SYST 763 SYLLABUS: FALL, 2012
CONCERNING PhD DISSERTATION RESEARCH FOR STUDENTS
IN THE VOLGENAU SCHOOL OF ENGINEERING
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INTRODUCTION

Please Note: This seminar is designed to assist all PhD students in the Volgenau School of Engineering regardless of their departmental affiliation and research interests. The major objective of this seminar involves study of an array of important matters encountered the generation, design, conduct, and analysis of research performed by our engineering graduate students that will form the basis for their doctoral dissertations. The research actually performed by students in these areas will involve many different topics studied by a variety of different methods that require careful consideration. In every research effort in these various areas possible conclusions of various sorts, usually in the form of specific hypotheses, are entertained. Of interest are the patterns of reasoning involved in the generation or discovery of hypotheses and relevant evidence bearing on them. These possible conclusions or hypotheses must then be tested according to evidential methods that will allow these conclusions to rest upon defensible and persuasive arguments concerning matters addressed in the research. **This seminar is especially designed to be of assistance to students preparing to propose and then perform and defend their doctoral dissertation research**. We will offer guidance about what students may expect to hear from their faculty advisors in a defense of their dissertation proposals, and guidance about what a final defense of their dissertations will involve. As we proceed we will discuss specific examples of current and past dissertations in relevant areas to illustrate various research issues that are encountered and how they might be addressed. **This being a seminar, it is very important for students to raise questions and offer comments about matters being discussed, especially those matters that they expect to encounter, or are encountering, in their own research**.

A SYNOPSIS OF THIS SEMINAR

Following is an account of the sequence of major topics to be discussed in this seminar. A more specific and detailed listing of these topics and their subtopics follows this synopsis.

Getting Your Dissertation Research Started

You have now taken many courses here at GMU, and possibly elsewhere, when the essential criterion has involved how careful and critical a *receiver* and *integrator* of existing knowledge you have been. But at the doctoral level there is now another major criterion, namely how good a *generator* and *transmitter* of *new knowledge* will you be. The doctoral course work you will complete is certainly important, but it is no exaggeration to say that your PhD dissertation research is your most important activity. It would be very wise to keep this fact in mind at the very outset of your doctoral studies. By long-standing tradition the PhD degree is a research degree awarded to persons showing exceptional promise of extending knowledge in some recognized area. Some of you may have had specific research interests in mind when you joined us in one of our engineering programs at GMU. From extensive experience, however, we believe that your specific dissertation research interests will emerge after you arrive and have had contact with members of our faculty. In fact, for various reasons, all dissertation research stems from the interaction involving students and one or more faculty members whose research areas are congenial to the students' interests and backgrounds. The emergence of your dissertation research can take place in a number of different ways. Here are a few "facts of life" about research in academic contexts that play important roles in determining how your dissertation research will emerge.

As we will discuss, your dissertation is always a collaborative effort involving you and several faculty members. Your specific dissertation research can emerge from this interaction in

one of several ways. First, as you have correctly heard, each one of your faculty members have established research interests and credentials indicating their past research accomplishments. These credentials establish that faculty members are competent to direct the dissertation research of graduate students who will work with them. However, as all faculty members soon learn, what is most important is what they will accomplish in the future; our past research can often be viewed simply as a prologue to our future research accomplishments. We naturally wish to interest students in our own areas of research so that they can help us follow our own lines of inquiry and research. But, equally important is our commitment to our doctoral students to help them begin to establish their own research credentials. Faculty members are obliged to obtain support for their research from various external agencies and organizations. Some of this research comes in the form of *grants* from such organizations as the National Science Foundation. Such grants will often support graduate students who will participate in the research initially proposed by one or more faculty members. The availability of research grant support waxes and wanes as we all discover. In the present research climate, much support comes via *contracts* initiated by various governmental, military, and industrial organizations that have identified problems and questions for which they seek solutions and answers from academicians like your faculty members. These facts have an important bearing on how you get your doctoral research started.

All research begins with the asking of questions. You may not have been the person who asked the initial questions that formed the basis for your doctoral research; here are two examples. First suppose the faculty advisor with whom you have chosen to work has generated what you regard as interesting research questions and is in the act of trying to answer them. This advisor may possibly have received grant support to answer these and related questions. Because of your interest in these questions, and your apparent creativity and motivation, this advisor may suggest specific research questions to you in the belief that you can supply imaginative and productive answers to these questions in your dissertation research. However, your advisor would certainly welcome your suggesting new or revised questions as your work together proceeds. If your faculty advisor has contractual research in progress, this advisor is obligated to supply specific answers to the questions posed by the sponsors of this research. The awarding of a research contract to your advisor indicates that these sponsors have confidence that your advisor, possibly with your active assistance, can supply imaginative and productive answers to the initial questions that have been posed, not by your faculty advisor or by you, but by some external persons who have definite problems to solve. So, who asks the basic initial questions leading to your dissertation research is of lesser importance than the further productive questions you can raise as your work proceeds and the degree of imagination or creativity you demonstrate in generating the specific research you intend to perform for your doctoral dissertation.

Nearly all of us on the faculty have had the experience of encountering doctoral students who generate some truly novel ideas for dissertation research they contemplate based on initial questions they have posed by themselves. This can happen and we would all acknowledge the novelty and imagination upon which these ideas rest. However, in many such cases a student will propose ideas in areas about which no member of our faculty feels competent to offer advice and research guidance. In all cases you will be required to form a doctoral dissertation committee of usually four faculty members, including your dissertation advisor, who are all committed to assisting you in various ways as your dissertation work emerges and progresses. This raises the next major topic in this seminar, your specific proposal for your dissertation research. This topic will illustrate how work on your dissertation, from beginning to end, will always involve you and members of your faculty committee who are committed to giving you all the assistance they can.

Your Dissertation Research Proposal

Taking account of the various ways just discussed concerning how your dissertation research can emerge, we next need to discuss the specific proposal for your research that you will present to your faculty dissertation committee. In ideal cases, perhaps, you may have

identified the required four faculty members of your dissertation committee at the very beginning of your work on drafting a proposal so that they can all give you continuous guidance about what will be required in your proposal and in your actual research. However, this ideal situation does not always occur. Commonly, you discuss your major research ideas with your dissertation advisor who will then recommend other faculty members who may be willing to serve on your dissertation committee. It would be a very rare event indeed if all of the faculty members on your committee were equally knowledgeable about the research area of interest to you. Your dissertation advisor will of course be knowledgeable about this area. In some cases a second faculty member can be identified as a co-director of your dissertation. The other dissertation committee members are chosen for various reasons including their awareness of and experience in dealing with the various research and other matters we will discuss in this course. These other committee members may in fact have had little experience with the substantive details of your research but can still offer you good advice about your research and the conclusions they believe you can reach from it. One important matter is that you must satisfy all members of your dissertation committee that the research you propose reflects your own ideas, is methodologically sound, is important, and is feasible. The defense of your dissertation proposal may require more than one hearing by members of your dissertation committee. It frequently happens that inadequacies are discovered during your first proposal attempt. If so, you will be allowed to remove these inadequacies in advance of making a revised proposal. In fairly rare occurrences, a proposal may be rejected after one or several attempts. This can be avoided by any student who has sought the counsel of a dissertation committee during the process of generating a research proposal.

Two major things are accomplished by an acceptable dissertation research proposal. The first is that you can proceed with confidence that your research ideas make sense to other persons having considerable research experience. The second is that the members of your dissertation research committee know what they are committing themselves to in agreeing to assist you in performing your research. If, in the process of doing this research, you change your mind about how you will progress with your work, it is necessary for you to let all members of your dissertation committee know about any change in your plans. This faculty commitment also extends to matters concerning the final defense of your dissertation as we will discuss later. As you know, there is a one-hour course [IT 990] designed to assist you, and in some cases, to prod you into submitting a doctoral research proposal. But in this SYST 763 course we will elaborate on many matters that may not be discussed in any detail in the IT 990 course. We will discuss examples of successful dissertation proposals and also discuss various reasons why initial proposals are often unacceptable and need various revisions.

Research in Science, Technology, and Engineering

We are all members of the Volgenau School of Engineering [formerly the Volgenau School of Information Technology and Engineering] and have research interests that, in various ways and to various degrees, can be said to be relevant areas of study in technology and engineering. But we have all had backgrounds in various areas of the sciences and mathematics. You already know this because of the courses you have been required to take in order to be admitted to our engineering doctoral programs at GMU. In addition, members of your faculty may in the past have performed, and may still be performing, research on matters in relevant areas of science and mathematics. These things being evident, some natural questions are: how does science compare with technology and engineering? And, how do the methods of science compare with methods in technology and engineering?

You may have heard the argument that *curiosity* is the mother of science but *necessity* is the mother of invention in technology and engineering. One major difficulty with this argument is that curiosity is obviously also a requisite of any work in technology and engineering. If you had no curiosity about supplying something necessary and desirable, or improving some necessary and desirable thing, you would never even be prompted to generate the questions required in order to get your research started. The history of science and technology reveals that members of

our species were inventors long before their interests in science emerged. We will discuss several accounts of how science differs from technology and engineering; but we will also discuss methodological and other matters involving their similarities.

You will find many books describing the methods of science, including some that describe the method of science; we will examine some of these works. But we will also discuss recent works showing that there is no such thing as the scientific method. In a further work we will discuss, it is argued that scientists are not epistemologically privileged, meaning that scientists are not the only ones having ready access to knowledge and truth. As we will discuss, the basic standards of good evidence and well-conducted inquiry are not possessed by the sciences alone but common to productive empirical research of any kind. These standards include respect for evidence, care in weighing it, and persistence in discovering it. This should come as comfort to you as you proceed with your dissertation on a topic in technology and engineering that would not be thought of as being basic science. What it comes to is that your dissertation research in technology and engineering, in common with scientific research, is an inferential activity that involves various patterns of reasoning that we will carefully discuss.

All research of any kind in science, technology, engineering, and elsewhere [even mathematics], is an inferential activity involving three very basic ingredients*: hypotheses*, *evidence*, and *arguments*. As we will discuss, hypotheses or statements of possible conclusions can come in many different forms depending upon the research topic and objectives. Similarly, evidence bearing on these hypotheses comes in a variety of recurrent forms and combinations, some of which are particularly encountered in various areas of engineering. Study of these forms and combinations of evidence is necessary in order to see how the three major credentials of all evidence are to be established: its *relevance*, *credibility*, and *inferential force or weight*. The force or weight of evidence can be assessed in different ways, each one supplying different but valuable ideas about this most important inferential ingredient. The force or weight of evidence is always graded in *probabilistic* terms. We will discuss five major reasons why all conclusions reached from evidence are *necessarily* probabilistic in nature. Defensible and persuasive arguments are necessary in order to demonstrate how the conclusions being stated follow from the evidential tests that were performed. Concern about the defensibility and persuasiveness of your arguments is obviously necessary in the writing you will do in preparation for a final defense of your dissertation research. The following five major topics in this course concern specific discussions of these necessary inferential ingredients of your dissertation research. These discussions will be made directly relevant to matters we believe are encountered by students performing doctoral research in areas of engineering.

Generating or Discovering the Ingredients of Your Research

If, in a research project, you were supplied with all hypotheses, evidence, and arguments, you would have no dissertation at all. Any person might ask: where were *your* ideas concerning the generation, design, conduct, and analysis of this research? In such cases you would be looked upon as merely an assistant whose only role was to implement the ideas of another person. However, be assured that members of your dissertation committee will not view you in these terms; they will expect that you have applied extensive imaginative or creative reasoning in combination with critical reasoning as your dissertation research progresses. Work on your dissertation research will involve various mixtures of three forms of reasoning: *deductive*, *inductive*, and *abductive*. Many persons have heard only about the first two forms: deductive reasoning showing that something is *necessarily* true, and inductive reasoning showing that something is *probably* true. But it has been recognized for some time now that we need to consider another form of reasoning involving the imaginative, creative, or insightful reasoning showing that something new is *possibly* true. This form of reasoning has been called *abductive reasoning* and it plays a central role in the process of *discovery* in which hypotheses and lines of inquiry are generated; it also plays an important role in the construction of defensible and persuasive arguments.

The study of discovery, or investigation, and the imaginative or abductive reasoning it involves, is a very rich subject containing thoughts that have come from a very wide variety of disciplines. One reason for this richness is quite apparent. In any discipline you can think of, persons have concern about how and where new ideas will come from in this discipline. A second reason is that the study of discovery, and how we are able to generate new ideas, has been recognized by many noted scientists and mathematicians as being among the most difficult and important subjects for further research. A third reason involves the fact that study of computer-assisted methods in discovery-related activities is today a vibrant research effort. In fact, the study of discovery or investigation has a life of its own. This we acknowledge by having an entire course entitled: *Scientific Discovery and its Enhancement in Engineering Applications* [SYST 944]. But in SYST 763 we cannot dwell on all the richness of the research on discovery. We will focus on just a few elements of this research that offer the greatest promise of being immediately useful to doctoral students in various areas of engineering.

Hypothesis Formulation in Various Contexts

The *Oxford English Dictionary* [OED] defines the word *hypothesis* as: "A proposition put forward merely as a basis for reasoning or argument, without any assumption of its truth". However, the OED also says that a hypothesis: "Is a supposition, an assumption, especially made as a starting-point for further investigation or research from known facts". Hypotheses come in many forms, often exist at various levels, and vary in the complexity of matters they address. In addition, you may entertain more than one hypothesis in your research. This often occurs when your research requires you to form an array of hypotheses involving propositions representing possible but uncertain outcomes of the process you are investigating. Complex hypotheses may be represented by mathematical models, such as those encountered in operations research, and various probabilistic and decision network models studied in systems engineering and in other areas. In other cases complex hypotheses may not involve mathematical models but refer to possible networks of processes involved in the design of an architecture of systems composed of other systems. Some, but not all, dissertation research will involve statistical analyses of various sorts. In such cases we encounter both research hypotheses and related statistical hypotheses that in most cases are not the same. It will be necessary to discuss how these two forms of hypotheses differ.

There are many useful and helpful works concerning what constitutes meaningful and productive hypotheses. But the most important criterion is that they be testable by evidence. If your hypotheses do not allow you to generate any ways of testing them empirically, they are useless. Hypotheses are especially fruitful when they suggest novel and unexpected evidential tests. It is frequently said that hypotheses that are not potentially *falsifiable* are useless, since they are either tautological or uninteresting because they are entirely fanciful. Hypotheses can always be revised in the light of evidence and in some cases be rejected entirely. In every situation there will always be rival hypotheses of the form H and not-H. But not-H is a vague hypothesis consisting of all the reasons why H might not be true. In some research it may be necessary to consider specific rival hypotheses. This occurs very frequently when alternative designs for devices, methods, or systems are being compared. The actual process of testing hypotheses by evidential methods is very important and so we will address this issue very carefully in our discussions.

Evidence and the Empirical Testing of Hypotheses

In terms of its substance or content, evidence varies in a nearly infinite way. However, we will discuss a very manageable categorization of recurrent forms and combinations of evidence that is "substance-blind" in the sense that applies regardless of the substance or content of the evidence. What will be of particular interest are forms of evidence routinely encountered in any area of research in engineering. In many but not all cases the evidence you gather will be quantitative in nature and so it will be necessary to consider how you will measure your observations. Measurement issues also arise in any statistical analyses you may be considering.

As noted earlier, all evidence has three credentials or properties that must be established. *Relevance* answers the question: so what?, how is this evidence linked to hypotheses being considered? *Credibility* answers the question: to what extent can we believe what the evidence records? *Inferential force or weight* answers the question: how strongly does the evidence favor or disfavor hypotheses of interest? The construction of defensible and persuasive arguments, which we consider later, must include the establishment of these three credentials.

On Research Design and Methods

The *design* of your research refers to the strategy you will use in gathering and analyzing the evidence you will consider in testing your hypotheses, whatever they are. There are many possible designs you may consider and many possible *methods* within each design. Design issues arise when you consider the basic questions you are trying to answer and how you will obtain answers to these questions. The methods you will employ depend on the questions you are asking. Although only some dissertation research in engineering is experimental in nature, virtually all research has some empirical components as you test your hypotheses or possible conclusions in various ways. We will consider a variety of experimental and non-experimental methods you may encounter in your research. Some of these methods require statistical analyses of various sorts that need to be considered. However, this present course is not a course in statistics. The prerequisite for this course, frequently waived, is STAT 554 in which various applied statistical methods are discussed. In the analysis of the evidence you gather it is always wise to keep in mind the array of possible analytic errors, artifacts, and even paradoxes you may encounter. Possible errors abound in the design, conduct, and analysis of your research. The word *artifact* is used here to represent instances in which you observe something not naturally present but which arises because of the particular procedures, methods, and analyses you have employed. You may also encounter paradoxical instances in which your results seem to favor apparently contradictory conclusions.

Defensible and Persuasive Arguments for Your Conclusions

Suppose you have reached the stage of your work at which the evidence you have gathered allows you to form conclusions that you believe are justified. Your task now is to convince others that these conclusions are defensible and persuasive. The first persons you will have to convince are members of your dissertation committee, about whom we will have more to say in a minute. But there are many other persons to be kept in mind who will also have an interest in your conclusions. In short, you are now prepared to write your dissertation. At the outset of this synopsis it was mentioned that the major criteria you face at the doctoral level involve your ability to *generate and transmit new ideas*. The writing of your dissertation is where you must consider how you can best transmit the ideas you have generated in the conduct of your research. It is generally required that your dissertation, or some version of it, be of publishable quality and will be of credit not only to you but to our school and this university. Although there are some very general items everyone expects to see in a doctoral dissertation, your dissertation committee members may offer you guidance regarding particular matters depending upon the substance of your work. This acknowledged, there are some basic elements concerning the arguments you will offer that form the very foundation of the dissertation you will defend.

In most cases your dissertation will, at least in part, be a narrative account of the research you performed, why and how you performed it, the importance of your research, the conclusions you reached, and your suggestions for further research. One major characteristic of the story you have to tell about your dissertation research is that it must be appropriately anchored on the evidence you obtained as a result of your studies. There happen to be three important arguments in this anchoring process. First, you must be able to show that the evidence you gathered was indeed relevant to the hypotheses you were considering. It would certainly be a painful experience to have a critic argue that your evidence has only a weak or no bearing on the conclusions you have reached. Second, you must be prepared to justify the extent to which you

and others can believe the evidence you have obtained. This credibility-related matter has many elements depending on the substance of your research. For example, if your research involves statistics of various kinds, there are often well-established methods for determining the extent to which your results are due to sampling errors or to chance alone. In non-statistical research, credibility assessments can be much more difficult. Finally, you must be able to defend the strength or force with which your assembled evidence favors the conclusions you have reached. In some instances there will be probability models of various sorts that allow you to justify applying probabilistic hedges on your conclusions.

But you should not be misled into thinking that the necessity of the above arguments only becomes apparent to you when you first begin to write your dissertation; they should be resident in your mind throughout your entire dissertation work. This is one area in which your dissertation committee members can assist you the most, if you take care to let them. Keeping your committee members abreast of your work at all stages is the best way of ensuring that they can help you in forming the arguments just mentioned in defensible and persuasive ways. Far too often it happens that members of dissertation committee only hear about a student's intended work for the first time during the student's dissertation proposal. Then, in many other cases, committee members may only hear for the first time about the actual work the student has performed when the student petitions for a dissertation defense. There can be unhappiness here if committee members have not been kept abreast of a student's work and find difficulties that might have been discovered earlier when they could more easily have been overcome. This raises an important matter that we now address.

Defending Your Completed Dissertation

By tradition, a doctoral dissertation defense is a public affair. Anyone with an interest in the dissertation topic is invited to attend and to ask questions about your work. Commonly, the student's family and friends will often attend. There are other persons, besides the student, having a stake in a public doctoral dissertation defense; the other persons are the student's dissertation committee members. The reason is that the student's dissertation advisor, as well as the other committee members, have agreed that the student's work is in fact defensible and important. If they are wrong, they will be as acutely embarrassed as the student will be. In many cases a student's work and the conclusions being reached are defensible but the student's oral arguments are, for various reasons, not persuasive. Our existing system for doctoral dissertation defenses is a two-stage affair consisting of a *pre-defense* and a *final defense*. The purpose of the pre-defense is mainly to help the student overcome any difficulties in explaining why the work the student has accomplished is not only defensible but also important. However, it can happen that a student's pre-defense can go poorly for another quite avoidable reason. If the student has made any changes in the design or conduct of the proposed research and has failed to make all of the student's dissertation committee aware of these changes, this invites difficulties during a pre-defense. Committee members hearing about these changes for the first time are not obliged to accept them even at this late stage in the process. So, one bit of advice to students is not to drop any surprises on your doctoral committee members at this late stage of your dissertation work. There is normally a two-hour time limit for a final defense, although the pre-defense can go longer depending upon the array of questions being asked by the dissertation committee members. In the final defense a student is usually told to spend an hour in the defense of the dissertation leaving an hour open for questions. We will have various suggestions about how you can best explain the complexities of your work in this limited amount of time.

A LISTING OF SPECIFIC TOPICS

1.0 Getting Your Dissertation Research Started

1.1 The PhD degree is a research degree.
1.2 Curiosity and questions as the starting points for your dissertation research.
1.3 You and your dissertation advisors.
1.4 The research climate in the Volgenau School of Engineering [VSE].
1.5 General Requirements for Doctoral Dissertations.
1.6 Examples of PhD research in the VSE.

2.0 Your Dissertation Research Proposal

2.1 Proposal structure and contents.
2.2 Frequently observed troubles with initial dissertation research proposals:
    2.2.1 Standpoint and frame of reference.
    2.2.2 The extent of originality is not made clear.
    2.2.3 Feasibility: A manageable dissertation or a life's work?
    2.2.4 Hypothesis troubles.
    2.2.5 Generality issues.
    2.2.6 Importance issues: who should care?
    2.2.7 Various methodological problems.
2.3 The defense of your proposal.

3.0 Research in Science, Technology, and Engineering

3.1 Relations among science, technology, and engineering.
3.2 Empirical research in science, technology, and engineering: different objectives and questions.
    3.2.1 In Science
    3.2.2 In Technology
    3.3.3 In Engineering
3.3 Is there such a thing as "The Scientific Method"?
3.4 Ingredients of inferences based on empirical research.
    3.4.1 Hypotheses in the form of possible conclusions or outcomes.
    3.4.2 Evidence generated by a variety of methods.
    3.4.3 Defensible and persuasive arguments from evidence to hypotheses.
3.5 The various roles of mathematics in research in science, technology, and engineering.
3.6 Examples of dissertations in VSE to illustrate these matters.

4.0 Generating or Discovering the Ingredients of Your Research

4.1 Discovery and imaginative reasoning.
4.2 Reasoning processes in the generation of hypotheses, evidence. and arguments.
4.3 Current views of abductive reasoning in the discovery process.
4.4 Examples of studies of discovery processes in current and past research in VSE.

5.0 Hypothesis Formulation in Various Contexts

5.1 Some Ideas from Science about Hypotheses.
5.2 Formulating research hypotheses in technology and engineering.
5.3 Some criteria for research hypotheses.
5.4 Hypotheses concerning causes.
5.5 Predictions vs explanations.
5.6 Scientific vs statistical hypotheses.

5.7 Hypotheses or conjectures in mathematics.
5.8 Examples of hypotheses in VSE..

6.0 Evidence and the Empirical Testing of Hypotheses

6.1 What constitutes evidence?
6.2 The credentials of evidence.
    6.2.1 Relevance and the "so what" question.
    6.2.2 Credibility and the believability question.
    6.2.3 Force or weight and the evidential strength question.
    6.2.4 Relations among These Credentials of Evidence
6.3 A "substance-blind" classification of forms and combinations of evidence.
    6.3.1 For recurrent individual items of evidence.
    6.3.2 For recurrent combinations of evidence.
6.4 Measurement issues for quantitative and qualitative evidence.
    6.4.1 Measurement scale levels and their permitted transforms.
    6.4.2 Measurement scales and statistical analyses.
6.5 Conclusions reached from evidence: necessarily probabilistic in nature.
    6.5.1 Incompleteness.
    6.5.2 Inconclusive evidence.
    6.5.3 Ambiguous evidence.
    6.5.4 Dissonant evidence.
    6.5.5 Imperfect credibility.
6.6 Alternative views of probability.
6.7 Examples of evidence in VSE..

7.0 On Research Design and Methods

7.1 Major research design issues.
    7.1.1 Experiments and replicable processes.
    7.1.2 Various non-experimental designs.
    7.1.3 Possible errors, artifacts, and paradoxes associated with designs and methods of analysis.
7.2 Experimental research and statistical analyses.
    7.2.1 Basic requirements for statistical analyses.
    7.2.2 Interpreting and choosing descriptive statistics.
    7.2.3 Linkages of statistical hypotheses to research hypotheses .
    7.2.4 Multi-factor analyses: main effects and interactions.
    7.2.5 Correlation and regression analyses.
    7.2.6 Decision rules for conventional statistical analyses.
    7.2.7 Statistical significance vs practical significance.
    7.2.8 Bayesian analyses as alternatives to conventional analyses.
    7.2.9 Meta-Analyses
    7.2.10 Latent Variable Analysis
7.3 Quasi-experimental designs of various sorts
7.4 Non-experimental designs.
    7.4.1 Case studies.
    7.4.2. N = 1 studies.
    7.4.3. Simulations.
    7.4.4 Tests of complex mathematical models and sensitivity analyses.
7.5 Examples of designs and methods in dissertation research in VSE.

8.0 Defensible and Persuasive Arguments for Your Conclusions

8.1 Comments on the "glue" that will hold your arguments together.
8.2 Complex arguments and inference networks.

8.3 Common argument errors to avoid.
8.4 Narrative construction: telling good stories that are also true stories.
8.5 On the persuasiveness of your work: who should care?

9.0 Defending Your Completed Dissertation

9.1 Preparing for your pre-defense.
9.2 Preparing for your final defense.

REFERENCES

There is quite obviously no single textbook for a course like this one. What I will do is to provide you with extensive notes on each one of the nine major topics just described. I will always hand out notes on these nine topics in advance of the time when a topic is to be discussed in class. This allows you to prepare questions and comments you should raise during the class discussions. This also eliminates the necessity for you to take notes during class and so you can spend your whole time in class listening and raising questions. These notes will also contain many references to the literature on the various topics discussed in them.

ON THE CONDUCT OF THIS COURSE AND STUDENT REQUIREMENTS

I have just given you an account of topics I believe are most relevant regarding the generation, design, and conduct of your dissertation research. My fondest hope is that you will find our discussions of these topics to be of great interest to you as you embark on your dissertation research. But I also hope that this course will serve the interests of my honored faculty colleagues as they work with our graduate students in VSE. My related hope is that other members of our engineering faculty will join us in our seminar discussions at any time and will provide us with their insights about matters in which they have a special interest.

Here is a tentative projection of the amount of time to be spent on each of the nine sections of this course.

Topic:	**Session Numbers/Dates**:	
1.0 Getting your dissertation research started.	1	28 Aug.
2.0 Your dissertation research proposal.	1 - 2	4 Sept.
3.0 Research in science, technology, and engineering.	3	11 Sept.
4.0 Generating or discovering the ingredients of your research.	4	18 Sept.
5.0 Hypothesis formulation in various contexts.	5	25 Sept.
6.0 Evidence and the empirical testing of hypotheses.	6 - 8	6 - 23 Oct *
7.0 On research design and methods.	9 - 12	30 Oct - 20 Nov.
8.0 Defensible and persuasive arguments for your conclusions.	13	27 Nov.
9.0 Defending your completed dissertation.	14	4 Dec.

* No class on 9 October

My intention is to require you to write an essay on one or more topics addressed in this seminar that you believe has direct relevance to your dissertation research. It would be desirable if this essay could form part of your doctoral dissertation or at least provide insights about matters you might not have previously considered. In part, this will allow me to be convinced that the subject matter in this seminar was indeed relevant and helpful to each one of you in generating, designing, conducting, and analyzing your dissertation research. I would gratefully appreciate your providing me with a hard copy of your final paper. The final grade I will assign you will depend upon my reactions to your written essay and also upon my reactions to how well you have contributed to our discussions during our seminar meetings.

WHERE TO FIND YOUR INSTRUCTOR

My new office is Room 2226 Engineering Building; my office phone number is 703-993-1694. If you can't find me at this location, never hesitate to call me at home: 703-698-9515. My GMU e-mail is: dschum@gmu.edu. My preference, however, is that you use my home e-mail address that is more reliable. It is: dschum398@earthlink.net.