AC 2009-191: BEYOND ANECDOTES: HOW TO ASSESS WHAT GOES ON IN YOUR CLASSES

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Abstract
New professors have many demands on their schedules and they often don't think about documenting and studying classroom practice. Doing so offers them insights and evidence as to what works in teaching. In order to be able to undertake evidence-based research of their teaching they need some practical advice on how to effectively and efficiently conduct such endeavors. While historically social science research has been hindered by skepticism of its validity and rigor, in truth educational research is not without protocols and standards. However, most beginning engineering faculty (and for that matter, seasoned engineering faculty) are not schooled in educational research and so the prospective of empirically studying what goes on in their classroom can be daunting. In this paper, we will share practical tips and suggestions on how to collect and analyze instructional data. Given the breadth of responsibilities that new faculty must take on, new professors need practical guidance on how they can contribute to engineering educational research. In this paper we share our hard-learned lessons on research approaches, data gathering, and analysis. We offer ideas that will help new professors streamline the process and approach these processes in an efficient and effective manner.

I. Introduction

New professors face many expectations including the ability to be an effective teacher. Accordingly, "university faculty have important responsibilities both for transmitting existing knowledge and for creating new knowledge: for teaching and learning." [1] Generally there is a plethora of resources on how to teach, but guidance for creating new knowledge on teaching and learning through educational research approaches are not as readily apparent for beginning engineering faculty. The American Society of Engineering Educator's division, Educational Research and Methods, addresses various aspects of the learning process including, research on learning, research on methods of instruction, dissemination of knowledge on teaching and learning, and development of procedures and materials for instruction[2], but many new professors often need specific guidance as they begin the process of empirically studying their instructional strategies and outcomes.

The need for "evidence based" practice in engineering education stems from various factors including, for example, a better understanding of how people learn, a new generation of "digital native" learners, and calls for educational reform particularly in the areas of science, mathematics, and engineering. New engineering educators are expected to, at the very least, to be versed in current pedagogy and have a working knowledge of relevant instructional issues. Given that engineers are theory-based thinkers, many want to know the "whys" behind instructional approaches and to hear about the supporting empirical findings. Taking only value judgments or trusting in approaches without any scientific basis goes against an engineer's core thinking. Yet a specific skill set is needed to rigorously produce valid evidence about instruction. Is it reasonable to expect a new faculty member to either have this skill set or to be willing to work for it?

In this paper, we offer our experiences and advice for new faculty as they begin the process of analyzing instruction. We caution that educational research is time consuming and that one needs to thoughtfully reconcile if it is worthwhile and if it is the right time in your career to take on such endeavors. We will share what we've learned in this process and warn you of the error of our ways. This paper is not meant to be an exhaustive explanation of the techniques and tools for scientific inquiry of education, but rather it provides a practical look at how and why to conduct systematic studies on instruction.

A basic definition states, "Educational research is the application of the scientific approach to the study of educational problems." [3] Educational research (a social science) along with other forms of scientific inquiry builds models or theories to be tested. Social science research aspires, at least, to find objective truths, free of illusions, biases, and faulty knowledge.[4] Educational research is similar to natural science research in that it is systematic, rigorous, and empirical.[5] Simply put, educational research involves the gathering of information about teaching and learning (from a wide variety of sources), analyzing, and interpreting it. Often quantitative methods are combined with qualitative methods that entail these basic processes: construction of hypotheses, identification and labeling of variables, techniques for the manipulation of variables, creating a research design, measurement procedures, the use of interviews and questionnaires, and the statistical analysis of data. For decades quantitative studies involving an experimental approach with the researcher having control over variables that may or may not influence the subjects was the common approach. That trend, however, has not continued for many studies now employ mixed methods and in fact some contend that "multi-method research is now discussed, planned, and conducted as a routine matter, part and parcel of normal social science." [6]

Despite efforts to produce rigorous educational research, education and other social sciences tend not to have the same scientific status given to natural sciences. Honoring objectivity and accuracy in the social sciences is done by minimizing bias and unnecessary assumptions and clearly identifying assumptions that are being made. While entire books, such as Shipman's, *The Limitations of Social Science Research*, [7] exist, for the benefit of the readers of this paper, we'll only include the following highlights noted by by Ary et al.:

- Complexity of subject matter – dealing with human subjects and many variables must be considered, acting independently and in interaction. Caution must be exercised in making generalizations.

- Difficulties in observation – interpretation from the observer is often required resulting in less objective perspectives. Since attitudes and motives cannot be observed, they are subjectively interpreted by the observer. Furthermore, observers have biases in what they assess and what they choose to see.

- Difficulties in replication – social science settings are often unique, singular events that provide many limitations when it comes to replication for observation.

- Interaction of observer and subjects – merely observing someone can result in changes in their behavior.

- Difficulties in control – there are many factors to control, lack of precise conditions and assessment approaches, and subject variability.

- Problems of measurement – the tools to measure are not as precise as those in natural sciences. Observation is difficult, complex, and hard to replicate.[3]

2. Basic Design Considerations

The inherent limitations of social science research coupled with the fact that engineering professors are not schooled in educational research approaches and terminology can make educational research problematic. That is not to stay that engineering professors shouldn't be or aren't involved in social science research, but that it is a field of study outside of theirs. Often engineers and educational specialists collaborate to conduct educational research and we suggest that if you have a college of education on your campus you should get to know people there, who can, at the very least, consult with you. Studying what goes on in your class and systematically researching it doesn't have to be daunting, but you have to think carefully about what you want to study and how to do so in order to produce credible results.

Applying rigorous and objective methodology in educational research will more than likely require you to get assistance from an educational specialist. As you plan your study, you will propose a research design, identify the population, and produce measurement instruments as well as plan for qualitative data sources. Data analysis will likely include statistical tests that aren't familiar to an engineer. Find a statistical expert to consult with so that you get guidance as you plan and analyze your study. It is imperative that you get assistance before you collect any data. A statistician can help you ensure that your sample size will provide sufficient power for rigorous analysis and that the measurement protocol is consistent with the hypotheses to be tested. For example, one can't compare student performance pre- and post-intervention unless the data are collected in such a manner as to allow individuals to be tracked.

Given that it can be difficult to conduct a randomized, controlled study of your classroom, you most likely will adapt a multifaceted approach to finding out what works in your classroom. Generating a good research question is the first step when beginning educational research. Take care to make your question focused and specific. Furthermore, it is important to consider to what extent results can be generalizable. Careful consideration of the question helps in the selection of appropriate outcome measures and the development of the research design.

The properties of teaching and learning measured by educational researchers can be simplistically identified as ABC – affective, behavioral, and cognitive.[8] Affective measurement refers to the assessment of students' interest or satisfaction. Questionnaires or focus groups are generally used for affective measures and developing reliable and valid measures can be tricky. Plan on refining and testing any instruments you use. Behavioral measures are context specific and get at how students are impacted by an approach or treatment. Demonstrating behavioral change doesn't happen in a single incident so a multiple sampling approach is needed. Finding how much knowledge has been acquired is done by cognitive assessment. These measures are generally considered the most psychometrically sound, but they should not take precedent over the other measures; each of the three measures provides insights and help to produce a more in-depth picture.

The purpose of your study influences how you will design and conduct your study. Your research question specifies what you are going to study. Next you'll operationally define variables and determine if your research design can have control conditions. You may be able to have a pre/post-test design. Keep in mind that the pre-test is to assess if the control group and the treatment group are effectively equivalent before the study begins. Pre-tests, however, are not neutral and can prime students for the learning that will take place in the study. You need to be able to randomly place students in either the control or treatment group and in an educational setting that may not be possible. Conducting a quasi-experimental study that looks at causality that presents or withholds an educational intervention can be used. Or a naturalistic design in which unplanned change occurs is also an option. In all likelihood, as a new professor, you will be looking at actual classrooms for demonstrations of efficacy. True experimental design in classroom settings can be problematic, but you are not restricted to only those designs for there are other research designs that provide rigor and result in quality findings.

We advise you to proceed with careful planning. You may see something in your classroom that you want to explore and to want to study it. Just don't jump in without thoroughly thinking about what you are questioning and how to best get an in-depth look. Not only will a haphazard approach create problems with data accuracy and storage, but if you fail to overlook existing empirical findings, your results are limited. Furthermore, if you are new to educational research approaches, it is wise to take a look at existing literature and its implications.

As you conduct classroom research, you will reflect and review your teaching. This process allows you to refine and improve. An iterative cycle of reflection and improvement is good for both teaching and learning processes.

3. Research with Human Participants

If you are going to share results of classroom studies, you have to follow a protocol to protect the subjects from harm. Each university will have an institutional review board (IRB) whose purpose is "to review research to assure the protection of the rights and welfare of the human subjects."[9] These IRBs are a result of the 1979 Belmont report which stipulated three essential ethical principles that must be followed when doing research with human subjects: protection of the human subjects from harm (physical or mental); respect for subjects' right to know the nature and purpose of the study and their right to give or withhold consent to participate; and respect for subjects' privacy. With this law, each college and university had to create an IRB to approve each proposal and certify that the research is conducted according to the law. What this means for you is that you have to fill out a request form and then wait for its approval before you begin your study. Allow ample time to complete and wait for results. Once you have filled out a form, it is easy to do the next time. Given that your educational studies are unlikely to place a subject "at risk" you should not have a hard time demonstrating that the physical, mental, and social risks will be no greater than those encountered in daily life. Each subject will have to sign an informed consent stating that their participation is voluntary, informed and given by a competent individual. You will also need to make it clear that if the subjects are your students, you will not have access to any of their results until grades are turned in.

4. Collecting Data

While deciding how and what to measure is a timely step, you will also have to think about the best way to actually make those measurements. Some constructs you want to measure, such as intelligence, self-esteem, critical thinking, motivation and so on are abstractions and do not have direct means for measurement. Somehow the construct has to be operationalized and specific tasks selected that are indicators of the construct. We can then give a test to measure these constructs. If you want to, for example, measure critical thinking, you can look at a standardized tests in the *Mental Measurements Yearbooks*. Or you may want to create your own test. Establishing validity and reliability is a lengthy process, but given that educators are in the business of test creation, you will very likely do so when looking at whether or not your students learned. We suggest that you create an instrument and give it to a representative target group before you use in your study. You want to make sure that the test questions are clear and appropriate.

Self-report data collected by a survey is a common measurement format in instructional research. Traditionally, surveys were collected by pencil-and-paper, but online surveys are becoming very common. There are advantages and disadvantages to online surveys. Your response rate can be lower when you ask them to respond electronically than if they filled out a paper questionnaire in a fixed time period, such as during a class session. However, data collected via online survey is already in electronic form so is easier to store. Another advantage is that students may feel more confident that their anonymity is assured if their responses are typed rather than handwritten. Finally, there may be students you want to survey who are not in your class and the best way to reach them can be through an online link.

Other data sources can include in-depth interviews or focus groups where questions are asked about an experience or social phenomenon. You will need to make sure that the subjects feel comfortable to share information and that you only collect information in ways that are approved by your IRB. You may be permitted, for example, to write notes during a focus group, but restricted from using a tape recorder.

Your study might include observations of real-time events or operations and you may be restricted from using any recording devices. Observers can take on various roles including: complete participant; participant as observer; observer as participant; and the complete observer.[10] These observations, conducted in various forms including observations, interviews, focus groups, or document analysis, often include check lists, scaled ratings, or other structured forms to look for specific behaviors. Observation often calls upon interpretation on the part of the observers. Caution has to be exercised so that what is observed and how it is observed is not unduly influenced by the observer's attitudes and values. At times, the mere presence of an observer can produce changes in a subject's behaviors.

5. Storing Data

Next you have to plan for data storage. There are three broad strategies to consider: spreadsheets, a simplified Database Management System (DBMS) with a graphical user interface (GUI), or an enterprise-grade DBMS. Each approach has its advantages and disadvantages that should be weighed carefully before data are even collected.

Spreadsheet software packages, such as Microsoft Excel, are designed for the storage and statistical analysis of small datasets. Advantages include (a) most spreadsheet packages are relatively inexpensive and typically already installed on the faculty member's computer system, (b) many engineering faculty are already familiar with the basic functions of common spreadsheet software packages, (c) no computer programming skills are required, (d) many packages are cross-platform or even web-based, which can simplify collaboration, and (e) easy to export data into statistical software and/or DBMS. The disadvantages of spreadsheet software are that (a) relationships between data points, e.g., multiple measurements from a given student, can be difficult to maintain, (b) it can be difficult to query (search) for data meeting given constraints, (c) if more advanced statistical analysis are needed, steps must be taken to export data into a format that can be imported into separate software tools, and (d) additional tools may be needed if data set needs to be shared among several collaborators.

When spreadsheet applications are not sufficient, DBMS designed for storing medium-sized data sets for use by individuals or small groups are a valuable alternative. Example packages include Microsoft Access and Filemaker Pro. Advantages of such simplified DBMS include (a) relationships between data points, e.g., multiple measurements from a given student, are naturally maintained, (b) ease of querying (searching) the data, (c) support for larger data sets, (d) GUIs that are similar in feel to more common tools such as spreadsheets, and (e) while customization may be possible, considerable functionality is typically available without programming skills. Disadvantages include (a) it may be more difficult to support cross-platform collaboration since packages of this type can be specific to a given operating system and there less web-based options, (b) statistical analysis may not be included, so the data typically must be exported in a format that will enable import into a separate software application, (c) engineering faculty may not already be familiar with these packages, meaning that there will be some time spent learning a new software application, and (d) while these packages are moderately priced, they may need to be purchased specifically for the project.

For large, complex studies, enterprise-level DBMS may be more suitable. An example of a full featured DBMS is Oracle. The advantages of a DBMS are (a) relationships between data points, e.g., multiple measurements from a given student, are naturally maintained, (b) ease of querying (searching) the data, (d) support for very large data sets, and (e) simple to directly interface with standard statistical languages/packages such as SAS. The disadvantages of a DBMS are (a) considerable specialized knowledge and skills are needed to set up, maintain, and use, (b) relatively expensive to the other options discussed here, and (c) engineering faculty may not be have prior experience using DBMS and there may be a substantial learning period.

In summary, there are advantages and disadvantages with every method for data storage. There is no single "right" answer, but instead these have to be considered given the specifics of your proposed study. There are also a few considerations that are more dependent on your institution's information technology infrastructure than the particular software package. For example, if you will be maintaining student identifiers on the data, then extra security precautions are needed to ensure confidentiality and privacy. The different mechanisms for this at your institution with each of the data storage options described above must influence your choice. In addition, the technical support available to you is another important factor. It may be more or less practical for you to use a given data storage system based on what technical support you can rely on receiving. Last but not least, methods for maintaining data integrity are essential. Before you start storing any data, you need to have a mechanism in place for backing up those data. Again, means for doing this at your institution may influence your choice of software for data storage.

6. Analyzing Data

You most likely will use multiple sources of data and multiple methods so that what you are studying is understood from various view points. It will be your goal to see if data collected from one procedure matches data collected from another.

When you have qualitative data in the form of field notes, interview transcripts, survey responses, and so on, you can be faced with a time-consuming process. You will find this process is both iterative and tedious. In order to make it manageable, it is suggested that you break it down into three stages: familiarization and organization; coding and recoding; and summarizing and interpreting.[3]

Before collecting quantitative data, work with a statistician to plan how they will be analyzed. The analyses are typically performed using specialized statistical tools such as SAS (Statistical Analysis System) or SPSS (Statistical Package for the Social Sciences). It is possible to import data into such packages from a variety of data storage formats, but this process will go more smoothly if the data store and analysis software are selected in a coordinated fashion before the study begins.

Again, we want to encourage you to get help in planning and conducting any data analysis. This will save you a great deal of time and effort in the long run. While this may seem daunting, there are often many resources available to assist faculty with data analysis. For example, most research-oriented institutions have statistical consultants or clinics that provide free, or low cost, assistance. Students currently enrolled in your school of education or that of a neighboring institution can be an inexpensive but very valuable addition to your team.

7. Time Management

There is little doubt that your days are full and tacking on educational research may sound too arduous. We won't fool you by saying that it is "a piece of cake." We do know, however, that if you are organized and systematic as you study what goes on in your classroom, it is manageable. It is something you should not do alone even though much of your teaching is private. Building upon the expertise of others who specialize in education and statistics, will not only lighten your load, but will result in more rigorous results.

You might also wonder "what's in it for me?" Why not just look at my teaching and tweak it as I go? For one thing, a systematic study will provide a robust look at the variables that influence learning. You may not be able to unearth what is happening without collecting evidence. Second, findings are useful for they can help you enhance your teaching and to get you involved in the scholarship of teaching and learning. By looking at discrete aspects of instruction, you will find things you can improve upon. Educational research documents your commitment to teaching and it will be visible in your teaching portfolio. Lastly, being able to share your results with colleagues at conference and in journal articles helps you as you build your reputation as an educator.

8. Conclusions

Contributing to educational research in engineering can be intellectually stimulating and invigorate your own efforts to constantly improve learning opportunities for your students. It is not, however, a venture to be taken on lightly. First, keep in mind that this may or may not be a suitable time in your career to explore your interests in educational research. We recommend that new faculty members first check with their department and school to find out how activities spent on educational research are considered in promotion and tenure evaluations.

Before embarking into educational research, you need to be committed for what it will involve. Here are the key issues to consider:

- Purpose of your study and how it relates to teaching enhancement
- Timing and whether or not it is a good time in your career to undertake educational research
- Amount of planning required,
- The learning curve (i.e., learning to navigate regulations on research with human participants and how to statistically analyze educational findings),
- Dealing with possible disruptions in your classroom.

Empirical findings are useful, but you also need to think about practical outcomes – what can you apply in your classrooms as well as what can you share with others so that they can improve their teaching?

If you are not sure where to begin, you might find it inspiring to keep a teaching diary and/or have your classroom teaching be observed by experienced colleagues for a semester or two. Such opportunities for reflection can bring to light aspects of your teaching that warrant investigation or intervention.

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