned were also discovered along the way.

Course Structure

The engineering mechanics course, CEGR 304, addresses several of the ABET³ outcomes and has several primary learning outcomes:

- To apply prerequisite knowledge from physics and math classes to engineering mechanics problems.
- To apply vector methods to solve engineering mechanics type problems.
- To construct clear and accurate free-body diagrams and use such diagrams to solve problems.
- To analyze the equilibrium of a body under an action of forces.
- To construct shear and moment equations and diagrams.
- To calculate center of gravity, centroid and moment of inertia of an object.

The course was taught by two different civil engineering professors over 4 semesters: spring 2012 semester and summer 2012 mini-mester (3 sessions), thereby sampling 56 students. Both professors taught during the summer 2012a mini-mester; one taught face-to-face using *MasteringEngineering*® with 8 students (Professor A's courses highlighted in pink), and the other (Professor B's courses highlighted in blue) taught the entire course online to 11 students without using *MasteringEngineering*®. Table 1 shows the breakdown of the courses such as grading weights of the final exam each time the course was offered by the 2 different civil engineering professors (denoted by color shading), which courses utilized *MasteringEngineering*®, and if the lowest homework grade was dropped. One of the instructors decided to drop the lowest homework since late assignments were not accepted, which was easy to enforce given that *MasteringEngineering*® would not allow students to change answers after a due date and time were set. (This is one of many advantages, where customizations per student can be made if necessary, even extensions of assignment due dates for University excused absences, for example, by adjusting the settings per student). It shall be noted that one of the instructors increased the weight grade for homework when *MasteringEngineering*® was used while the other instructor actually decreased it. These factors and their effect on students' final grade will be examined in the next section of this paper.

Table 1: Composition of CEGR 304 for Comparative Assessment of Data Collected

Semester at Morgan State University (HBCU)	Number of Students	Used *ME (Yes or No)	Homework Percentage of Final Grade	Lowest Homework Grade Dropped (Yes or No)	Final Exam Percentage of Final Grade
Spring 2012-f2f	30	No	10%	Yes	30%
**Summer 2012a-f2f	8	Yes	25%	Yes	30%
**Summer 2012a-online	11	No	20%	No	40%
Summer 2012b-online	7	Yes	10%	No	40%
TOTAL	56				

*ME denotes *MasteringEngineering*®

**Note: Both professors taught during the summer 2012a mini-mester; one taught face-to-face using *MasteringEngineering* and the other taught the entire course online without using *MasteringEngineering*.

Selection of Homework Assignments and *MasteringEngineering*® Features

Each instructor individually selected the problems for his/her students for the traditional (written) homework and online (electronic) homework. As such, two homework assignments were assessed in this study with one assignment covering problems related to structural analysis of trusses and the other one covering problems related to the construction of shear and moment diagrams. Student performance on these homework problems will be assessed and compared to evaluate students' overall success for each class as reflected by the measuring instruments of the final exam and final grade students' earned for the course. Note that separate comparisons will be made given the differences in the format (i.e. face-to-face [f2f] vs. online) and grade weights for the course as noted in Table 1.

Figure 1 shows an example of the selected truss problem from Professor A's class originating from the R. C. Hibbeler's *Engineering Mechanics: Statics* text that is linked with *MasteringEngineering*®.

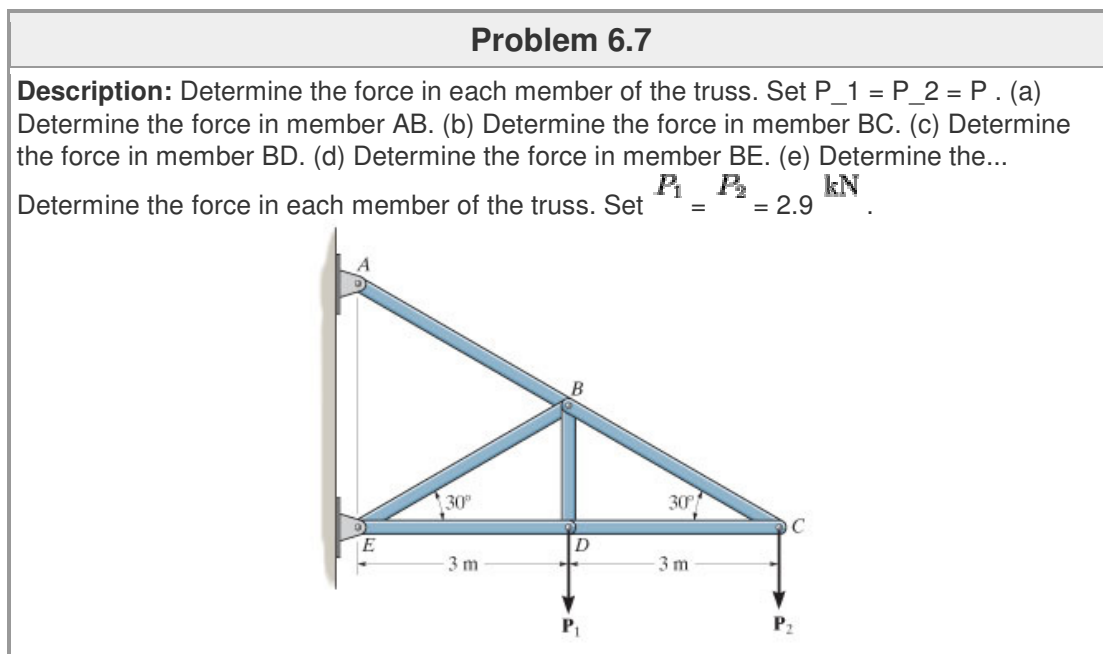


Figure 1: Truss problem used for comparative assessment

With *MasteringEngineering*®, problems can be selected and assigned to a particular homework assignment. Problems from different chapters can be combined into one assignment if desired. This tool also offers tutorials that students must complete. There are several different settings that can be assigned, depending on the instructor's preference, such as the number of points for the problem and number of attempts before points is deducted. When selecting problems, the level of difficulty is displayed along with the problem itself and approximate time it should take to complete the problem. ABET learning outcomes are associated with certain problems, which is useful for assessment. Student results can be sorted based on length of time to complete the assignment, assignment grade, and performance as defined by the ABET learning outcomes, to name a few. "End-of-section" problems can also be assigned for which the solutions are not in a solution manual for students who illegally have the solution manual. Any problem can be selected for grading or for practice. The instructor just defines the start and due date for the assignment. In summary, *MasteringEngineering*®⁵ provides the following diagnostic data for an assignment as taken directly from the help menu:

- **Item Score**—See average student score, by item.
- **Item Time**—See median student time to complete, by item.
- **Item Difficulty**—See average difficulty, by item.
- **Student Score**—See student scores for the assignment as a whole.
- **Student Time**—See student times for the assignment as a whole.
- **Score Histogram**—See distribution of student scores vs. the number of students for each range of scores.
- **Time Histogram**—See distribution of student times to complete the assignment vs. the number of students for each range of times.

Along with automatic grading of an assignment, this instrument also automatically populates the data into the "Gradebook," which can be exported into several formats such as a .csv, .xls, or even Blackboard. Once exported, the data can be imported to Blackboard, for example, as was used in all of the classes for this study. A 10-point grading scale was used for all courses to evaluate student performance such that 90-100 A, 89-80 B, 79-70 C, 69-60 D and below 59 F, was used.

Analysis of Results

MasteringEngineering® provides a wealth of information for diagnostics in terms of student activity, amount of time spent per problem, amount of time spent per student, and scoring per problem (and per student) for an assignment.

Course Performance

For Problem 6.7, students spent an average of 15 minutes (m) for this relatively simple problem (lowest level of difficulty=1) as revealed in Table 2. The students in the summer 2012a course all arrived at the correct answer in fewer attempts than the system average as also revealed in Table 2. By allowing students multiple attempts to arrive at the same answer, all students received a 100% on the problem compared to an average of 95.2% as computed from the traditional (written) homework grades, which is a 5% improvement given this relatively basic problem.

Table 2: Summary View of Results from Problem 6.7

Problem 6.7	Answer Stats % correct (average)			Difficulty		Median Time		Wrong/student	
	This Course	System	Spring 2012	This Course	System	This Course	System	This Course	System
**Summer 2012a-f2f	100	95.6	95.2	1	1	15m	16m	0.9	0.8

**Note: Both professors taught during the summer 2012a mini-mester; one taught face-to-face using *MasteringEngineering*® and the other taught the entire course online without using *MasteringEngineering*®.

Again, allowing multiple attempts (up to 4) and opportunities for students to enhance their subject mastery of the topic using *MasteringEngineering*®, it was observed that the average score was a 95.5% compared to 69.5% when traditional (written) homework on the same topic was assessed, thereby showing an improvement of 27%. The data infers that students perform better when given multiple chances to get advice, understand the topic, and earn their grade. Since these assignments were configured to allow the student multiple attempts, *MasteringEngineering*® provides details on the wrong answers that were submitted for the problem for diagnosis and troubleshooting, which helps the instructor to review "tricky" concepts to deepen student understanding. Moreover, the individualized tutoring is evident, thereby helping the students to arrive at the correct answer without major penalty in this case.

Table 3: Summary of Wrong Answers Submitted and Advice to Student for Problem 6.7 as produced by *MasteringEngineering*®

Wrong Answers for This Course (MEHEAD67089)		
% Wrong	Answer	Response
16.7%	10.6units{kN}	
16.7%	12units{kN}	
16.7%	8.6units{klb}	One or more of the units you entered is not recognized. Click help to view a list of recognized units.
16.7%	-10.6units{kN}	
16.7%	10.2units{kN}	
16.7%	12.6units{kN}	Not quite. Check through your calculations; you may have made a rounding error or used the wrong number of significant figures.
16.7%	800units{lb}	Use SI units for your answer.
16.7%	-12units{kN}	
16.7%	8.6units{kN}	
16.7%	12.3units{kN}	Not quite. Check through your calculations; you may have made a rounding error or used the wrong number of significant figures.

Data were collected and compared to evaluate the impact of electronic (online) homework on the final exam and final grades for all of the 56 students in Professor A and B's classes. Figure 2 shows a plot of student performance and how these final exam grades are higher, on average, when electronic (online) homework *MasteringEngineering*[®] (abbreviated ME in the "legend" of the plots) was used. Specifically, for Professor A's courses, final exam grades increased from an average of 75.6% to 82.9%, an improvement of 8.8%. For Professor B's courses, final exam grades increased from an average of 61.9% to 75%, showing an improvement of 17.4%. Further to the point, Figure 3 ultimately shows a plot of the final grades, where naturally if homework grades and final exam grades increase, then the final grades would increase.

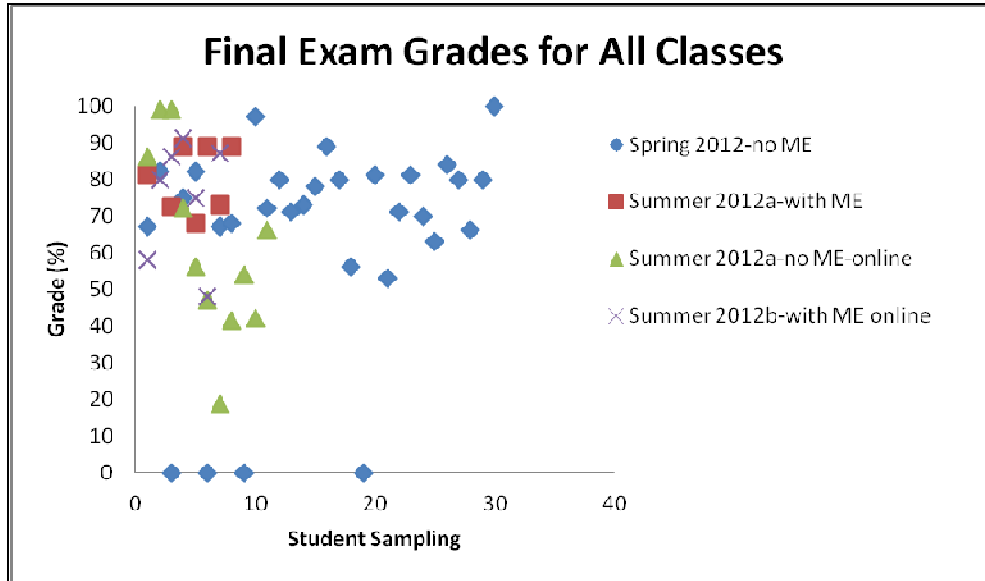


Figure 2: Final Exam Grades for all classes used for comparative assessment

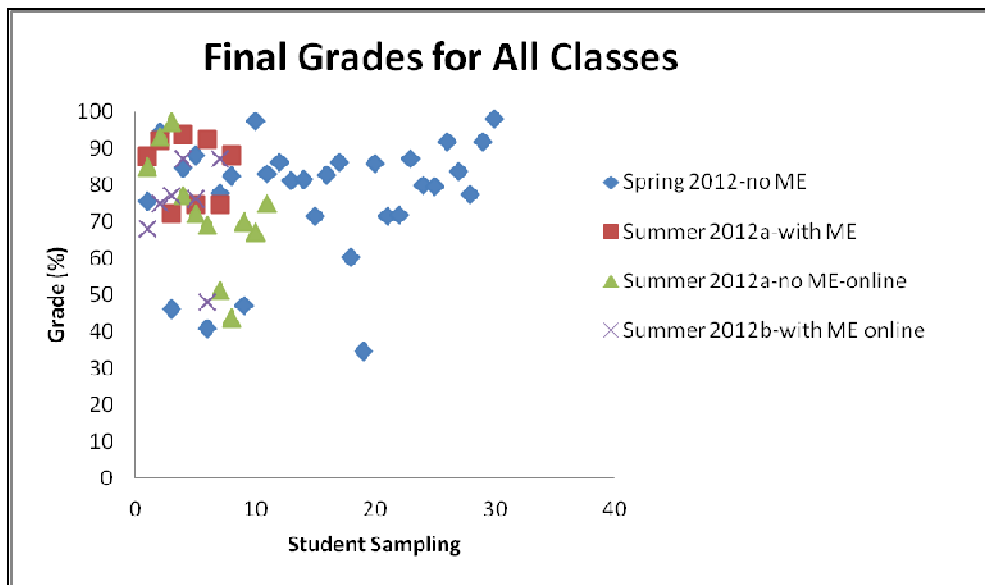


Figure 3: Final Grades for all classes used for comparative assessment

ABET Information for Data Collection

Tracking of data as it relates to ABET⁵ learning outcomes can be time-consuming. However, *MasteringEngineering*^{®6} helps to correlate assigned problems to their appropriate ABET learning outcome, which is another useful feature. Table 4 shows how Problem 6.7 was correlated the appropriate learning outcome. For Problem 6.7, 87.5% completed the objective of the problem.

Table 4: Summary of ABET Learning Outcome Data for Problem 6.7 produced by *MasteringEngineering*

ABET Learning Outcome (a)	% Complete	% Avg Score
An ability to apply knowledge of mathematics, science, and engineering	87.5	99

Conclusions

From data sampling 56 students in an engineering mechanics course at a Historically Black College and University, overall results show that the use of online homework aids in improving student grades, thereby suggesting an enhancement of student learning. Although students are given multiple attempts for homework that resulted in an increase in homework grades, the final exam and consequently, final grades also improved. For Professor A's courses, final grades increased from an average of 77.3% to 84.4%, an improvement of 8.4%. For Professor B's courses, final grades increased from an average of 72.7% to 74%, showing an improvement of 1.8%. The data also show that students who took the course face-to-face performed better the students who took the course online. A more dramatic improvement in grades was observed when *MasteringEngineering*[®] was used in the online courses. Future studies are being conducted to carefully investigate this phenomenon in addition to ways to improve overall student performance as revealed in the course average for the final grades.

MasteringEngineering[®] proved to be an effective tool to support instruction and enhance student learning. Some especially useful features of *MasteringEngineering*[®] that supported both student and instructor benefits include:

- tracking time students spend doing problems (where unreasonable little time spent with perfect scores and no 2nd attempts may raise a "red flag"),
- assigning practice problems for students to complete online,
- providing individualized tutoring,
- keeping homework sessions open for review and rework,
- allowing customizations per student through the adjustment of settings (i.e. granting an extension on an assignment due to an excused University absence)
- automatically grading assignments to provide immediate feedback to students
- automatically grading assignments to populate data into "Gradebook," which can be a time- and labor-intensive process depending on number of students and instructor's teaching/research/service/personal workload
- exporting "Gradebook" data into common formats such as .csv, .xls and Blackboard,
- providing an eText option for students who purchase the access code plus eText,
- diagnosing "tricky" concepts based on wrong answers logged by students, and

- aligning problems (automatically built into *MasteringEngineering*®) with ABET learning outcomes.

While *MasteringEngineering*® was quite user-friendly, some challenges were presented when students provided the correct answer but were told that their response was incorrect due to systematic issues. This happened on occasion where Professor A just used an honor system and told students to print his/her response and the correct response to show that they were the same yet were penalized. Another tidbit when using *MasteringEngineering*® is that advance preparation is recommended for an instructor to acquire the course access code through Pearson after a login has been established for the instructor. Doing this in advance allows the instructor to include the information on the syllabus to alert students on what is needed for the course and to lessen student frustrations to a friendly tool that can assist their learning by completing homework online. Academic dishonesty is always a topic of concern, where it is not always certain whether or not a student has received or given help. To help overcome this issue, Professor A and B also gave in-class quizzes to also assess student learning of topics. From these results, it was quite evident which students were actually trying to learn the content and which ones were still struggling despite the higher average for homework grades. Overall, the authors feel that despite some of these nuances, the student and instructor benefits far outweigh any of these challenges, where *MasteringEngineering*® can support instruction and aid in enhancing a deeper understanding for student learning.

Bibliography

1. Knight, A.M., Nicholls, G.M., and Compton, P.J. (2012). Measuring the Effect of Online Homework Procedures on Student Exam Performance. *Proceedings of the 119th ASEE Annual Conference & Exposition*, San Antonio, TX.
2. Liberatore, M.W. (2011). Improved Student Achievement in Material and Energy Balances Using Personalized Online Homework. *Proceedings of the 118th ASEE Annual Conference & Exposition*, Vancouver, British Columbia.
3. Devine, J. and Lokuge, W. (2012). Engaging distance students through online tutorials. *Proceedings of the Australasian Association of Engineering Education*, Melbourne, Australia.
4. Palazzo, D.J., Lee, Y.-J., Warnakulasooriya, R., Pritchard, D.E. (2010). Patterns, correlates, and reduction of homework copying, *Physics Education Research* 6, 010104.
5. "Criteria for Accrediting Engineering Programs," ABET, Baltimore, MD, 2005-2006.
6. *MasteringEngineering*® Help Center, Web.
http://help.pearsoncmg.com/mastering/instructor/standalone/index_Left.htm#CSHID=get_started_instrlStartTopic=Topics%2Fget_started.htmlSkinName=ms_instr-CSH.