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Pedagogical Methods and Advances for Synchronous/Asynchronous Instruction of Laboratories in Engineering Technology Programs

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Abstract

Significant research has been done on the subject of distance learning (DL) instruction for many academic disciplines. However, when it comes to engineering technology (ET) programs, particularly, engineering laboratory work, limited studies are available. It is unquestionable that engineering laboratory work is essential for the successful preparation of individuals enrolled in ET programs. The focus of ET programs is on the correct use and application of engineering principles with a direct focus on practical application rather than on theory alone. The difficulties increase significantly when laboratories are offered in DL mode, particularly for ET programs. It is well known that DL instruction provides the unique opportunity to individuals to achieve an academic degree without being required to attend classes live during the day. A great number of people cannot attend face-to-face (F2F) lectures due to employment reasons, personal limitations, and/or military commitment, among other things. DL programs offer a viable solution to these limitations. Assessment of DL courses becomes more challenging than those that are F2F. As a result, asynchronous instruction is required to be more interactive than synchronous for obvious reasons. It is the interest of the authors to provide guidelines for the successful preparation and delivery of engineering laboratory work in asynchronous mode for ET programs. The guidelines will provide adequate techniques and methods for assessment in line with ABET outcomes for engineering technology programs. Lastly, the paper includes considerations to follow for continuous improvement models.

1. Introduction

The main interest of ET programs is to prepare students for successful transition into employment positions. The traditional college student in ET programs is no longer a recent graduate from high school. With the advent of computers and the new age of technology, students are being more accustomed to do things online. In fact, students feel more comfortable doing things online than we would like to admit. More and more students are employed full time and raising families. Consequently, they have less time available to attend colleges and universities the traditional way. Because of this change, ET programs have developed online courses in synchronous and asynchronous modes. Synchronous courses are taught live and transmitted to distant locations via Webex, a high-quality video system that allows the student to stream courses live while being videotaped. Those who can watch the courses live at the time they are offered can do so by simply logging into a secured server account. Those who cannot are able to watch video archives later during the day. Attending live lectures, of course, is highly encouraged by faculty. However, not everyone can actually benefit from this because several students live in different time zones, making this option impossible. Therefore, faculty members must account for this condition when developing their online course schedules. Imposing mandatory attendance and giving pop quizzes may result in problems to several students. Therefore, there has to be some flexibility on the part of the faculty.

Engineering laboratories form integral part of ET curricula. There are several laboratory types such as materials testing, fluids, soils, thermal, computer, and power energy labs, to name a few. Significant work has been documented in the past decade for asynchronous course development but not specifically for ET laboratories. This paper focuses on the development of a materials testing laboratory in asynchronous mode. The main goal is to set up guidelines for developing a successful laboratory online.

Tota-Maharaj [1] discussed the importance of providing an online support system for student's access to remote and distributed laboratory facilities. In addition, he emphasized that laboratory exercises are a key component of the learning experience. Feisel and Rosa [2] stated that engineers must have a knowledge of nature that goes beyond mere theory, knowledge that is traditionally gained in educational laboratories. Stefanovic [3] presented fundamental objectives of learning through distance learning laboratories as well as the special issues connected with these labs, including their effectiveness. Students' feedback was also discussed. Fabregasa et al. [4] used two main software tools: Simulink and Easy Java Simulations, which are control and authoring tools to build interactive applications in Java without special programming skills. The interactive remote laboratories RLs created by this approach give students the opportunity to perform experiments with real equipment from any location, at any time, and at their own pace. The paper also discusses an evaluation of the approach used according to students' criteria and academic results. Daud and Razali [5] described a proposed design and approach to improve asynchronous engineering technology laboratory experience using communication and control technology. They used the UniMAP e-Lab system that enables experimental knowledge in a particular field of engineering technology, and experimental results of the research are disseminated and exploited effectively. Solution design of hardware and software, as well as the characteristics of education, were discussed.

2. Materials Testing Laboratory

The materials testing laboratory is taught in conjunction with the strength of materials course as a pre or co-requisite. The lab aims to conduct experimental testing at a small scale. The lab focuses on safety practices, oral and written communication, analytical skills, team-work effort, equipment use, collection and processing of data, and observations. In addition, the lab is a writing intensive or W course. This means that at least 51% of the course has to include writing expectations, feedback, and report preparation as a part of the course syllabus. One of the main goals of the lab is to teach students to become effective writers. We must also train the students regarding experimental work. The student must be able to follow instructions, procedures, and be able to collect, process, and evaluate data. The grading of the reports heavily relies upon the student's ability to write coherently. The learning process must include techniques specially designed to improve the writing of professionally written reports. We can initiate this process by keeping the same rules utilized for teaching on campus labs but focusing more on the fact that students are not present. So the main constrain is how to overcome the fact that the student is not in the laboratory. Can we effectively teach someone things that are meant to be taught in person online? This largely depends on the course layout and techniques used that will be demonstrated here.

3. Course Layout

The lab must be well structured. Table 1 shows the breakdown of the course offered during a typical summer semester. The overall length of time is approximately fourteen weeks. Proper explanation of each section or module is required. The faculty must be able to develop an assessment process that combines both ABET student outcomes with course objectives. The student is required to complete a quiz at the end of the experiment, write a professionally written report that includes developing a short video explaining the findings, and taking a final comprehensive examination at the end of the course. Since this is an under-graduate course, students are guided through the process of generating a written report. A template is provided for the development of the report. A template is presented in the Appendix. The template is consistent with industry practices and can be implemented later on when they join professional practice.

Table 1 Course Schedule

Exp. No.	Title of Experiment	Starting Date	Ending Date or Due Date
-	Course Overview & Syllabi	May 14	May 19
1	Verification of a Testing Machine	May 20	May 26
2	Tension Test of Metals	May 27	June 2
3	Hardness Test of Metals	June 3	June 9
4	Compression and Flexure Test of Concrete	June 10	June 16
5	Compression and Flexure Test of Wood	June 17	June 23
6	Torsion Test	June 24	July 1
7	Impact Test	July 1	July 7
8	Fatigue Test	July 8	July 14
9	Nondestructive Testing	July 15	July 21
10	Shear Test of Metal Fasteners	July 22	July 28
-	Comprehensive Final Exam	July 29	August 1
-	Summer School Ends	August 3	-

The course objectives are noted below.

Course Objectives:

1. Understand the differences between experimental and theoretical designs.
2. Observe/learn how laboratory equipment operates.
3. Learn about safety in a laboratory setting.
4. Learn about collecting, processing, and presenting laboratory data.
5. Review and apply fundamentals learned in statics and strength of materials.
6. Prepare professionally written reports using Word and Excel or similar software.
7. Work effectively in teams.
8. Improve communication skills.

Additional lab objectives for each experiment must be developed by the faculty in charge. The use of measurable objectives is highly recommended such as determine, calculate, develop, construct, etc.

4. Student Interaction

One of the key components when teaching an asynchronous lab is to have constant communication with students. Since in-person instruction is not possible, it is important to explain procedures using a combination of techniques. This allows for an interactive experience, which enhances the learning process. Some recommendations are noted below.

1. Writing – Include in the experiment background clear writing procedures and instructions. A stepped process is recommended.
2. Graphs – If the student is required to develop a graph, a template should be included to avoid ambiguity.
3. Tables - If the student is required to develop a table, a template should be included to avoid ambiguity.
4. Pictures – Pictures are extremely helpful to provide an insight of the topic at hand.
5. Short videos – Short videos from the faculty member allow a break from long reading sessions and provide a sense of connection with the students. It also gives an opportunity for the student to get to know you.

It was mentioned earlier in the course layout section that students must develop and submit a short video with each report submittal. Since the course is asynchronous and interaction F2F is nonexistent, asking students to develop a short video explaining their reports solidly contributes to their development of communication skills. The evaluation of the student is simplified in Table 2. The students are provided about a week to review the lecture notes or modules associated with the lab. After completing this part, they have to write the technical report. The video presentation summarizes a week's worth of work.

Table 2 Oral Video Rubric

Items	9-10pts	7-8pts	5-6pts	Less than 5pts
Self-introduction	Provided his name	Provided his name. The setup can be improved	Provided his name, but the setup is marginal	Did not provide his name, and/or the setup is not ideal
Provided lab number and title	Clearly identified what he/she is doing	Provided a short version of the lab	Somewhat identified the lab	Very vague/poor identification of the lab
Provided summary	Provided clear goals and objectives	Somewhat provided goals and objectives	Provided some, but not all of the goals and objectives	Very poor presentation of goals and objectives

Provided requirements	Discussed in detailed form all lab requirements	Somewhat discussed all lab requirements	Provided some of the lab requirements	Very poor presentation of lab requirements
Discuss equipment and materials used	Discussed all equipment and materials used	Somewhat introduced the equipment and materials	Provided some of the equipment and materials	Very poor presentation of materials
Discussed collection and processing of data	Adequately discussed collection and processing of data	Somewhat discussed collection and processing of data	Provided some, but not all of the collection and processing of data	Very poor presentation of collection and processing of data
Discussed results	Very clear presentation of results	Somewhat discussed the results obtained	Provided some of the results but were incomplete	Very poor presentation of results
Provided a conclusion	A conclusion was provided highlighting main observations and results	Somewhat of a conclusion was provided highlighting observations and results	Provided a brief conclusion with some of the observations and results	Very poor conclusion with little to no observations and results

5. Effective Use of Technology

The background provided for each experiment is not intended to replace a book. While great effort is placed in providing equations and procedures, the lab is taken concurrently with the strength of materials course. At the very least, the student must have already taken the pre-requisite in order to take the lab. Hence, the student must research the subject matter. The lab course is also intended to teach the student about the use of Excel and Word. The student is required to use these to improve their presentation skills. For instance, setting up a database and being able to enter equations of engineering mechanics to eventually plot graphs, add titles, change the scale of the axes and/or identify relevant points on the graph itself. These exercises solidly contribute to the correct use and application of technology in the classroom. Most of the equipment is also operated by commercial software and students are provided with operational procedures. This allows the student to become familiar with different lab equipment vendors.

6. Communication and Feedback

One of the key components in asynchronous courses is the students' communication and feedback. The most difficult thing for students is to read information and have a clear understanding of the procedures and lab requirements. It is thus suggested to be specific and concise when developing instructions and/or procedures. Likewise, the grading process must be thorough. Comments must be added to the pdf submitted by the student following a well-crafted rubric. The lab course is linked to Blackboard, which is a communication tool between the faculty member and the students. It is also a place where course documents, handouts, announcements, and grades can be accessed. The faculty member shall post frequently asked questions FAQs, friendly reminders, and general feedback shortly after entering grades at the grade center. Individual feedback is provided on the reports, which are transmitted to students electronically. It is the recommendation of the authors to provide comments on the reports, but to be concise. In addition, constructive criticism is highly encouraged.

7. Assessment

The students must be assessed using the overall and specific course objectives. These must be tied to the ABET student outcomes. For materials testing laboratory, the following ABET outcomes are recommended:

c. an ability to conduct, analyze, and interpret experiments, and apply experimental results to improve processes
e. an ability to function effectively on teams
f. an ability to identify, analyze, and solve technical problems
g. an ability to communicate effectively

These outcomes are taken from the 2018-2019 Criteria for Accrediting Engineering Technology Programs. In addition, the students must be assessed analytically. Likewise, it is very important to obtain feedback from the students in the form of surveys. Surveys should be made available immediately after submittal of each report. Some of the basic questions asked are presented below.

Q1. Based on your experience with online courses, what is your overall impression about this module?
Q2. Were the module objectives clear?
Q3. Were module activities aligned with the module content and resources?
Q4. Were the module resources helpful in understanding the content and completing your assignments?
Q5. What worked best for you in this module?
Q6. What worked least for you in this module?
Q7. What other comments and suggestions do you have about this module?

8. Conclusion

This paper provides effective guidelines for the successful preparation of an asynchronous laboratory. The organization and structure of the lab plays a very important role in the success of this model. The lack of F2F interaction requires constant communication from the faculty and the student. The use of the rubrics provides an effective system of evaluation. The introduction of the development of a video presentation by the student to explain his/her findings significantly improves the overall results of the course. In addition, the student significantly improves presentations skills. Use of common Microsoft products like Word and Excel are emphasized throughout the lab. The inclusion of templates to prepare tables, graphs, and reports provides consistency in the work produced by the students and similarities to the work they will encounter in engineering consulting practices. This altogether provides an additional sense of understanding of what is expected after college.

References

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Biographical Information

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Dr. ALOK K. VERMA, P.E. is Ray Ferrari Professor in the Engineering Technology Department at Old Dominion University (ODU). Dr. Verma received his BS in Aeronautical Engineering from IIT Kanpur, MS in Engineering Mechanics and PhD in Mechanical Engineering from ODU. Prof. Verma is a licensed professional engineer in the state of Virginia, a certified manufacturing engineer, and has certifications in Lean Manufacturing and Six Sigma. Dr. Verma's research interest lie in the areas of organizational productivity, process improvement, agility of organizations, lean manufacturing, six sigma and non-traditional manufacturing processes.

Appendix

1. Report Template

The report must include a cover letter with the following information at the minimum.

1. Full Name
2. Course and Term
3. Experiment name and number
4. Department's name
5. Date of submittal

Table of Contents

1. Summary

This is an abstract. Briefly explain what the experiment is all about. The sections noted below can be organized back to back. Use single space and Times New Roman number 12 font.

2. Procedure

Provide the necessary steps required to conduct the experiment. Be specific.

3. Laboratory Equipment

Indicate the name of the equipment needed to conduct the experiment. Also, indicate all other necessary instruments required. Add pictures of the equipment to enhance your report presentation. Add a figure number and a name/title to each one.

4. Experiment Requirements

This is what is expected to be determined. Make sure the goals and objectives for each experiment are met. See the coursepak for details.

5. Required Data

This is the data that is collected to produce the report. Use the data tables' format provided in the coursepak to organize/present this information. Embed the necessary tables and graphs from Excel or similar software.

6. Sample Calculations

Add sample calculations to substantiate how you arrived at your results. No need to repeat the same process for all data points or subsequent steps. If the procedure changes then add additional sample calculations.

7. Sketches/Graphs

Provide sketches or free body diagrams of the specimens for testing. Use a reasonable scale if you decided to draw anything. Feel free to use AutoCAD, if you like. Also, provide any tables or graphs that may be needed to obtain results. Clearly indicate what your selections are and/or how you made any selections. The use of Excel to develop tables and graphs is mandatory.

8. Conclusion/Analysis

Provide a brief conclusion of the laboratory. What did you find out? What constraints did you run into? What potential suggestions you have in order to obtain similar results? Did you meet the objectives for the lab? Be original in your response. The conclusion is not a book type response.

2. **Table 3 Report Rubric**

Item	5 9-10pts	4 8-9pts	3 7-8pts	2 6-7pts	1 Below 6pts
Report Template **10%**	Used the template provided. Modified all parts. Name, title of experiment, and date are required.	Used the template but some sections are somewhat incomplete.	Used the template but sections are missing or incomplete.	Used the template but hardly made changes to it.	Did not use the template or didn't follow instructions at all.
Equipment and materials used **15%**	Included pictures, figures, and diagrams of the equipment and materials. All specimens are clearly defined. All items are identified.	Included pictures, figures and diagrams but some are not clearly defined or properly identified.	Some pictures, figures, and diagrams are missing and are not properly defined or identified.	Hardly any information related to the materials and equipment used in the lab.	Did not follow instructions at all.
Lab Procedure **20%**	Clearly identified the lab procedure without copying and pasting directly from the coursepak. Shows clear understanding of the procedure.	Shows understanding of the procedure but is missing some parts.	The procedure is incomplete and unclear.	The procedure is very vague.	Did not follow instructions at all.
Data processing and analysis **20%**	Collected the data correctly. Included theoretical analysis and used Excel to solve the problem. Included graphs.	Collected data correctly but some of the theoretical analysis is missing or incorrect. Used Excel but graphs are missing some information.	Collected data well but did not correctly made calculations. Used Excel but the plot is missing relevant information.	Collected data but did not provide calculations. The plots are done by hand as opposed to using technology.	Did not follow instructions at all.

Clarity/Organization /Completeness 15%	The report is deemed excellent. The doc is well organized, proper font size, line spacing, titled all, graphs, identified figures, order and sequence is correct, and references were provided.	The report is deemed good. However, some of the organization is not in line with the experiment. May use correct font in some sections but not all. Some issues with indentation.	The report is deemed adequate.	The report is marginal.	The report is not meeting expectations.
Conclusion/Results 20%	The conclusion is aligned with the goals and objectives for the experiment.	The conclusion is on the right direction but is missing some of the most important parts.	The conclusion is somewhat incomplete.	The conclusion is not relevant or complete.	The conclusion is not included or is incorrect.