STRUCTURAL HEALTH MONITORING EDUCATION UNIT PLANNING AND IMPLEMENTATION GUIDE



Prepared By

Dr. Vijaya K. A. Gopu, PE, Stuller Settings -Matthew Stuller/LEQSF Regents Professor, University of Louisiana - Lafayette

Dr. Ayman Okeil, PE, Roy P. Daniel Professor of Civil and Environmental Engineering, Louisiana State University

Dr. Roger K. Seals, PE (Retired), Professor Emeritus of Civil and Environmental Engineering, Louisiana State University

PREFACE

The purpose of this Guide is to help faculty who adopt, and possibly adapt, the Structural Health Monitoring (SHM) Education Unit to facilitate the planning and implementation of the Unit at their institution in two steps: (1) implementation of the SHM Fundamentals Education Subunit in an undergraduate structural analysis course followed by (2) implementation of the SHM Applications Education Subunit in an undergraduate structural design course. While this is the recommended implementation strategy, it is by no means the only feasible implementation strategy. It is also conceivable that the Unit could be adapted for implementation in an introductory structural engineering graduate course. With the online resources provided for both the faculty and students, the Project Team has attempted to minimize or eliminate the barriers faculty normally face in introducing new content into their courses and the curriculum. Further, our Team is prepared to assist faculty in any way possible to facilitate the process of implementation.

We also encourage faculty who adopt this Unit at their institution to contribute to improving and enhancing the educational resources. Further, we encourage faculty adopters to join with us in a "community of scholars" to promote SHM education nationally and more broadly Field Monitoring and Measurements (FMM) education within undergraduate civil and environmental programs. The results of this pilot project have clearly demonstrated that FMM fundamentals and applications can be incorporated across the curriculum into existing undergraduate courses and laboratories without negatively impacting the traditional student learning outcomes established for those courses.

TABLE OF CONTENTS

PREFACE i
STRUCTURAL HEALTH MONITORING EDUCATION UNIT PLANNING AND IMPLEMENTATION GUIDE 1
I. INTRODUCTION 1
II. SHM FUNDAMENTALS EDUCATION SUBUNIT 3
A. PLANNING PHASE 3
1. Who? 3
2. What? 5
3. When? 6
4. Where? 7
5. Introductory Classroom Presentation. 7
B. IMPLEMENTATION PHASE 7
1. Overview. 8
2. Implementation Sequence. 8
3. Managing the classroom discussion session. 10
4. Assessment Survey 11
5. Student Focus Group Interview (Optional). 12
III. SHM APPLICATIONS EDUCATION SUBUNIT 12
A. PLANNING PHASE 12
1. Who? 13
2. What? 14
3. When? 14
4. Where? 14
5. Fabrication of the SHM Applications Education Subunit Demonstration Model. 15
B. IMPLEMENTATION PHASE 21
1. Implementation of the SEMs/SAMs 21
2. Implementation of SAM2 24
APPENDIX 27
ATTACHMENT A1 SUGGESTED TEXT FOR INCLUSION IN STRUCTURAL ANALYSIS COURSE SYLLABUS .. 28

ATTACHMENT A2 SUGGESTED CONTENT OF PRESENTATION TO STUDENTS IN STRUCTURAL ANALYSIS COURSE 30

ATTACHMENT A3 Sample Master Schedule for SHM Fundamentals Education Subunit 32

ATTACHMENT A4 Description of the FMM Project Home Page and the Faculty and Student Webpages 33

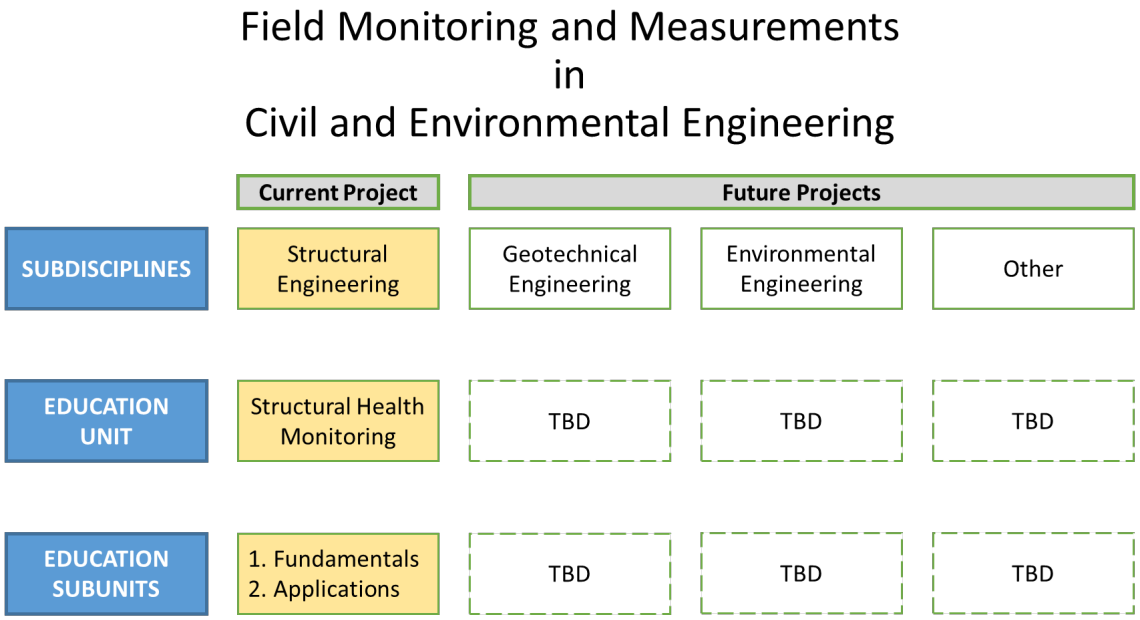
ATTACHMENT A5 Details of Demo Model Specimen 35

This page intentionally blank

STRUCTURAL HEALTH MONITORING EDUCATION UNIT PLANNING AND IMPLEMENTATION GUIDE

I. INTRODUCTION

Conceptually, as depicted visually below, the Field Monitoring and Measurements Project sponsored by the Division of Undergraduate Education of the National Science Foundation was designed to potentially encompass the development and implementation of education units in the various sub-disciplines of civil and environmental engineering. Due to funding limitations, we chose to demonstrate the viability of this concept by developing an education unit in Structural Health Monitoring within the sub-discipline of structural engineering.



The Structural Health Monitoring (SHM) Education Unit consists of two subunits- the SHM Fundamentals Education Subunit and the SHM Applications Education Subunit. Figure 1 graphically depicts the components of the SHM Education Unit. The Unit was developed by Gopu, Okeil and Seals in partial fulfillment of the objectives of the Field Monitoring and Measurements in Civil and Environmental Engineering Project. The two Subunits of the SHM Education Unit were designed to be implemented sequentially in required undergraduate courses in structural analysis and structural design (normally reinforced concrete or steel). As planned, these Subunits were introduced to undergraduate civil engineering students at Louisiana State University (LSU) and University of Louisiana at Lafayette (UL-Lafayette) during the 2016-17 Academic Year by Okeil and Gopu, respectively. In so doing, they received excellent cooperation and support from faculty members at LSU and UL- Lafayette, respectively.

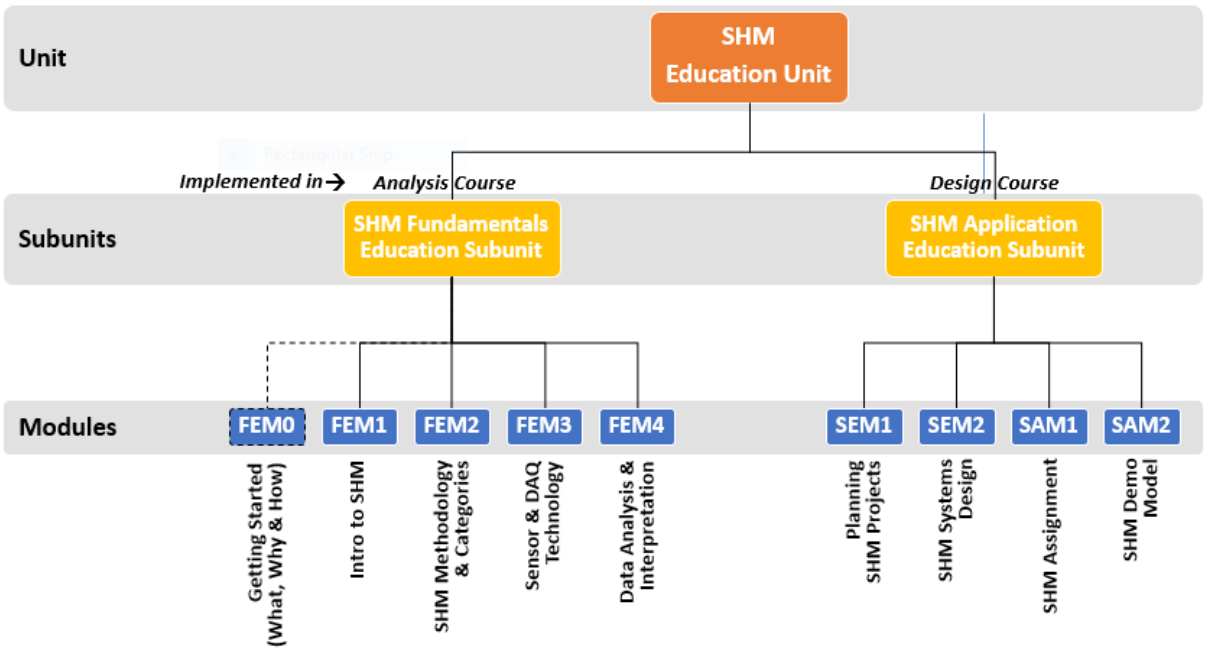


Figure 1. Graphical Depiction of Components of the SHM Education Unit

SHM Fundamentals Education Subunit

FEM0- Getting Started- What, Why and How

FEM1- Introduction to Structural Health Monitoring

FEM2- Structural Health Monitoring Methodology and Testing Categories

FEM3- Sensor and Data Acquisition Technology

FEM4- Analysis and Interpretation of Sensor Data

SHM Applications Education Subunit

SEM1- Planning SHM Projects

SEM2- Design of SHM Systems

SAM1- Develop SHM Plan

SAM2- SHM Demonstration

The guidance herein provided for planning and implementation of the SHM Education Unit is not meant to be strictly prescriptive. The guidance is based on our actions, experience and student assessment results in implementing the Unit at LSU and UL-Lafayette during the 2016-17 AY as well as the results of the implementation and assessment of the unit at four partner institutions: Case Western Reserve University- 2017/18 Academic Year; Tuskegee University- 2017/18 and 2018/19 Academic Years; University of North Florida- 2017/18 Academic Year; and VA Tech, Summer 2018 and 2019. However, it is understood that local conditions and circumstances may dictate alternate approaches. Please feel free to contact one of us if you have any questions at any time during your local efforts.

Vijaya Gopu	v.gopu@la.gov	225-767-9102 (O); 225- 802-8778 (C)
Ayman Okeil	aokeil@lsu.edu	225-288-4224; (C) 225-578-7048 (O)
Roger Seals	ceseal@lsu.edu	225-335-5327 (C)

We definitely solicit your comments, criticisms, and suggestions aimed at improving the quality of the educational materials, pedagogy and experience.

II. SHM FUNDAMENTALS EDUCATION SUBUNIT

A. PLANNING PHASE

The Planning Phase for implementing the SHM Fundamentals Education Subunit consists principally of addressing the following questions, more or less in the order indicated. Our guidance is based on our experience in implementing the Subunit at LSU and UL-Lafayette over the 2016-17 Academic Year. Your local circumstances may dictate somewhat different approaches.

1. Who? You may or may not be the faculty member in whose course the SHM Fundamentals Education Subunit is implemented. If you are not teaching the requisite structural analysis course during the implementation semester, it will be necessary for you to negotiate with a colleague to implement the Subunit.

This negotiation will require you to come to an agreement with the relevant colleague concerning the following issues:

Permission to implement the SHM Fundamentals Education Subunit in the relevant course.

Identification of at least two 50-minute class periods (or two lab classes) to conduct the classroom discussion sessions. It is desirable that these sessions be scheduled during the first 2/3's on the semester if at all possible.

Willingness of the course instructor to:

1) include a section in their syllabus concerning the plans for introduction of the SHM materials. See Attachment A1, Appendix.

2) give the students some meaningful credit for their participation in the SHM Fundamentals Education Subunit. If possible, this should also be clearly indicated in the course syllabus.

Considering the amount of time (based on assessment survey data) and effort required of the students, we believe that a maximum of about 3 % of the total grade represents a reasonable amount of credit for the students. Of course, the exact amount of credit awarded students is up to the course instructor. It will be your responsibility to provide the course instructor with a numerical grade for each of the students in the course. You have three assignments on which to base this grade: score(s) on the "Readiness" exams; classroom discussion question responses; and one-minute papers. Ayman used the following model to determine the numerical grades for the students. His model is simply provided as an example not as a required procedure.

The grading model for each education subunit implementation in LSU courses was based on the average of the student's grade for all modules in the subunit. The student's grade for each module was basically a weight-based grade of 4:2:1 for the readiness exam, discussion question, and one-minute paper, respectively. This translates into the following:

57.1% Readiness Exam grade*

28.6% Response to Discussion Questions**

14.3% One-minute paper grade**

* Students received 100% if score≥75%, 80% if 75%>score≥50%, and 50% if score<50%

** Students received full credit for responding to the discussion questions and turning in the one-minute paper

3) provide you with 10-15 minutes in a class period several weeks in advance of the implementation of the relevant Subunit to introduce the topic and the education pedagogy. Attachment A2 (Appendix) provides a summary of the possible content and scope of that discussion. Attachment A3 (Appendix) is an example of the Master Schedule for the SHM Fundamentals Education Subunit referred to in Attachment A2. Encourage but do not require the instructor to embrace the program with some explicit supportive comments to the students.

4) make a commitment from the instructor to limit or eliminate course homework assignments during the SHM Fundamentals Education Subunit implementation period.

5) send email reminders about the out-of-class activities for the SHM Fundamentals Education Subunit, or give you access (email list for class roster) to be in charge of the reminders. We recommend the latter approach.

2. What? You will need to decide how and in what form you will make the following documents available to the students.

Pre-treatment survey- one version which is administered in advance of implementation of the Fundamentals Education Subunit

Fundamentals education modules- FEMs - a total of five FEMs (FEM0-FEM4)

Readiness exams- two each for FEM1- FEM4

Classroom discussion question response forms- one each for FEM0-FEM4

Assessment surveys- one each for FEM0-FEM4

Editable versions of all these documents can be accessed via the password protected Faculty Instructional Resources hyperlink at the following URL:

https://www.ltrc.lsu.edu/nsf/

This page is referred to as the FMM Project Home Page because it provides links to both the Faculty Instructional and Student Education Resources.

Clicking on the Faculty Instructional Resources hyperlink opens the Faculty Instructional Resources webpage but is password protected. So, in advance of attempting to link to this webpage, a username and password must be requested and received as per the guidance provided. The editable documents listed above will be found at the password protected Faculty Instructional Resources webpage.

The Student Education Resources webpage that can be accessed via the FMM Project Home Page provides PDF versions of the Fundamentals Education Modules as well as the corresponding discussion question response forms and assessment surveys for each of the education modules. Also included is a description of the process to be followed by the students in addressing each of the modules. The students access the Student Education Resources webpage via the FMM Project Home Page.

A more detailed description of the FMM Project Home Page and faculty and student webpages, their content and management, is provided in Attachment A4, Appendix.

The readiness exams (two versions) required by the students must be provided by some alternative means. Ayman provided the education modules, the readiness exams, and the classroom discussion response forms to the students via Moodle, LSU's open-source learning management system. Embedded in the Moodle package are URLs for the anonymous online pre-treatment and assessment surveys which were implemented in SurveyMonkey. If your institution uses Moodle, the ready-for- upload package of the entire subunit can be transferred to you.

Subsequently, the readiness exams were restructured to allow them to be implemented in SurveyMonkey using the self-grading feature of the software. However, the readiness exams provided on the password protected Faculty Instructional Resources webpage have not been implemented in SurveyMonkey.

In a perfect world, we would share our developed modules as an electronic package and every site would seamlessly import it into their MOODLE, CANVAS, or whatever instructional management they use. We know that UL-Lafayette had issues importing LSU's MOODLE content into their version of MOODLE. Not a good sign for this seamless integration. Learning that several of our faculty partners' institutions have adopted CANVAS, Ayman investigated the extent to which the MOODLE could be imported into CANVAS. Here is his account of that effort:

> *"After our webinar, I was curious whether CANVAS; a commercial platform, can do better since it is used by many of our partners. So, I opened a free account and imported the MOODLE FEM Modules there. It did it, but there is a catch.*
>
> - *To my surprise, the readiness exams and the entire question bank transported successfully.*
> - *The layout is not exactly the same. ∴ Instructor will have to spend time rearranging the different items. (about an hour for an experienced user)*
> - *Dates and rules of availability for various items will have to be adjusted for each institution's schedule of course. (another 0.5-1.0 hours for an experienced user)"*

The good news is that the most time-consuming components of the Subunit- readiness exams and surveys- can be implemented safely and easily by migrating Ayman's MOODLE package to CANVAS (or possibly other learning management systems).

3. When? Planning and any needed negotiations with colleagues should be initiated several weeks in advance of the date that course syllabi are normally prepared.

It has already been indicated the desirability of implementing the Subunit before the last third of the semester. Our experience has indicated that during the last third of the

semester, the students are more focused on typical end of semester course and project requirements.

The SHM Fundamentals and Applications Education Subunits should be implemented sequentially. This requirement more or less dictates the need to implement the SHM Fundamentals Education Subunit in the Fall and the SHM Applications Education Subunit in the Spring. However, we recognize that local circumstances may dictate an alternative approach. Ultimately, you are free to implement the Education Subunits in a manner which you judge best to address your local circumstances while achieving the expected learning outcomes of the project.

4. Where?

a. Relevant courses. Generally speaking, most civil engineering undergraduate curricula include an introductory structural analysis course which is normally preceded by prerequisite courses in strength of materials and a materials laboratory course. The SHM Fundamentals Education Subunit was designed for implementation in such a course. Normally, the structural analysis course is followed by a structural design course or courses, possibly reinforced concrete design or steel design. It is irrelevant which design course is used to implement the SHM Applications Education Subunit. The critical issue is that the structural design course should immediately follow the structural analysis course and deal with the same or a sizable subset of the student cohort from the structural analysis course.

b. Space. There are no special space requirements for either Subunit. Classrooms with movable rather than fixed seating are more conducive to forming student discussion groups but discussions can be satisfactorily accomplished in either setting.

5. Introductory Classroom Presentation. As recommended in Section I.A.1 above, as the "SHM instructor" you should make a presentation to the class several weeks in advance that summarizes the rationale and scope of the SHM Education Unit.

B. IMPLEMENTATION PHASE

The SHM Fundamentals Education Subunit introduces students to the principles, rationale, methods and technologies of structural health monitoring through a series of four Fundamentals Education Modules (FEMs).

FEM1- An Introduction to Structural Health Monitoring

FEM2- Structural Health Monitoring Methodology and Testing Categories

FEM3- Sensor and Data Acquisition Technology

FEM4- Analysis and Interpretation of Sensor Data

Listed in each FEM are the expected student learning outcomes for that FEM.

1. Overview. Preceding the initiation of the FEM series is a module (FEM0) termed the "rationale brief" which explains the "What", "Why" and "How" of the SHM Education Unit.

With the exception of FEM0, associated with each of the FEMs are two versions of a readiness exam consisting of eight multiple choice or true/false questions designed to determine the extent to which the students are adequately prepared to intelligently participate in the classroom discussion sessions associated with each FEM.

Subsequent to the students' completion of their review of a specific FEM and the relevant readiness exam, the content of each of the FEMs is supplemented by a classroom discussion of an assigned question. Prior to the classroom discussion session, the students submit a response form summarizing their response to the classroom discussion question plus any questions they might have about the content of the particular FEM under consideration.

To the extent possible, you are encouraged to review the students' response form submissions in advance of the classroom discussion session and note possible topics for a second discussion question, time permitting, and any prevalent questions that should be addressed during the classroom session.

Following the classroom discussion session, students should be required to submit a "one-minute paper" listing any lingering questions or misunderstandings they may have. Based on your subsequent review of the one-minute papers, you may determine the need to clarify or amplify one or more issues at the subsequent classroom discussion session. The final student activity is that they are asked to complete an online assessment survey which can be accessed via the Student Education Resources webpage via a tab provided on the FMM Project Home Page.

2. Implementation Sequence. The sequence in which the FEMs and other elements are implemented (i.e., the education pedagogy) is depicted graphically in Figure 2.

Implementation of the Fundamentals Education Subunit begins with your presentation to the class as described in II.A.5. Attachment A2 provides a summary of the possible content and scope of that discussion. In advance of that presentation, you will need to prepare the Master Schedule for distribution, an example of which is provided in Attachment A3. The Master Schedule will have to be adjusted to fit your other calendar commitments and/or agreement with the class instructor. Of equal if not greater

importance is the presentation and explanation of the education pedagogy (see Figure 2) that clearly defines the process that will be followed for each of the education modules.

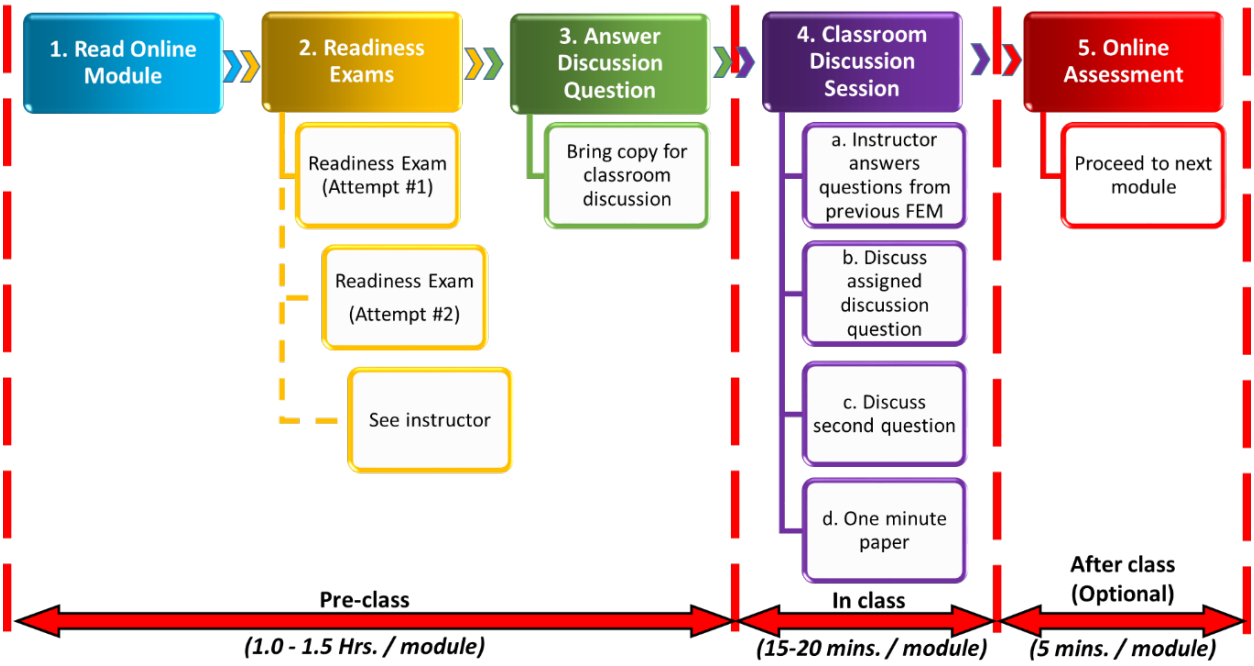


Figure 2. The Education Pedagogy for the SHM Education Unit

At the time of this presentation, the students should be asked to complete the online pre-treatment survey in advance of initiating work on the Fundamentals Education Subunit.

The order and timing of the implementation of FEMs are summarized by the Master Schedule provided to the students. This schedule will be dictated by the amount and periods of class time you can negotiate with the course instructor. As noted previously, PowerPoint slides of the FEMs are available to the students via the Student Education Resources webpage which is accessible via the FMM Project Home Page. The same but editable versions of the FEMs are posted in the password-protected Faculty Instructional Resources webpage.

Upon completing their review of an FEM, with the exception of FEM0, the students should be directed to take a readiness exam on the content of the FEM. Some means will have to be devised to provide students access to the exams. For example, the exams may be implemented in SurveyMonkey or some other relevant software which incorporates an automatic grading feature. Thus, upon completion of the exam, a

percentage score (number of correct answers/total correct answers) is determined. If a student achieves a score of 80% or greater, he or she is judged to pass the exam. Students should have been previously directed to print a copy of the corrected exam, write their name on the copy and submit the copy to you. Two readiness exams are provided for each FEM except FEM0. If the student did not achieve a score of 80% or better, they must take a second exam and submit that scored exam as previously described. Should that score be less than 80%, the student should be asked to discuss the matter with you.

Once a student has successfully completed the readiness exam(s), they should be directed to complete the discussion question response form on which they are asked to write their qualitative response to a specific discussion question and list any questions they may have about the content of the FEM. One of several means can be used to facilitate this process: 1) students use the links provided in the Student Education Resources webpage to complete the discussion question response form, print it and turn it into you; 2) students are provided hard copies of the form to complete and submit to you; or 3) migrate the MOODLE content to your institution's learning management system (e.g., CANVAS) as discussed in Section I.A.2.

Based on self-reporting, the students indicated that they generally completed review of the FEM, taking the readiness exam and submission of the discussion question response form within 1 ½- 2 hours but usually in 1 ½ hours or less. Completion of the assessment survey following the classroom discussion session requires another 10-15 minutes at most.

3. Managing the classroom discussion session. The classroom discussion session is designed to promote the students' active learning. No more than about 15 minutes should be devoted to each discussion question. In the Pedagogical Model (Figure 2) provided to the students at the initial implementation of the SHM Fundamentals Education Subunit, the students are asked to bring a copy of their discussion question response to class with them. At the outset, explain the plan for the discussion: (1) step one- students form groups of 2 -4; (2) step 2- students in group compare their answers, develop a consensus response and agree on a spokesperson for the group (provide 2-3 minutes); and (3) step 3- you will randomly call on groups (you can start by asking for volunteers) to summarize their response to the question- particularly emphasize the need to add to not simply repeat previous responses. You will have to be the judge of when to terminate the discussion. Depending on the amount of remaining time, you could introduce a new discussion question or supplement the previous discussion or answer prevalent questions you noted on the students' response forms.

In our implementation, discussion of the assigned classroom discussion questions for FEM0, FEM1, and FEM2 were scheduled for the initial classroom discussion session (a 50-minute class). The second classroom discussion session (also a 50-minute class) encompassed the assigned discussions questions for two FEMs- FEM3 and FEM4. Content-wise, these FEMs are somewhat more complex. Thus, expect the corresponding discussions to be more difficult. Time permitting, it is desirable to quickly review a selection of the "one-minute papers" after each of the FEM discussions and comment or address questions. Questions posed during discussions of the first three FEMs (classroom discussion session one) can be delayed until the second classroom discussion session but that approach will not be possible in the case of questions submitted regarding FEM3 and FEM4.

Note: You rather than the course instructor will be responsible for conducting these sessions. The instructor should be invited to attend the discussion sessions if he or she is available.

To the extent possible, you are encouraged to review the students' response form submissions in advance of the classroom discussion session and note possible topics for a second discussion question time permitting and any prevalent questions that should be addressed during the classroom session.

Following the classroom discussion session, for each module, allow time for the students to submit a "one-minute paper" listing any lingering questions or misunderstandings they may have. Based on your review of the one-minute papers, you may determine the need to clarify or amplify one or more issues at the subsequent classroom discussion session or, in the case of the second classroom discussion session, address prevalent questions within the scope of the session if possible.

As indicated on the Master Schedule, Attachment A3 (an actual schedule used by Ayman in Fall 2016 at LSU), the five FEM discussion sessions can be accomplished in as few as two 50-minute classes. More time is desirable but not mandatory.

Note: Attachment A3 can be used as a template to prepare a Master Schedule for the SHM Fundamentals Education Subunit at your institution. In addition, Figure 2 is adaptable for SEM 1-2 and SAM 1 of the SHM Applications Education Subunit as well.

4. Assessment Survey. Subsequent to each classroom discussion session, students should be requested to complete the relevant assessment surveys. Editable versions of the assessment surveys are provided on the password-protected Faculty Instructional Resources webpage of the FMM Project Home Page. Some means will have to be devised to either provide hard or electronic copies to the students if revised versions of the assessment surveys are preferred. Otherwise, students can access the existing

assessment surveys on the Student Education Resources webpage which is accessed via a hyperlink on the FMM Project Home Page.

5. Student Focus Group Interview (Optional). Upon completion of the Fundamentals Education Subunit, it is desirable but not mandatory to conduct a focus group interview. However, this activity should not be conducted by you. A description of the focus interview process is provided at:

https://en.wikipedia.org/wiki/Focus_group

Whereas an experienced moderator is preferred, an adequately prepared colleague can manage the interview. You will need to develop no more than 3-5 questions to be explored during the interview. For example:

What the students liked about the Fundamentals Education Subunit?

What the students disliked about the Subunit?

How could the Subunit be improved?

III. SHM APPLICATIONS EDUCATION SUBUNIT

The SHM Applications Education Subunit encompasses two types of learning modules. One set of modules (SEM1 and SEM2) relate to structural engineering in general and more specifically to bridge design and management. Thus, they can be termed Structural Engineering Education Modules (SEMs) and supplement the content of the FEMs which encompass the broader and non-discipline specific Structural Health Monitoring (SHM) principles, methods, technologies, equipment and practices. The latter modules (SAM1 and SAM2), termed Structural Engineering Assignment Modules (SAMs), serve to introduce students to the specific techniques and equipment of Structural Health Monitoring through both design/evaluation and demonstration of SHM systems.

A. PLANNING PHASE

The Planning Phase for implementing the SHM Applications Education Subunit mirrors that of the SHM Fundamentals Education Subunit. Like the SHM Fundamentals Education Subunit, the Applications Education Subunit consists of four learning modules- two SEMs and two SAMs. The latter SAM encompasses the demonstration of a SHM system using a specially designed model. Thus, an important and time-consuming aspect of the planning phase is the fabrication, instrumentation and preliminary testing of the demonstration model- details follow in Section III.A.5.

As previously discussed, planning the implementation of the SHM Applications Education Subunit consists of addressing the following questions, more or less in the order indicated. Our guidance is based on our experience in implementing the Subunit at LSU and UL-

Lafayette over the 2016-17 Academic Year. As noted earlier, this guidance was also based on the results of the implementation and assessment of the Subunit at four partner institutions: Case Western Reserve University- 2017/18 Academic Year; Tuskegee University- 2017/18 and 2018/19 Academic Years; University of North Florida- 2017/18 Academic Year; and VA Tech, Summer 2018 and 2019. Your local circumstances may dictate somewhat different approaches.

1. Who? You may or may not be the faculty member in whose course the SHM Applications Education Subunit is implemented. If you are not teaching the requisite structural design course in the subsequent semester, it will be necessary for you to negotiate with a colleague to implement the Subunit.

This negotiation will require you to come to an agreement with the relevant colleague concerning the following issues:

Permission to implement the SHM Applications Education Subunit in the relevant course.

Identification of at least two 50-minute class periods (or an equivalent period of time consistent with the structure of the course) to conduct the classroom discussion sessions. It is desirable that these sessions be scheduled during the first 2/3's of the semester if at all possible.

Willingness of the course instructor to:

1) include a section in their syllabus concerning the plans for implementation of the SHM Applications Education Subunit. See Attachment A1;
2) give the students some meaningful credit for their participation in the SHM Applications Education Subunit. If possible, this should also be clearly indicated in the course syllabus. See the discussion in Section II.A.1 for some ideas concerning a possible grading model;
3) provide you with 10-15 minutes in a class period several weeks in advance of the implementation of the Subunit to introduce the topic and the education pedagogy. Attachment A2 provides a summary of the possible content and scope of that discussion. Attachment A3 is an example of the Master Schedule referred to in Attachment A2. Whereas Figure 2 provides a graphical representation of the SHM Fundamentals Education Subunit pedagogy, it can be easily adapted to the SHM Applications Education Subunit. Encourage but do not request the instructor to embrace the program with some explicit supportive comments to the students. However, the instructor can certainly be invited to comment if he or she desires;
4) limit or eliminate course homework assignments during the SHM Applications Education Subunit implementation period; and

5) send email reminders about the out-of-class activities for the SHM Applications Education Subunit, or giving you access (email list for class roster) to be in charge of the reminders. **The latter approach is recommended.**

Note: All the noted Attachments are a part of this Guide making it possible to revise the documents to coincide with your local circumstances and schedule.

2. What? You will need to decide how and in what form you will make the following documents available to the students.

SEMs (SEM1 and SEM2) *

SAMs (SAM1 and SAM2) *

Readiness exams (two for each SEM and SAM)

Classroom discussion question response forms (one for each SEM and SAM) *

Assessment surveys (one for each SEM and SAM) *

*Note: Students can access these documents directly from the Student Education Resources webpage which is accessed via a tab on the FMM Project Home Page.

Editable versions of all these documents are available on the password protected Faculty Instructional Resources webpage which is reached via the FMM Project Home Page.

Note to new adopters: It will be necessary for new adopters to develop a scheme to provide their students with access to the readiness exams. That will also be the case if alternative assessment surveys are desired.

Ayman provided relevant documents (suggested Master Schedule and Subunit Pedagogy), the modules, the readiness exams and the classroom discussion response forms to the students via Moodle, LSU's learning management system. If your institution uses Moodle, the "ready for upload package" of the entire Subunit can be transferred to you.

3. When? Planning and any needed negotiations with colleagues should be initiated several weeks in advance of the date that course syllabi are normally prepared.

It has already been indicated the desirability of implementing the Subunit before the last third of the semester. Our experience has indicated that students are more focused on normal course and project requirements during the last third of the semester which obviously detracts from their attention to the requirements of the Subunit.

4. Where?

a. Relevant courses. Generally speaking, most civil engineering undergraduate curricula include a required structural design course (possibly reinforced concrete or steel) which is normally preceded by prerequisite courses in strength of materials, materials testing and structural analysis. The SHM Applications Education Subunit was designed for implementation in such a course. It is irrelevant which design course is used to implement the SHM Applications Subunit. The critical issue is that the structural design course should immediately follow the structural analysis course and deal with the same or a large subset of the student cohort from the structural analysis course. Students for whatever reason did not complete the SHM Fundamentals Education Subunit can be asked to review FEM0-FEM4 in advance of initiating their work on the SHM Applications Education Subunit.

b. Space. Classrooms with movable rather than fixed seating are more conducive to forming student discussion groups but can be satisfactorily accomplished in either setting. As discussed later, some advance consideration does have to be given to the suitability of the classroom for the model demonstrations.

5. Fabrication of the SHM Applications Education Subunit Demonstration Model. It is important to initiate fabrication of the SHM Applications demonstration model well in advance of the date of its use in the SHM Applications Education Subunit. Sufficient time must be provided to secure materials, fabricate the model, experiment with the model, and refine any components of the model or your demonstration methods.

***Note to new adopters:* The fabrication and use of the demonstration model herein described have been found to be satisfactory by the project investigators. However, new adopters should not feel constrained to exactly duplicate either the components of the model or the demonstration of the model.**

The model consists of the following elements and components: end supports (2); the test specimen- a beam incorporating a means to introduce damage; a load application system; instrumentation (LVDT, two strain gages and a tilt meter); an LVDT support bracket; a four-channel intelligent Ethernet node; and a laptop loaded with the data acquisition and data graphing software. While we have not found that to be the case, a lateral support system for the top chord of the test specimen may be required. The instrumentation, software and Ethernet node are listed on the password protected Faculty Instructional Resources webpage that is accessed via the FMM Project Home Page.

The other components must be fabricated by new adopters. The end supports, lateral support system, test specimen and load application system will require acquisition of materials and fabrication of elements.

a. End supports. Pictured below is one of the two end supports for the demonstration model. The beam rests on a circular dowel spanning the two vertical legs of the support. Note in the LHS photo that if necessary, the space above the beam on the support can be used to accommodate a lateral support system for the compression face of the beam. The RHS photo illustrates a spacer that provides lateral support for the beam at the support.





Given the photos above and with the materials and connectors in hand, time of fabrication should not exceed 4 hours. Alternate designs that incorporate the features of the supports pictured are acceptable. It is important to provide adequate vertical clearance between the floor and the lower edge of the specimen to accommodate the loading yoke, the load hanger and the loads. Whereas stable supports are mandatory, also being lightweight will facilitate transport to a classroom for the demonstration. The cost of the materials should not exceed $50 at a local Home Depot or Lowe's.

b. Lateral support system. Whereas this is a consideration in the design and fabrication of the support system, we determined that a lateral support system was not required. *Within the range of load utilized for the demonstration tests, the compression face of the beam did not show a tendency to buckle.*

c. Test specimen. As indicated in the shown photo, the recommended test specimen is a PVC board with actual dimensions of 1" x 3 1/2" x 10' (available at Lowes at a cost of about $30). We recommend the purchase of two identical boards; one to simulate an undamaged beam scenario and the other modified to simulate the damaged scenario.



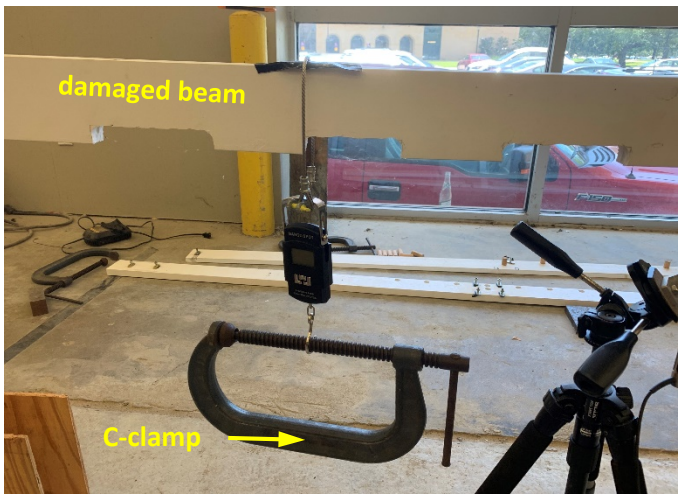
The board is configured as a simply-supported beam loaded at the third points. Attachment A5 (Appendix), provides a drawing of the details of the beam. It is recommended that the following locations be marked on the specimen: locations of supports for a span of 7 ft; midspan; and locations of load applications at the third points. As explained in Attachment A5, we initially simulated damage by drilling a total of seven 0.75" inch diameter equally spaced holes in the compression zone within the middle third of the beam. An additional hole is drilled at the center of the depth of the member at midspan. The plan was to tightly fit wooden dowels in these holes to simulate the undamaged state. Initially, the plan worked satisfactorily, however, with repeated loadings of the beams, the holes became loose for the wooden dowels. Therefore, we switched to an alternative plan where two beams would be used; a damaged beam and an undamaged one as seen below.



d. Load application system.



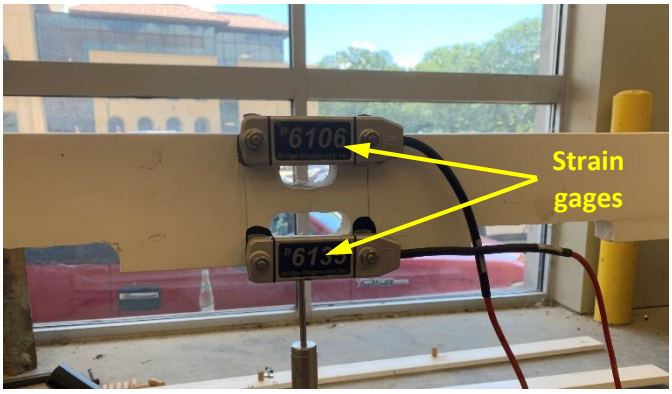
Application of loads at the third points of the span is recommended. This will allow placement of the strain gages and LVDT at midspan without interference from the loading system. As depicted in the photo below, the load application system is composed of two components: two loading yokes and a load platform. The loading yoke is fabricated using a 1/8" diameter stainless steel cable to which 1/8" thimbles have been swaged on either end. The total length of the yoke from end to end is approximately 9". This is not a particularly critical dimension but is sufficient to allow the thimbles of the yoke to extend below the test specimen where they can be joined to allow insertion of the hanger for the load platform. The yokes can be fabricated by either a marine supply or hardware store for less than $10. You will need two. The load hanger (two required) consists of a ¼" dia x 6" long open eye-bolt with a wooden or metal plate on which to place slotted weights. One possible source of such weights is the geotechnical laboratory at your institution which typically uses such weights for consolidation and, in some cases, direct shear testing. However, any weights that can be securely hung from the yoke can be used. We successfully used C-clamps weighing approximately 7 pounds each in our demos. Inexpensive scales luggage were used to measure the loads.



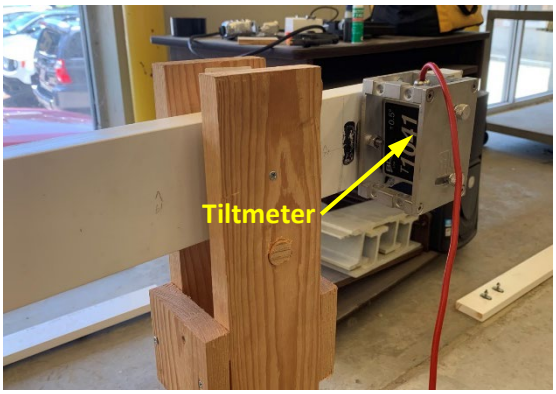
e. Installation of monitoring instrumentation. The BDI instrumentation package used by the project includes a LVDT, two strain gages, and a tilt meter. See a complete listing of the equipment in the password protected Faculty Instructional Resources webpage that is accessed via the FMM Project Home Page.

All the devices are wired. Also included are a data acquisition unit and data acquisition and processing software. Considering the test specimen is a simple beam loaded at the third points, the locations for the installation of the monitoring devices were selected to correspond to those that would result in maximum outputs.

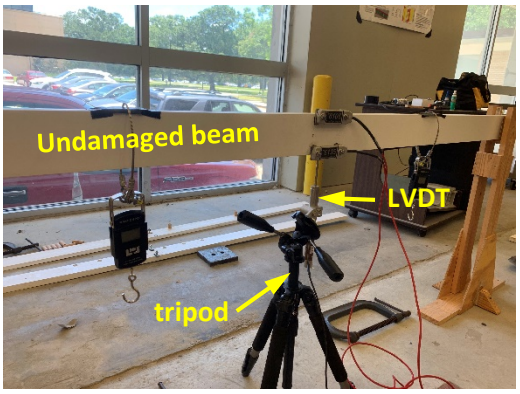
i. Strain gages- The strain gages are affixed to tabs epoxied as close as possible but equidistant to the lower and upper extreme fibers of the test specimen at midspan. The tabs are provided as part of the BDI instrumentation package and were epoxied using Loctite 410 black cyanoacrylate adhesive and Loctite 7452 amber activator to accelerate the setting time.



ii. Tilt meter- The tilt meter is affixed to studs epoxied to the lower chord of the test specimen near the RHS support.



iii. LVDT- The LVDT is not attached to the specimen but to a free-standing tripod resting on the floor. Thus, it is arranged after the specimen has been placed on its supports. In the test configuration, the device is positioned below the midspan of the test specimen.



It is important to organize and protect the wires from inadvertent disturbance during the demonstration period. Cautioning the students to be avoid the wires is a good practice.

The SHM Applications Education Subunit encompasses demonstrations with a physical model that will require a floor space approximately 3' x 10'; a table to place a SHM Data Acquisition (DAQ) system and a laptop loaded with the SHM software. Even though our laptop and DAQ system were battery powered, a typical power source may still be needed to power auxiliary attachments. In addition, the end supports, specimen, and lateral support system will need to be transported and set up in the classroom. Thus, some consideration should be given to the ability to access the classroom in advance of the class to prepare the model. Alternatively, the students could be advised to meet in an available laboratory space where the model could be assembled in advance.

All the detailed instructions and drawings concerning the SHM demonstration model will be posted on the Faculty Instructional Resources webpage.

Note for new adopters: ***There are obviously a number of options that exist for designing and fabricating a model and utilizing equipment likely available in your laboratories that can be used to demonstrate the devices and practices used for SHM. Faculty members adopting the SHM Education Unit for implementation at their institution are encouraged to use their expertise and locally available resources to achieve the stated student learning outcomes for SAM2.***

B. IMPLEMENTATION PHASE

1. Implementation of the SEMs/SAMs. The SHM Applications Education Subunit introduces students to the design, planning, and employment of structural health monitoring through a series of four modules consisting of two Structural Education Modules (SEMs) and two Structural Assignment Modules (SAMs). Unlike the SEMs and SAM1, SAM2 is an activity organized around the SHM demonstration model. In practice, implementation of SEM1-SEM2 and SAM1 closely follow the same pattern as that used for FEM0-FEM4. Specific implementation guidelines for SAM2 are provided in Section B.2 below.

SEM1- Planning SHM Projects

SEM2- Design of SHM Systems

SAM1- SHM Assignment: Develop SHM Plan

SAM2- SHM Demonstration Model Testing

Listed in each SEM and SAM module are the expected student learning outcomes for the module.

Links to PowerPoint slide shows are posted on the Student Education Resources webpage. Links to the same but editable versions are posted on the password protected Faculty Instructional Resources webpage that is accessed via the FMM Project Home Page.

Note: Editable versions of the PowerPoint slides for the SEMs and SAMs are provided to the faculty on the password protected Faculty Instructional Resources webpage accessible through the FMM Project Home Page but care should be taken that any revisions adequately address the stated student learning outcomes and do not invalidate the readiness test questions.

a. Overview. According to the proposed implementation sequence, the students in the design implementation course should have already been exposed to the SHM Fundamentals Education Subunit in the preceding semester or certainly preceding the SHM Applications Education Subunit. Therefore, we do not have a module like FEM0 that is dedicated to informing the students on the overall scope of the SHM Education Unit. Instead, the FEMs (FEM0 through FEM4) are available to them on the Student Site in case they would like to refresh their memory.

The pedagogical model for the SHM Applications Education Subunit is essentially identical to that explained earlier (see Figure 2), which is briefly summarized here:

A total of four learning modules- two Structural Education (SEMs) and two Structural Applications (SAMs) which are to be completed sequentially. The latter SAM is actually an activity using the SHM demonstration model.

Two versions of a readiness exam consisting of 8 multiple choice or true/false questions for assessing the students' level of achievement of the identified learning outcomes for each module.

Upon satisfactory completion of the readiness exam, students submit their response to an assigned classroom discussion question using an online response form. The response form also solicits any questions the students might have concerning the content of the relevant learning module.

Should time permit, you are encouraged to review the students' classroom discussion response form submissions in advance of the classroom discussion session and note possible topics for a second discussion question should time permit. In addition, any prevalent questions should also be noted and addressed to the extent possible during the classroom discussion session.

At the end of the time allocated to the classroom discussion, students submit a "one-minute paper" listing any lingering questions or misunderstandings they may have. To the extent possible and within the constraints of time, you should review the one-minute papers and do your best to address any pervasive questions/concerns.

Finally, the students complete an assessment survey. Access to PDF versions of the surveys is provided on the Student Education Resources webpage which is accessible via the FMM Project Home Page.

***Note for new adopters:* WORD versions of the surveys are provided in the password protected Faculty Instructional Resources webpage accessible via the FMM Project Home Page should there be a desire to use revised versions of the surveys.**

b. Implementation Sequence. The sequence in which the SEMs and SAMs are implemented (i.e., the education pedagogy) is similar to that depicted graphically in Figure 2.

Note: As previously indicated, Figure 2 depicts the SHM Fundamentals Education Subunit pedagogy not the SHM Applications Education Subunit

pedagogy. However, the figure can easily be revised to illustrate the SHM Applications Education Subunit pedagogy.

Implementation of the SHM Applications Education Subunit begins with your presentation to the class as described in I.A.5. With some minor revisions, Attachment A2 can easily be adapted to be used as a guide for the possible content and scope of that discussion. In advance of that presentation, you will need to prepare the following documents (adapted/revised for the Applications Education Subunit) for distribution: Master Schedule (Attachment A1) and a graphical representation of the SHM Fundamentals Education Subunit pedagogy (Figure 2). The dates listed on the Master Schedule will have to be adjusted to fit your other calendar commitments and/or agreement with the class instructor.

No online pre-treatment survey is suggested or provided for use in advance of the implementation of the SHM Applications Education Subunit. However, such a pretreatment survey might be used to determine if a significant number of the students did not complete the SHM Fundamentals Education Subunit.

As with the SHM Fundamentals Education Subunit, the order and timing of the implementation of SEMs/SAMs has to be summarized by the Master Schedule provided to the students. This schedule will be dictated by the amount and periods of class time you can negotiate with the course instructor. The three discussion sessions for SEM1-SEM2 and SAM1 can be accomplished in as few as two 50-minute classes. The discussion session for SAM2 is actually an activity with the demonstration model, which can also be completed in 50 minutes with proper preparation to avoid unforeseen snags.

Based on self-reporting, students at LSU indicated that they generally completed review of each of the SEMs and SAM1, taking the readiness exam and submission of the discussion question response form within 1 ½- 2 hours, normally less. Completion of the assessment survey following the classroom discussion session requires another 10-15 minutes at most.

c. Managing the classroom discussion session. The same recommendations on conducting classroom discussions described earlier for the SHM Fundamentals Education Subunit can be used for the SHM Applications Education Subunit.

Note: Again, we would like to emphasize that YOU, rather than the course instructor, will be responsible for conducting these sessions. The course instructor should be invited to attend the discussion sessions if he or she is available.

To the extent possible, review the students' response form submissions in advance of the classroom discussion session and note possible topics for a second discussion question should time permit. To the extent possible, any prevalent questions submitted by the students on their classroom discussion question response forms should be addressed during the classroom discussion session.

Following the classroom discussion session for each module, allow time for the students to submit a "one-minute paper" listing any lingering questions or misunderstandings they may have. In conclusion, ask the students to complete the assessment survey. Based on your review of the one-minute papers, you may determine the need to clarify or amplify one or more issues at a subsequent classroom discussion session if possible.

2. Implementation of SAM2

a. Overview- The basic goal of SAM2 is to demonstrate typical instrumentation installations and monitoring for SHM applications. This goal is achieved with the use of an instrumented demonstration model designed and fabricated to illustrate non-damaged and damaged behavior of a simply-supported beam under static loading (see Section II.A.5). Monitoring is achieved in three ways: (1) one LVDT located at midspan of the beam; (2) two strain gages mounted adjacent to the upper and lower chords at midspan of the beam; and (3) one tiltmeter mounted on the lower chord of the beam near the RHS support. Adequate time is needed to test the beam in both its undamaged and damaged configurations. In our experience, at least 35 minutes are needed to test both beams. This includes engaging the students in the experiment and providing them with the real time results on the classroom screen, which they should record on a lab sheet that is included in SAM2.

b. Suggested span and loading arrangement- A span length of 7'-0" is recommended for the beam. Within the recommended loads and loading configuration, that span length will produce reasonable responses from the monitoring devices but avoid lateral torsional buckling due to the compression side of the beam. Loads should be applied at the third points of the beam via the loading apparatus described in Section II.A.5.d. A four-point loading also has the advantage that the midspan of the beam is accessible for mounting the strain gages and locating the LVDT. Given the beam and loading configuration previously described, individual loads of 7 lbs. resulted in satisfactory responses

of the monitoring devices in both the undamaged and damaged states of the beam. More details about the beam's geometry can be found in Attachment A5.

c. Suggested demonstration protocol- The model should be completely configured in advance of the demonstration if possible. This will help dedicate the class time to the demonstration itself, discussions, and interpretation of results. The following steps are suggested:

Step 1: After a brief description of the test configuration and circumstances, the students can be asked to identify and justify the "best" locations for each of the monitoring devices: strain gages, LVDT and tilt meter.

Step 2: Initial readings are recorded for each of the monitoring devices. It is desirable to have access to a white board or poster stand to record these readings. The beam is statically loaded at the as described earlier using a load of 7 lbs. at each loading location. The new readings for each of the monitoring devices are recorded and posted. The Graphic User Interface (GUI) of the Data Acquisition (DAQ) software is displayed on the screen. This allows the students to observe the changes in sensor readings in real time. Once the readings stabilize, the differences in the unloaded (initial) and loaded readings for the beam are determined and recorded by the students on the lab sheet provided in SAM2 material. It is suggested that test is repeated at least three times by unloading and then reloading the demo model. This will ensure a representative and quantitatively consistent set of readings is available for comparison purposes.

Step 3: After the undamaged beam testing is completed, and the damaged beam is configured using an identical setup (span length, load points, sensor locations) to what was used for the undamaged beam. Before being reloaded to it previous loaded state, the students are asked to speculate on both the nature and the quantitative changes in the monitoring device readings, for which they can use some of their responses to SAM2 readiness exams. That is, will they decrease, increase or stay the same- that should be easy! Harder, is to speculate on the relative magnitude of the changes in the readings. It may be best to provide possible choices- less than 20%, 20%, 50%, 100%, 150%, 200% and greater than 200%. It would be illustrative to have these choices posted on a white board or poster and have the students anonymously vote their choices. Concentrating specifically on the relative deflection values, the students are likely to be surprised by the comparatively small differences in the deflections for the undamaged and damaged beam. Thus, using their

knowledge of structural analysis, can they provide a qualitative explanation for the comparatively small difference in the deflection readings?

Finally, the students should spend a few minutes to interpret the results as suggested in SAM2 by preforming the data analysis of the pre- and post-damage readings.

Note: The suggested means and questions to engage the students are certainly not the only possibilities. We encourage you to think of other creative ways to engage the students, thereby making the experience more meaningful and educational.

APPENDIX

ATTACHMENT A1
SUGGESTED TEXT FOR INCLUSION IN STRUCTURAL ANALYSIS COURSE SYLLABUS

Structural Health Monitoring (SHM) Education Unit: Fundamentals Subunit

During this semester, you will be introduced to the principles, tools, methods, purposes, utility, and limitations of Structural Health Monitoring (SHM) through a series of five SHM Fundamentals Education Modules (FEMs). In a subsequent semester, you will explore SHM applications through a series of two structural engineering modules (SEM1-SEM2) and two applications modules (SAM1-SAM2). The latter module actually features testing a SHM demonstration beam.

Along with other courses in your curriculum, these education modules and experiences will contribute to several student learning outcomes established by the Accreditation Board for Engineering and Technology (ABET) as essential to engineering graduates. Specifically, the following outcomes specified by the 2021-22 Accreditation Criteria,

> 2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
>
> 5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
>
> 6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
>
> 7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Within the context of your structural analysis course, you will complete five SHM Fundamentals Education Modules (FEMs):

- Fundamentals Education Module 0 (FEM0): Rationale Brief
- Fundamentals Education Module 1 (FEM1): An Introduction to Structural Health Monitoring
- Fundamentals Education Module 2 (FEM2): SHM Methodology and Testing Categories
- Fundamentals Education Module 3 (FEM3): Sensor and Data Acquisition Technology

- Fundamentals Education Module 4 (FEM4): Analysis and Interpretation of SHM Sensor Data

These modules will build upon fundamentals from courses in Mechanics of Materials and Mechanics of Materials Laboratory as well as Structural Analysis. You will be introduced to the applications of Structural Health Monitoring during your subsequent structural design course.

The instructional methodology for the SHM Fundamentals Education Modules (FEMs) will consist of the following sequential elements:

- You will read and study the content for the module on-line. You will be provided with a detailed schedule for completion of the education module and the dates of the classroom discussions.
- With exception of FEM0, you will complete a readiness exam on the content of the module. Must complete with a score of 80% or greater.
- You will submit a response to a discussion question and list any lingering questions you may have about the content of the FEM.
- You will actively discuss your response to the discussion question with classmates in a subsequent class and be prepared to discuss the responses of your discussion group in a classroom setting.
- Following the classroom discussion session, you will be asked to submit a "one-minute paper" to the instructor listing any of your unanswered questions concerning the content of the FEM.
- Finally, you will be asked to complete an assessment survey regarding the quality of the module.

At the conclusion of the SHM Fundamentals Education Subunit, you may be asked to voluntarily participate in a focus group evaluation interview.

Note: Course Credit- To be determined by course instructor but should be listed in the syllabus. It is important that the students understand that they will receive course credit for their participation in the SHM Education Unit.

ATTACHMENT A2
SUGGESTED CONTENT OF PRESENTATION TO STUDENTS IN STRUCTURAL ANALYSIS COURSE

Structural Health Monitoring Education Unit- Fundamentals: Extra (?) Credit Opportunity

Note: This example only strictly applies to your classroom presentation regarding the SHM Fundamentals Education Subunit but with some revision can be adapted for introducing the SHM Applications Education Subunit.

With the cooperation and support of your course instructor, you will be introduced to the fundamentals of a comparatively new and important technology- Structural Health Monitoring (SHM)- through a series of five online education modules and two classroom discussion periods (state dates). For your active participation in this Unit, you will have the opportunity to not only enhance your academic preparation for professional practice but earn credit in the course.

You will explore SHM Applications next semester in your reinforced concrete (steel?) design course (***Note: adapt this statement to your local circumstances***). This will include an opportunity to observe a demonstration of an actual SHM monitoring system installed on a model beam which can simulate both undamaged and damaged behavior.

The manner in which you will proceed through each of the SHM Fundamentals Education Modules (FEMs) is depicted on the flowchart (Figure 2) provided. We anticipate that the completion of each FEM will require no more than approximately 1 ½ hours of your time.

Since this is the initial introduction of the SHM Education Unit at (your institution), it is important to collect assessment data which can be used to improve the Unit for subsequent implementations. Initially, we ask that you complete the pre-treatment survey prior to (**give a specified date**). (Note: You will need to indicate how the students will complete the survey.) You will also be asked to complete a brief assessment survey subsequent to your completion of each FEM. These surveys are accessible via the Student Education Resources webpage.

Note for new adopters: ***Editable versions of the assessment surveys are provided on the password protected Faculty Instructional Resources webpage accessible via the FMM Project Home Page should you desire to revise the surveys in any way.***

The Master Schedule (Attachment A3) provides both suggested completion dates for the various elements of the SHM Education Unit plus specific deadlines for the submission of responses to the discussion questions for each of the FEMs. It's important that you do your best to adhere to the suggested completion dates and deadlines.

Note: The Master Schedule will have to be revised for the specific circumstances at your institution.

ATTACHMENT A3
Sample Master Schedule for SHM Fundamentals Education Subunit

MASTER SCHEDULE FOR STRUCTURAL HEALTH MONITORING (SHM) FUNDAMENTALS EDUCATION SUBUNIT- Fall 2016

Unit	Component	Target Completion/Submission Date	Date of Classroom Discussion
	Pretreatment Survey	12 pm (noon), Friday, November 04,2016	
FEM0	Foundational Education Module Readiness Exam Discussion Question Submission Form Classroom Discussion	Friday, November 4, 2016 Not applicable 10 pm, Friday, November 04,2016	Monday November 7, 2016
FEM1	Foundational Education Module Readiness Exam Discussion Question Submission Form Classroom Discussion	Sunday, November 6, 2016 6 pm, Sunday, November 06, 2016 7 pm, Sunday, November 06, 2016	
FEM2	Foundational Education Module Readiness Exam Discussion Question Submission Form Classroom Discussion	Sunday, November 6, 2016 9 pm, Sunday, November 06, 2016 10 pm, Sunday, November 06, 2016	
FEM3	Foundational Education Module Readiness Exam Discussion Question Submission Form Classroom Discussion	Tuesday, November 8, 2016 6 pm, Tuesday, November 08, 2016 7 pm, Tuesday, November 08, 2016	Wednesday, November 9, 2016
FEM4	Foundational Education Module Readiness Exam Discussion Question Submission Form Classroom Discussion	Tuesday, November 8, 2016 9 pm, Tuesday, November 08, 2016 10 pm, Tuesday, November 08, 2016	
	Assessment	TBD	

Note: These are suggested dates and times. Students may deviate from the suggested schedule but all submissions are due no later than 2 hours in advance of the class for which the FEM is scheduled to be discussed

ATTACHMENT A4
Description of the FMM Project Home Page and the Faculty and Student Webpages

Introduction

The FMM Project Home Page can be accessed by clicking on the following link:

www.ltrc.lsu.edu/nsf/

While the Home Page is continually being updated and enhanced, in its current form the Home Page will provide you with the resources needed for planning and implementing the SHM Education Fundamentals and Applications Education Subunits. For implementation purposes, both Faculty Instructional Resources and Student Education Resources are needed and can be accessed via hyperlinks on the FMM Project Home Page.

The Faculty Instructional Resources webpage is password protected to ensure the resources can only be used by pre-qualified users and are not accessible to the students. While we do not intend to restrict potential users in any way, registration allows us to track and communicate with, as well as assist, interested faculty members. Guidance to acquire a password is provided via the hyperlink to the Faculty Instructional Resources webpage.

I. FMM PROJECT HOME PAGE

The FMM Project Home Page provides clickable hyperlinks to the following: details about the project and project personnel including relevant institutions; Faculty Instructional Resources (password protected) webpage; Student Education Resources webpage; and an email popup to contact one of the PI's of the project. A brief explanation of the contents of these links are discussed in the following sections.

A. The Project

1. Contents. Contained in this section of the Home Page is an overview and rationale for the project; brief bios of the project investigators; details concerning our Institutional Partners including bios of the lead faculty members at each institution; bios of the members of the Project's Advisory Panel and its External Evaluator; and bios of other project personnel.

2. Access. Public

B. Instructional Resources

1. Contents. Contained within the Faculty Instructional Resources webpage are: guidance to secure a logon id and password; copies of the PowerPoint versions of the FEMs, SEMs and SAMs copies of the pre-treatment and assessment

surveys; copies of the readiness exams and answers; copies of the discussion question response forms; and the Planning and Implementation Guide. The Instructor Guidance section includes a number of additional relevant documents, including but not limited to: results of a survey of local consultants on the relative importance of SHM education and results of a survey conducted through IISHMI to determine the relative importance of the operative student learning outcomes.

2. Access. Access to the Faculty Instructional Resources webpage of the FMM Project Home Page is password protected. Logon ids and passwords can be requested by completing and submitting a brief response form at:

http://www.ltrc.lsu.edu/nsf/register-for-access-to-instructional-resources.html

II. STUDENT EDUCATION RESOURCES WEBPAGE

As noted above, access to this page is via a hyperlink located on the FMM Project Home Page.

A. Contents. Links are provided for editable PowerPoint versions of the FEMs, SEMs, SAMs as well as editable versions of the discussion question response forms; the pre-treatment and assessment surveys (one for each FEM, SEM and SAM); and the readiness exams (two versions for each module).

Note for new adopters: ***As previously mentioned, new adopters will need to use the WORD versions of the discussion question response forms, readiness exams and pre-treatment and assessment surveys found in the password protected Faculty Instructional Resources webpage of the FMM Project Home Page if they wish to create revised versions of these documents.***

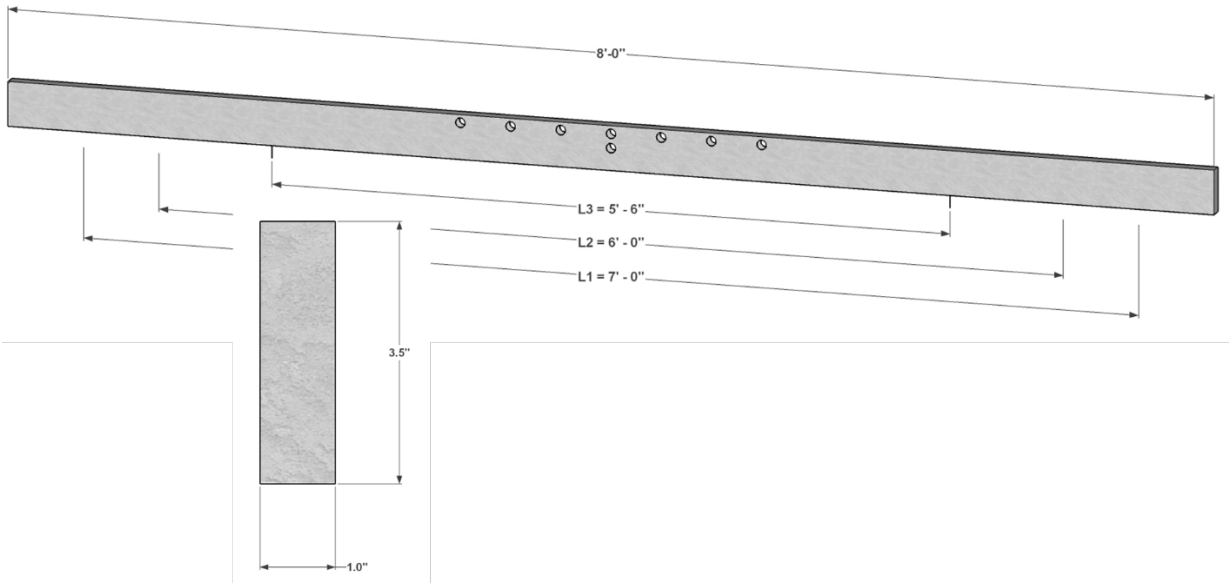
B. Access. Access to the Student Education Resources webpage is open, no password required. As with the password protected Faculty Instructional Resources webpage, the students access the Student Education Resources webpage via a hyperlink on the FMM Project Home Page.

ATTACHMENT A5
Details of Demo Model Specimen

Note: This appendix provides the thought process and details of the demo specimens that were implemented at LSU and ULL. Adopters should feel free to build similar models or design new ones that are more suitable for their available resources.

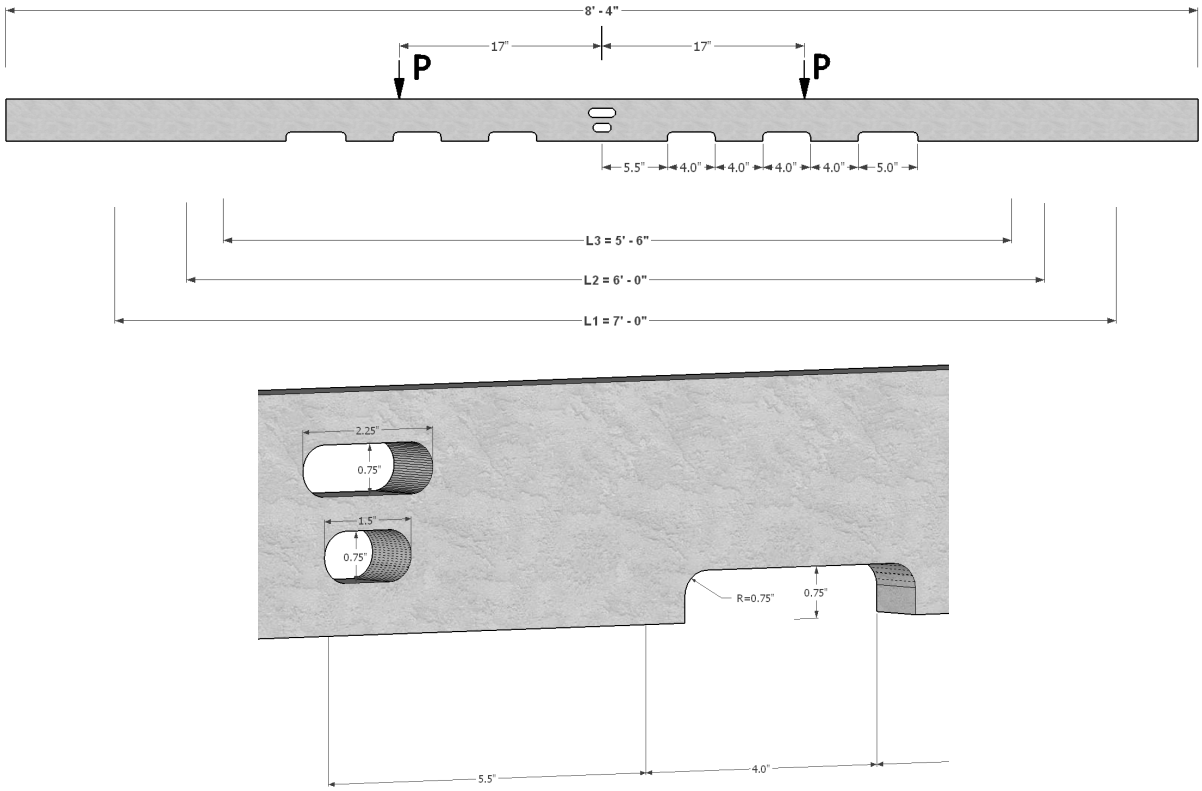
As stated in Section III.A.5, the demo model was fabricated from cheap PVC trim boards that are available at a nominal cost at Lowe's and Home Depot. This material choice was made to avoid the need to apply higher loads if the beam was made out of other materials instead (e.g. aluminum or timber). In addition to complicating the logistics, higher loads also pose more danger to undergraduate students in a hands-on demonstration.

Initially, an attempt was made to use a single beam that is damaged by drilling holes at various locations as can be seen in the figure below. The holes would then be plugged by inserting wood dowels in the holes, thus *simulating* an undamaged beam. This neat idea worked well initially. However, it was found that the holes got wider because of the repeated use of the wood dowels. Therefore, this attempt was abandoned for clearer damaged/undamaged scenarios with a slight increase in investment.



The current demo model requires two PVC trim boards; one will be undamaged, and the other will be damaged. The damage was simulated by trimming six locations at the bottom fiber as can be seen below. Trimming was easily done using a drill with a circular sanding drill bit. This more extensive damage than what was used in the initial model was thought to be necessary to make the difference between damaged and undamaged readings clearer to students. To make transporting the demo model easier, the 10-ft trim board was first shortened to 8ft-4in. Two 7-pound loads were applied in a 4-point

loading arrangement as shown in the figure. The beams' span length could be adjusted to any desired length. We chose to use a 7-ft span length (L1) in our implementation courses.



The LVDT was installed on a tripod and positioned to measure midspan deflections. Sensor tabs were pre-attached to the beams at the desired locations for both beams:

- Two for strain sensors at the top and bottom fibers of midspan where maximum flexure takes place.
- One for tiltmeters at one of the support locations where maximum slope takes place.