Engineering Education Research Snack Pack

2022

CEEA ACEG
CANADIAN ENGINEERING EDUCATION ASSOCIATION
ASSOCIATION CANADIENNE DE L'ÉDUCATION EN GÉNIE

This compilation of Engineering Education Research Snacks is available on the CEEA-ACEG Resource page: https://ceea.ca/resources-2/

Check the website for new additions.

This pack contains:

1. **Grab Your Spoon**
   An overview of the elements in an EER study.

2. **Starting Your Line of Research**
   A line of research requires more than just a good idea. This snack walks you through the development process and particularly the lit review stage.

3. **How to Create Research Questions**
   A walk through the FINER framework.

4. **What is a Paradigm and How Can I Tell if I'm Swimming in One?**
   This snack introduces you to the concept and provides some examples of some of the most common paradigms in EER.

5. **Quant, Qual and Mixed Nuts**
   A brief walk through the three broad methodologies: quantitative, qualitative and mixed methods

6. **Statistical Studies: Quantitative Design**
   An overview of quantitative study types such as sample, observational, and experimental.

7. **How to Design an Intervention Study**
   Intervention studies are very common in EER. This snack provides a starting point for study design.

8. **Construct – What's that?** **-- Bonus track** (Not yet available on the CEEA-ACEG site)
   Explains what a construct is, and introduces conceptual frameworks.

9. **A Quick Survey on Surveys**
   Advice on the use of surveys in EER.

10. **Validity and Reliability** **-- Bonus track** (Not yet available on the CEEA-ACEG site)
    These concepts are foundational to the design of research studies in general and quantitative studies in particular.

11. **More on Validity** **-- Bonus track** (Not yet available on the CEEA-ACEG site)
    More detailed aspects of validity that pertain to different research methodologies.

12. **Selecting a Sample for a Quantitative Research Study**
    An overview of different sampling methods; pros and cons.

13. **Human Research Ethics: Can I use my own class for my research study?**
    Good question! This snack provides an answer and more on ethics.

14. **Interdisciplinary Research**
    Perspectives from 6 engineering education researchers

15. **Reporting your Research** **-- Bonus track** (Not yet available on the CEEA-ACEG site)
    A guide to the elements to include in a research dissertation, report, or paper. This guide is also a great place to start when you are designing a study.

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Engineering Education Research Snacks

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Grab Your Spoon

Every year, for the past few years, I have had the privilege of teaching the Institute for Engineering Education Research (IEER) with a changing cast of wonderful people. We did this in person, when that was possible, and in 2020 we offered it as a set of two workshops remotely. The workshops have had great attendance and I thought that while I am on leave, holed up at a desk in my closet during a pandemic, I might start a series of short pieces that each discuss just one concept in engineering education research. Many of these topics are covered in our workshops, but not all. And, addressing them one at a time might provide a digestible pace of information for people interested in EER. So grab your spoon….

Adapted from Patel (2015) and Crotty (1998)

CEEA-ACEG Institute for Engineering Education Research

The umbrella diagram we use in the workshop shows a cascading set of elements that make up a research study. This diagram was adapted from Patel (2015) and Crotty (1998). While it is shown as a cascade, in fact this is not a unidirectional process. In developing the framework for a study, we often move back and forth, iteratively, much as we do in engineering design.

All studies have all of these elements. They are sometimes labelled differently (e.g. Creswell refers to “worldview” instead of ontology, epistemology, and axiology), but they are always present. For example, all research has an axiology and logic, whether the researcher intentionally selected or considered an axiology or not, it is there. However, not all research studies are well aligned. For example, the methodology may not fit the research question. That is, the methodology may not be a valid, reliable means of addressing the research question. One goal of intentionally considering each of these elements in your research plan is to create a well aligned framework. The process and thinking that goes into this will result in a better design piece of research, and help you think more deeply about what you are researching.

Crotty, M. Foundations of Social Research: Meaning and Perspective in the Research Process. London; Thousand Oaks, Calif.: Sage Publications, 1998.

Patel, S. (2015). The research paradigm – methodology, epistemology and ontology – explained in simple language. Retrieved from: http://salmapatel.co.uk/academia/the-research-paradigm-methodology-epistemology-and-ontology-explained-in-simple-language/

Author: Susan McCahan, University of Toronto

Acknowledgement: Thank you to Jillian Seniuk-Cicek, Sylvie Doré, Marnie Jamieson, Robyn Paul, and Lisa Romkey who developed this diagram, have been lead instructors in IEER, and amazing colleagues. Thank you also to all of the people who helped vet this snack.

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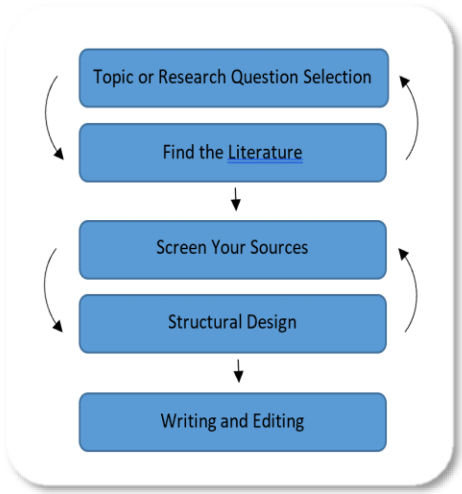
Starting Your Line of Research with a Literature Review – the Basics

While it is well worth the time to think deeply about your prospective line of research *before* reading all about it, there is much to be said for doing a thorough literature review on the line of research that you would like to undertake. In the spirit of "you don't need to reinvent the wheel", it is worth knowing if your "wheel" (line of research) already exists. If you already know the field well, you may be able to write a review that reveals shortcomings in the "wheel" that may have been missed by others.

At its most basic, the purpose of a literature review is to understand the current state of the field and to provide new insights into it. However, you might want to be more focused than that. You could be trying to review one aspect of the field, for instance. So how does one do this successfully? There are tried and true steps to follow, as shown in the figure below and in Randolph (2009), Webster and Watson (2002) and Pautasso (2013). Also, a good approach for systematic literature review in engineering education is given in Borrego (2014).



Step 1: Pick a Topic or Research Question

A key issue is "how focused is your topic/question"? Broadly speaking, there are three types of papers and other resources on your topic. There are ones on your exact topic (subject matter and context match), there are ones closely related (right subject and wrong context, usually) and there are ones peripherally related (related subject). If you have a choice, which you may not, you want to focus your topic/question such that you have a manageable number of core sources plus a healthy number of closely related ones. Focusing may involve considerations discussed in Step 2.

Step 2: Finding the Literature

Start with popular journals like JEE, conference proceedings like CEEA-ACEG, databases such as ERIC, or helpful search engines like Google Scholar with engineering education in an appropriate field as applicable. When you find good papers, then start using the "snowball" method: i.e., look at the references of your favourite sources to find others. If your topic isn't too broad, they will *eventually* cite papers that you already know and have. One of the key points in this step is to record every detail of where and how you look for references. A tool, such as RefWorks, EndNote, or Zotero can be helpful here, for which your institution may have a license. Just as good science is reproducible, a good literature review should provide enough details on the search method (databases, keywords, etc.) to also be reproducible. If you have less than 20 core sources, consider broadening your scope if you can. If you have more than ≈50, consider focusing more. If you have a big topic, one of the ways you can limit the scope of your review is by being selective amongst the broader literature. This can be done by only using references from a certain (recent) time period or from certain journals or databases.

Step 3: Screening Papers

You probably identified your resources in Step 2 by reading titles and/or abstracts. However, titles can be misleading. Besides, you need to start thinking about the structure of your paper. So, an initial screening of your found literature is necessary and valuable. A very useful tool at this stage is an annotated bibliography. Basically, read the papers and make notes on them as you go. Include key ideas, themes, findings, methods, contexts, and conclusions. These are worth their weight in gold.

Step 4: Your Review's Structural Design

Your primary goal in this whole "lit review" exercise is to provide insight to readers on the literature that you have reviewed. Your job is to see the forest for the trees. Most reviews achieve this with one of three structures. Chronological reviews look at the evolution of ideas. The chronological sequencing may provide insights and/or may suggest directions for future work. Other reviews will break the literature into themes, characterize them, and then comment insightfully on them. Another type of review proposes a framework for analyzing the literature, puts the literature into that framework, and then discusses implications of that framework. The framework is often the big insight in this approach.

Step 5: Writing/Editing

The last step is writing and editing. There are many resources providing recommendations on this topic, but suffice to say that a common approach that works well is to get all your ideas down first (i.e. do not try to write each sentence perfectly). Like design, good writing is iterative. Much like sculpting, this may be done coarsely at first, and in more detail later. Remember you are trying to convey new insights with your review. Are you extending concepts or frameworks, developing new perspectives, or identifying gaps that deserve attention? If you feel that you have identified a real gap, just make sure you were thorough in your review!

There is much to master in each of these steps, but even if this is your very first literature review, you are likely to do well with it if you follow these basic steps and concepts.

Randolph, Justus (2009) "A Guide to Writing the Dissertation Literature Review", *Practical Assessment, Research, and Evaluation*: Vol. 14, Article 13. DOI https://doi.org/10.7275/b0az-8t74

Webster, J. and Watson, R.T. (2002) "Analyzing the Past to Prepare for the Future: Writing a Literature Review", *MIS Quarterly*: Vol. 26, No. 2, pp. xiii-xxiii

Pautasso, M. (2013) "Ten Simple Rules for Writing a Literature Review", *PLoS Comput Biol*: Vol. 9, No. 7, DOI https://doi.org/10.1371/journal.pcbi.1003149

Borrego, M., Foster, M.J. and Froyd, J.E. (2014), Systematic Literature Reviews in Engineering Education and Other Developing Interdisciplinary Fields. J. Eng. Educ., 103: 45-76. https://doi.org/10.1002/jee.20038

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How to Create Research Questions

Many engineering educators are interested in conducting engineering education research (EER) while teaching. A research inquiry begins with research questions, which serve as an "anchor" throughout the research process. How can we frame research questions? What are some of the criteria for self-assessing our own research questions? This post aims to address these questions.

In general, research questions come from a gap in practice or literature. Therefore, it is important to specify the problem that needs to be solved. Then, you can phrase a question to address the problem. Good research questions will guide your research plan and help determine your decisions along the way. There are many paths to framing research questions. Ideas may initially stem from your reflections on your own teaching practice or readings of current issues in engineering education. You may discuss your preliminary ideas with colleagues to refine your thinking. Reading about how others have engaged with EER on the topic of your interest also helps inspire ideas. Further, theoretical perspectives on your research topic can inform your research questions as well. Eventually, your initial ideas about a research topic narrow down to one or a few specific research questions. One of the most common mistakes people make is to create research questions that are too broad, e.g. "how do my students learn?"

If you are unsure what is considered a solid research question, the FINER framework can help (Hulley, Cummings, Browner et al., 2007). This is a framework used by some academic publishers, such as Elsevier. FINER represents the following five criteria for evaluating research questions:

- **Feasible –** Can your research question be answered given the resources you have, including time, expenses, technology and expertise? If you choose to conduct an empirical study that involves human participants, how are you going to have access to the individuals who have the knowledge or experience for your research? Do you have the knowledge and skills to analyze the data you going to collect? Many engineering educators have a wealth of expertise in quantitative research but may find it challenging to analyze qualitative data, such as text-based data.
- **Interesting** – Your research question must be something that *you* find interesting in the first place. You may be interested to explore a question for various reasons, including your own curiosity and practical needs you have identified. Then, you ask: How can the knowledge gained from answering this research question contribute to practice and understandings of engineering education? Why should a funding agency be interested to investigate this question?
- **Novel** – A good research question guides your research to fill a gap in a particular area of knowledge in EER. An in-depth review of what has been known and what research has been conducted on the topic will inform you of the existing gaps. If you are unsure, you can check on the proceedings that are made available by EER communities such as the Canadian Engineering Education Association (CEEA) and the American Society for Engineering Education (ASEE).
- **Ethical** – EER often involves the participation of engineering students, alumni or educators. We as researchers must be committed to showing respect for individual persons and concern for any potential impact of research on individuals' welfare, and

treating people fairly and equitably. Our research questions must demonstrate these core principles for research ethics. From the start of our research, we need to consider how to protect individuals' privacy and ensure confidentiality of their information throughout the study. More details on the ethics of human research can be found in other Research Snacks.

- **Relevant** – The research addressing your questions needs to be "well-timed" and lead to research outcomes that are relevant to particular educational practice or current discussions on matters in engineering education. You could ask yourself: Why do your research questions need to be answered at this particular time or place?

When framing your research questions, you can also consider what is the nature of your proposed research? Your research questions can be descriptive, relational or causal (Trochim, 2000). Descriptive and relational are also sometimes called observational.

Descriptive	Relational	Casual
• Aiming to explore what is currently taking place.	• Aiming to determine associations between potentially linked objects.	• Aiming to ascertain whether or not one object (such as an intervention) leads to particular outcomes.
• e.g. What are the experiences of students who have followed extant engineering transfer pathways in Ontario? (Smith & Frank, 2020)	• e.g. Do the identified WeBWork usage patterns relate to student exam outcomes? (d'Entremont et al., 2020)	• e.g. Does a utility value intervention influence student interest in a multidisciplinary engineering design course? (Turoski & Schell, 2020)

Ultimately, how you have phrased your research will direct what methods you will use for data collection and analysis. Generally, you can use qualitative research design to answer "how" or "what" questions; and use quantitative design to address "what," "do/does," or "how much" questions.

d'Entremont1, A.; Verrett, J; Hu, S.F.; Abelló, J.; Negar M. Harandi, N.M.; Leonzio, T.; & Fong, W.C.W.F. (2020, June). *Multi-factorial patterns of online homework usage in engineering: A pilot study*. Paper in the proceedings of the annual Canadian Engineering Education Association conference.

Hulley S, Cummings S, Browner W, et al. Designing clinical research. 3rd ed. Philadelphia (PA): Lippincott Williams and Wilkins; 2007.

Trochim, M.K. (2006). *Research methods knowledge base* (3rd ed.). Available online at: http://www.socialresearchmethods.net/kb/

Smith, H., & Frank, B. (2020, June). *Investigating student experiences of engineering technology to engineering transfer in Ontario*. Paper in the proceedings of the annual Canadian Engineering Education Association conference.

Staci A. Turoski, S.A., Schell, W. J. (2020, June). *Advancing student motivation and course interest through a utility value intervention in an engineering design context.* Paper in the proceedings of the annual Canadian Engineering Education Association conference.

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What Is a Paradigm and How Can I Tell if I'm Swimming in One?

Engineering Education Research (EER), like research in many fields, centers on human subjects. As such, even when it is conducted by engineers and not social scientists, it exists in a social domain. When we shift our analytic focus from the physical to the social world, we must consider our assumptions about the nature of reality (ontology), the nature of knowledge (epistemology), and our perspectives on the credibility of various methodologies. Together these assumptions shed light on our entering research paradigms. According to Kuhn, scientific paradigms are "universally recognized scientific achievements that, for a time, provide model problems and solutions for a community of practitioners."[1] Kuhn's characterization of paradigms is conceptually helpful, but it fails to account for the concurrent diversity of models in engineering education research. Guba and Lincoln[2] have characterized paradigms as both competing and concurrent. They define a paradigm as "a set of basic beliefs with ultimates or first principles. It represents a worldview that defines, for its holder, the nature of the world, the individual's place in it, and the range of possible relationships to that world and its parts"(p.107).

You may be wondering why it is important to consider your personal worldview as an engineering education researcher. Here is a concrete example from my own research. During my undergraduate training in psychology, I was taught that the gold standard for social science research was experimental or quasi-experimental design. For my honour's thesis I used two experimental groups and one control group to examine judgements individuals make about personality. As part of the training for the experiment, research participants wrote a paragraph about the personalities of two individuals – me, and another student in the lab – who they had never met in-person. The research participants knew us only through our answers to a battery of questions on personality. In reading through the paragraphs, I found it interesting that almost all study participants thought I (cis-gender female) was male and my cis-gender male colleague was female simply because he was more emphatic than I was. I shared this finding with my supervisor who said, "great, tell me about your ANOVAs." This experience catalyzed my paradigm shift from positivism (my supervisor's paradigm, and the one I had been socialized to accept through my undergraduate education) to social constructivism. What my supervisor saw as interesting but not relevant to the analysis, I saw as a critical part of understanding the phenomena – we saw the same words, but had two different perceptions about the importance of the data.

I began to believe it was more important to analyze the full diversity of human interpretations of our experiences, than to test a small number of pre-set hypotheses about these experiences. Four years later, I began to see the power of critical theory to explain societal inequity. In both cases, my beliefs about the nature of social reality (ontology), and the nature of knowledge (epistemology) shifted in ways that impacted what I believe to be credible data.

Now it is your turn. **Table 1 below shows some of the distinctions between three (of many) competing paradigms** present in engineering education research—positivism, constructivism, and critical theory. Reflect on these three paradigms. Do you find yourself agreeing or disagreeing with the notion that research ought to be truthful, socially constructed, or transformative? Your ability to acknowledge and understand your assumptions about what constitutes credible research is more than a philosophical exercise. It enables you to optimize alignment between your research question, theoretical perspective, methodology, and methods.

It also allows you to communicate findings with those who swim in paradigms informed by competing assumptions. For more information on two paradigms commonly used in educational research, please see Guba and Lincoln's chapter on social constructivism,[2] and Kincheloe and McLaren's chapter on critical theory.[3]

Table 1: Ontological, Epistemological, and Methodological distinctions between Competing Paradigms

Paradigm	Positivism	Constructivism	Critical Theory
Purpose	Reveal truths about and relationships between social phenomena	Co-create social meaning in context from multiple perspectives	Reinterpret and transform inequitable social relations
Ontology	Realist (social facts exist independent of the observer)	Nominalist (universals exist only as concepts)	Dominant understandings of social phenomena are treated as real (reified)
Epistemology	Objectivity and neutrality are possible and desirable	Human understanding of social reality is always subjective	It is impossible to understand social reality independent of our social locations
Methodological goal	Nomethetic—explain social phenomena and the relationships between them in general terms (derive laws)	Ideographic—interpret the perspectives of actors in context	Examine patterns of privilege in society & unpack assumptions embedded in dominant policies, practices, and norms
Methods & Methodologies (examples)	Experimental design, randomized control trials, surveys (validated instruments), observation	Interviews, surveys (open ended), focus groups, ethnography, grounded theory	Critical discourse analysis, institutional ethnography, secondary analysis of survey data, critical auto-ethnography
Related theories (examples)	Post-positivism, logical empiricism, structural functionalism	Phenomenology, interpretivism, symbolic interactionism	Marxism, Critical Race Theory, Eco-feminism, queer theory, poststructuralism

1. Kuhn, T.S., *The structure of scientific revolutions*. 3rd ed. 1996, Chicago: University of Chicago Press.
2. Guba, E.G. and Y.S. Lincoln, *Competing paradigms in qualitative research*, in *Handbook of Qualitative Research*, N.K. Denzin and Y.S. Lincoln, Editors. 1994, Sage Publications: Thousand Oaks, CA. p. 105-117.
3. Kincheloe, J.L. and P. McLaren, *Rethinking critical theory and qualitative research*, in *Handbook of Qualitative Research*, N.K. Denzin and Y.S. Lincoln, Editors. 1994, Sage Publications: Thousand Oakes, CA. p. 138-157.

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Quant, Qual and Mixed Nuts

Engineering Education Research (EER), like research in many fields, can be categorized as qualitative, quantitative, or mixed methods. Creswell and Creswell (2018) have written extensively on research design, and these categories of research, and we strongly recommend reading their book on the subject.

As engineers, we are very familiar with quantitative research. Generally, engineering research is based on the statistical analysis of experimental results, and those results are typically in the form of continuous data. This is not always the case for quantitative research in EER. Studies may be observational and data may be continuous, ordinal, or categorical. Also, the concept of "validity" is somewhat different in EER than typical engineering lab experiments. However, fundamentally, in quantitative research we are trying to answer a research question using a statistical study.

Qualitative

Qualitative research uses words, pictures, or other information to investigate the world. This information is analyzed, but often not through numbers or statistics. For example, we might analyze the changes to accreditation requirements over time and how that has impacted engineering curricula across Canada. Or we could do a set of extensive interviews with France Cordova and analyze her career path in the context of changing attitudes toward women in STEM professions. Some of this work may include considering the frequency of a theme in an interview transcript, or the number of courses that fall into the "design" category in a curriculum, but fundamentally, qualitative research is analyzing the meaning of qualitative information.

Quantitative

Quantitative studies may include some qualitative work. For example, you might analyze the performance of students before and after a change in teaching method, and then hold some focus groups with students to hear how they think the change impacted their learning. Some people consider this to be essentially a quantitative study, and others would call this “mixed methods”. Similarly, many qualitative studies involve some statistical analysis (Saldaña is a good reference on this), but it may be in service to the qualitative analysis.

Mixed Methods

Mixed methods fully approaches the research using a mix of quantitative and qualitative methods. There has been much written about mixed methods and I would encourage you to do some reading on it before you decide that this is the way you want to set up a study. John Creswell, in particular, has written extensively on mixed methods, and his writing on this subject would be a good place to start. Bottom line: the decision about whether to choose qual, quant, or mixed should be aligned with your research questions and theoretical paradigm in your study design.

Creswell, J.W., and Creswell, J.D. (2017) Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 5th Ed, Sage Publications.

Author: Susan McCahan, University of Toronto

Acknowledgement: Thank you to Jillian Seniuk-Cicek, Sylvie Doré, Marnie Jamieson, Robyn Paul, and Lisa Romkey who developed this diagram, have been lead instructors in IEER, and amazing colleagues. Thank you also to all of the people who helped vet this snack.

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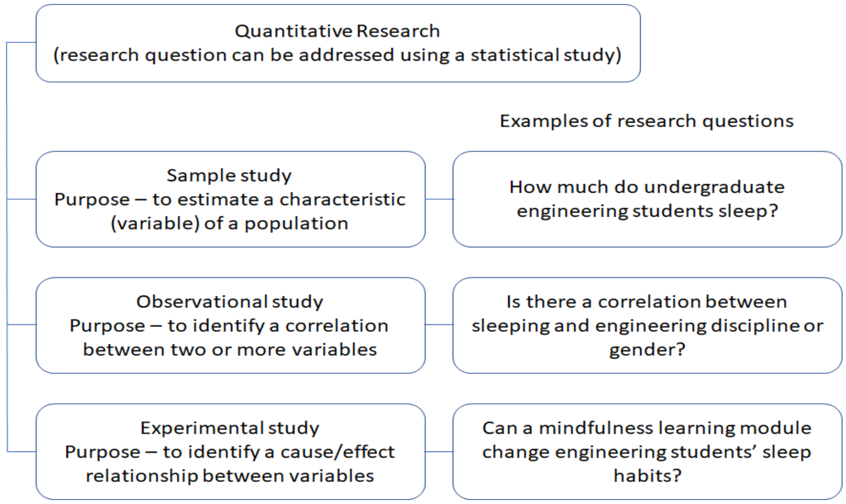
Statistical Studies: Quantitative Design

In engineering research we typically set up an experiment. There is a hypothesis or two, and we control the conditions of the experiment. We decide which parameters to hold constant and which will be varied. We manipulate the world (in a laboratory setting) to identify cause and effect relationships between variables. However, in engineering education research (EER), not all studies are experimental (see figure below).

A study, or part of a research study, may involve observing how the world works without interfering or "manipulating" the world. For example, we might survey our students to see how much sleep they get every night. Or we might identify the ways people teach in introductory courses and observe how students do in subsequent courses to see if there is a correlation. These types of studies are called sample studies and observational (or correlational) studies.

In a *sample study,* we are observing one parameter (e.g. sleep hours). We might look for a trend in this data; e.g., do students sleep less over time? In an *observational (correlational) study* we are looking for a correlation between two or more variables of interest; e.g. is there a correlation between year of study, discipline, and sleeping? Interestingly, observational studies do not always involve actually observing or surveying people. An observational study may involve, for example, analyzing students' grades, analyzing assignments or other assessments, or analyzing the comments teaching assistants make on student papers. In all of these cases we are looking at the world as it exists and operates, rather than changing up the "normal" flow of academic activity.



Observational studies cannot be used to prove a cause/effect relationship. We may find that fourth year mechanical engineering students pull more all-nighters, but we cannot infer that the fourth year mech eng curriculum causes this behavior. Maybe students who tend to pull all-nighters also tend to pick mech eng. We can only observe that there is a correlation.

Experimental studies are used to prove a cause/effect relationship. In an experimental study, subjects are assigned to groups, and their world is manipulated to see how the subjects are affected. This can be done ethically to answer some research questions, but not all research questions. For example, we could not randomly assign a group of students to one of eight disciplines of engineering to see if fourth year mechanical students pull more all-nighters. This would be unethical.

When you are designing a research study think about the research questions you are asking. Do they require an experimental study? Could they be accomplished using an observational study? What sources of data do you have available? This may help you shape a set of research questions and select a methodology that works best for your research goals, timelines, and so on.

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How to Design an Intervention Study

Many engineering educators have attempted to improve their teaching practice and student learning using an intervention. An intervention could be the use of a new teaching tool, introduction of a new method, or a change to assessments in a course—anything that might potentially change the student experience. Many interventions have been reported in CEEA conference papers, but relatively few include a significant research element. This post will focus on how an intervention study can be designed and executed in an engineering education setting.

An intervention study examines the effect of an educational intervention. Typically, it asks a causal research question, for example: Does a utility value intervention influence student interest in a multidisciplinary engineering design course? (Turoski & Schell, 2020). The overall design of the study aims to identify and examine the causality, typically between the intervention and learning outcomes or student experience.

A powerful research design for identifying a cause-and-effect relationship is an experimental study (Gravetter & Wallnau, 2013). Two equivalent groups are created using random assignment and then the intervention is applied to one group (known as the treatment group) but not to the other (known as the control group) under controlled conditions.

There are several ethically appropriate ways to group students into the experimental group and control group for an intervention study. You can use the existing student groups—for example, using two different courses or the same course taught in two different terms—and apply the intervention to one of these classes. Often a pre-test/post-test design is used, in which both the treatment and control groups are given a "pre-test" assessment to identify the baseline, and after the intervention they are given the same assessment, to measure improvement.
You can run a study without a control group, by comparing the results from the pre-test and post-test assessments. This allows you to report the "gain", but this does not allow you to evaluate the intervention specifically because other factors may contribute to the change in students' performance[1].

Alternatively, you can randomly assign students to the treatment and control groups. If you split students in the same class into two groups (treatment and control) you need to give both groups an opportunity to be exposed to interventions that you believe have an equal benefit for the students for ethical and equity reasons. A common way to do this is

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[1] This type of study design may make sense for a short, specific intervention where other factors or experiences have limited influence on outcomes. For example, in a safety training session, you might measure the students' appreciation for the value of safe practices before the training session and then measure it again afterwards to see if it has gone up.

a “cross-over” study where each group experiences the same intervention but at different points in time: e.g., Group A experiences the intervention before the midterm, and then Group B gets it after the midterm. In any experimental design, you need to identify the elements in the environment that possibly confound the effect of the intervention and try your best to minimize their influence or control for their effects using statistical methods.

You can also consider establishing “process causality” (Anderson & Scott, 2012) by identifying the “generative mechanisms” that can explain how the changes took place, which can include individuals’ belief, reasoning and action in response to the intervention. You can do this by asking your research participants to explain how the intervention made a difference to the outcome of interest (e.g., student learning) via open-ended survey questions, interviews or focus groups. Then you can analyze the qualitative data by using methods such as causation or pattern coding (Saldaña, 2016). When you include this component in your pre-test/post-test quantitative design, you have conducted a mixed-methods study.

There are some good references for designing an intervention study (Harackiewicz & Priniski, 2018). An intervention study starts with identifying and assessing the specific problem, population and context targeted by an intervention. You also need to consider what measurement you will use to assess particular academic outcomes, which serve as a measure of intervention efficacy. These outcomes can be course-specific (e.g., motivation for taking a course), school-specific (e.g., graduation rate) or field-specific (e.g., retention rate of female engineering students), depending on the scope of the intervention. The outcomes can be cognitive (e.g., development of problem-solving skills) or affective (e.g., self-efficacy). Some outcomes can be demonstrated shortly after the intervention and others may be more appropriate for a longer-term. So, you also need to decide when to measure the outcomes.

A study design that follows these principles can provide a substantially enhanced level of quality to your research, and your papers, because it uses a rigorous research process to assess your intervention.

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Construct – What's that?

What the heck is a **construct**? This term gets used prolifically in engineering education research, and education research in general, but it is rarely explained. So let's give this a try….

Are you familiar with the story of the blind men and the elephant? It is found in Buddhist, Hindu, and Jain texts[1] and describes a group of blind men who are interested in discovering what is an elephant. Each put their hands on a different part of the animal. The man who touches the ears thinks that an elephant is like a fan, the man who touches the tail thinks that an elephant is like a rope, the man who touches the leg thinks that an elephant is like a tree trunk…. You get the idea. Each of these experiences informs an aspect of what "elephant" means to us – and each of us has a different understanding and meaning we attach to "elephant". "Elephant" is a construct and each of these parts are aspects of the construct. Obviously, fully understanding elephants requires putting together all of this learning, and a lot more: where do elephants live, what do they eat, what are their social characteristics, etc. The construct we call "elephant" is a human constructed definition; indeed, the whole concept of a "species" is made up by us. It has aspects that we consider objectively true -- absolute truths that are true of elephants regardless of context or observer. And it has aspects that are unique to the observer – our attitudes about elephants, the value we place on them.

So a construct is a concept, and the associated aspects of the concept. More specifically it is the concept as we each uniquely comprehend it. Merriam-Webster[2] says a construct is something constructed by the mind: a theoretical entity, a working concept, or a product of ideology, history or social circumstances.

Elephants are relatively well defined, tangible things, but let's use a different example that is less tangible: grief. Suppose you are interested in exploring the relationship between the grieving process that occurs when a student fails a course and academic advising. You might start by exploring the construct of grief and the grieving process. You would want to read up in the literature on different types of grief, the stages of grief, and other aspects of this construct. Perhaps you have personally experienced grief, and this would also inform your understanding – keeping in mind that your grief is unique to you and not necessarily generalizable. You will find that there are not as many "absolute truths" in this construct compared to elephants. However, there are probably some agreed upon aspects of the construct. For example, you would find that there is general agreement that there are stages in grief.

How does this help shape your research? Constructs are often explored through surveys, observations, experiments, (i.e., research) and captured in theoretical frameworks. A theoretical framework is a model or structure that captures, and perhaps characterizes or labels, some aspects of a construct (idea, thing, process, system). For example, it might describe the construct of "motivation", or "competence". It often reflects the perspective, or area of interest, of the researcher, and it makes it easier for people to have shared conversations about complex ideas. For elephants, a conceptual framework might look like an anatomical diagram, or a habitat and food map, or a social network diagram. All of these capture some important aspects of elephants, but no diagram or description will capture all aspects.

[1] According to Wikipedia. I honestly didn't do more research than that.
[2] https://www.merriam-webster.com/dictionary/construct

For grief, you may find existing frameworks for the stages of grief such as the framework developed by Kubler-Ross (denial, bargaining, anger, depression, acceptance).[3] This doesn't capture every aspect of grief, or perfectly describe the construct and all of its complexity, but it provides some of the major aspects that give you a starting point for your research. How could you use this particular construct and associated conceptual framework? Examples:

- You might start by explaining how you decided to use this pre-existing term coined in another context to describe an engineering education experience--what would you miss and what would you see with greater clarity?
- You could observe student advising sessions and code your observations using this 5 stage theoretical framework as a starting point for your coding.
- You might devise approaches to academic advising that align with each of these stages and test whether a stage-specific approach works better than a generic approach to advising.
- Etc.

Constructs are frequently the focus of surveys and construct validity is an aspect of survey design. Construct validity is increasingly viewed as critical to a well-designed survey, and reviewers will look for this in your research write-up. Construct validity means that either you are using an existing survey that is built around a theoretical or conceptual framework, using pre-defined items on a scale that has been validated to assess grief, or you are building your own survey around a conceptual or theoretical framework. The survey should also cover the major aspects of the construct.

Some surveys may explore more than one construct, but it should be clear that the items "load" onto the constructs of interest – that is, the items all measure aspects of the same construct. Typically, you want a set of items that cover different aspects of the construct without too much overlap (redundancy), but includes some triangulation (i.e. criterion validity). This "loading" should be described in your write-up so the logic in your survey design is explained, and it can also be tested statistically once you have results.

Together, constructs and theoretical frameworks are foundational to educational research. Constructs and theoretical or conceptual frameworks reflect the way a researcher knows, values, and experiences the world. They say something about what aspect of the phenomenon the researcher has chosen (foregrounded) for their work, which also speaks to the researcher's values. They help us put the pieces of the elephant together so we can discuss a concept as a cohesive thing and come to some shared understanding and language or identified areas of disagreement.

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[3] E. Kubler-Ross, "On Death and Dying", originally published in 1969.

A Quick Survey on Surveys

One of the most common data gathering tools engineering education researchers will use, especially initially, is a survey. Keep in mind that ethics clearance will usually be required to gather data from students (or instructors). Select or create your survey early in the research process because the ethics board will want to see it. More importantly, your survey should be designed to help you answer the research question(s) for your study. Much like design generally, survey design is underappreciated. It looks simple enough, but it can be difficult to do well. This snack provides a few nuggets on good survey design. We also encourage you to look at tip sheets and other sources online: We have referenced a couple of these at the end of this snack.

Before you begin ask yourself: do you really need to use a survey? Surveys are fraught in many ways. You will probably only get a 30% response rate (if you are lucky) and the people choosing to fill out the survey may not really be representative of your population of interest. Also, people are not terrific at self-assessing things like learning, or their own resilience, etc. And survey fatigue is becoming endemic. If you can gather information that answers your research question any other way, consider using a different method. If you must use a survey, consider adding other data sources to triangulate your findings.

0) Find an Existing Survey

A good survey (also referred to as an instrument) should be carefully crafted and developed. It should be validated. The items (i.e. questions) on the survey should load onto identified constructs and the survey should be tested to make sure that is the case. All to say, creating a survey is not something you do casually. So if you can find an existing, well tested survey that meets your needs, **use it!!** Using an existing survey or survey items can also allow you to compare your results to others. Jaeger, Freeman et al. (2010), winner of an ASEE best paper award, is a good example. If you use an existing survey or survey items, make sure you are aware of the copyright requirements – some surveys are proprietary (i.e. must be licencsed), others can be used for free with some conditions. Even within a survey you construct yourself, you might want to use validated items from other surveys. For example, if asking demographic questions, consider using items developed by StatsCan for the population census. If you have decided that you must use a survey, and a search of the literature does not provide you with an existing one, then you must enter the swamp of survey development …

1) Tell Us How You Really Feel

You need to be careful how you phrase the question and answers to get quality data. You want responses that reflect how your respondents feel about the question as you understand it, and you don't want biased responses. Consider the question "To what extent did you find the xxxx learning experience valuable?" Potential multiple choice answers could include "not at all/somewhat/quite/extremely". Note that every possible answer makes sense after reading the question. This is important for clarity. Also important is that the answers are clearly distinguishable and well-spaced. This is a "one sided" question in that answers range from zero on up. Another kind of question lends itself to a two-sided answer set. Likert scales provide a range of responses that measure the extent of agreement with a statement. Consider the statement "Active learning is fun". If respondents are asked to what extent they agree with this statement, a Likert response scale could be "strongly disagree/disagree/neither agree nor disagree/agree/strongly agree". Note that it is symmetric with a neutral center. It is unbiased and does not suggest a "correct" answer or even a correct type of answer (positive or negative).

2) Recall versus Recognition

Multiple choice questions are useful in surveys because they are quick to answer, and they can be analyzed quantitatively. The problem is, you aren't letting the respondents answer your questions in a natural manner. You are guiding them. And sometimes your guidance will obscure valuable insights. So it is very valuable to often include "Other" as an option in a question so that a respondent can write in their own answer. Even better, ask open-ended follow-up questions such as "Why do you like active learning techniques?" You could offer multiple choice answers for this one or let respondents write their own. It's the difference between recognition and recall. With multiple choice, you ask them to recognize reasons. With open-ended questions, you ask them to recall reasons. Results between the two often differ.

3) I will Answer this Question on One Condition

Where possible and appropriate, try and make your survey adaptive to your audience. No one likes to have to answer questions that aren't for them. So include questions that are "gatekeepers". For example, "did you take GE xxxx?" If the answer is "no", allow the respondent to skip the questions that pertain to GE xxxx. This is easy to do with most survey software like Survey Monkey, and you will get higher survey completion rates if you can make them shorter for respondents. Note: check to see whether your institution has a site license for a survey tool that you can use for free.

4) Analyze Before You Finalize

Although you won't conduct survey analyses until after you've deployed your survey and received responses, it's very important to consider your survey analysis plan before you finish your survey design. Some of this will be obvious: for Likert scale questions, you might plan to analyze based on frequency of response, or by converting the Likert scale to a numerical scale and calculating a median, (note that calculating means can be tricky with Likert scales). You should also consider whether your open-ended questions will be analyzed using a particular theoretical framework, whether you'll be looking at the relationship between survey questions, and how your survey questions map to (and address) your research questions. This exercise might reveal changes that need to be made in your survey design.

In summary, only use a survey if you have to, and if you have to, try to find an existing one. If you must create your own, be thoughtful about the items. Follow guidance for good item development. And, ideally, test the items with a sample of your participants before putting it out into the population. There is a huge literature on surveys and interpretation of survey results. You don't have to be an expert in all of this, but some knowledge of what you are doing is critical.

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Engineering Education Research Snacks

CEEA ACEG CANADIAN ENGINEERING EDUCATION ASSOCIATION ASSOCIATION CANADIENNE DE L'ÉDUCATION EN GÉNIE

Validity and Reliability: Quantitative Research Study Buddies

Good quantitative research studies are designed to be as valid and reliable as possible, while recognizing the constraints that we have when doing research in the real world.[1] What does this mean? What enhances the validity and reliability of a research study?

✸ **Validity** – are we measuring what we purport to measure?

The validity of a study depends on the design of the research setup all the way through to the interpretation of the results. It starts with the instrument or measurement system you are using to collect data that is relevant to your research question. An instrument could be a grading system, a survey, a methodology for collecting observations, a test, or some other measure of a phenomena. To support validity, we ask ourselves:

1. Is the instrument or assessment a good measurement tool? Is it aligned with the research question?
2. During the study, are there internal or external factors that impact validity?
3. And then, is your interpretation of the results aligned with what you measured and how you measured it?

The first question is answered by ensuring that you either use an instrument or measurement system that has been tested by others, or that you test it yourself. For example, if you are trying to test students' ability to apply basic concepts in physics, you might use the Force Concept Inventory (FCI), which is a standard exam that has been extensively tested/validated.[2] Alternatively, you could create your own exam or other measurement system, but then you would want to go through a process of developing an instrument based on theory or findings from the literature, and testing and refining your proposed tool before using it in your study.

The corollary to this: Is your measurement system aligned with your research question? You can have a highly validated assessment instrument (e.g., the FCI), but if you misuse it then it is not a valid measure (e.g., use the FCI to measure advanced physics topics). Examine your research question carefully. Are you using a measurement approach that is as direct and aligned as possible with the question that you are trying to address?

The second question is answered during your study. Did something happen to threaten validity? This could include an unusual pattern of people dropping out of your study, or perhaps your study design did not account for differences between groups (Creswell has a couple of nice tables showing types of threats to validity, p. 169-172).

The third question: Are you interpreting your results in a manner that aligns with what the instrument purports to measure and the way you have used it. That is, are the claims you are making in your discussion and conclusions based on valid data? Do your claims follow from, and align with, what you measured? Heale and Twycross (2015), for example, note that you cannot draw conclusions about depression in a population using a survey that measures anxiety. The resulting data are not valid for this purpose.

✸ **Reliability** – are our measurements dependable/consistent?

The reliability of a study design substantially depends on the method and actual circumstances happening when the study was running. That is, if you ran the study again, in the same context with comparable participants, would you get the same results? Are your results dependable? Reliability is enhanced, for example, by having a larger sample size, a sample that is representative of your population of interest, and ensuring that the circumstances during the trial or observation did not substantially interfere with the study.

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[1] In qualitative studies some authors (Creswell) talk about validity. However, others use the analogous concept of *methodological integrity* which includes *fidelity* and *utility* (see *Reporting Qualitative Research in Psychology*, H.M. Levitt, 2020).

[2] The Force Concept Inventory was originally proposed in 1985 by Hestenes, Wells, and Swackhamer. There is an extensive literature on this standard test.

Let's consider the FCI again. Suppose you give a group of students the FCI before they take a physics course and at the end. This is called a pretest-posttest study, and you are looking for gain, that is; the degree to which students demonstrate better understanding of basic physics at the end of the course. But suppose the power in the building goes out during the posttest so the students are writing the test in the dark, or suppose you only test 3 students in the class, or suppose your posttest is at 8:00am the day after the prom. All these circumstances (some under your control and some not) will erode reliability – to a greater or lesser extent. Just as in science experiments, running more trials, making sure external factors don't mess with your measurements, and so on, improve reliability. Researchers use various reliability coefficients (which essentially represent correlations) to inspect reliability. One example is Cronbach's α, commonly used for surveys. There are others used for tests and other methodologies.[3]

✸ **Limitations** – all studies have them

Is any study perfectly valid and reliable? Absolutely not. There is just no such thing. The reality of research, especially in engineering education, is that you usually cannot run a survey or test an intervention many, many times over years and years. And you can only validate your measurement approach so many times in so many ways given resource and time limitations. So how do you effectively manage validity and reliability?

First, pay close attention to your study design. Have you chosen a measurement approach that has strong validity for what you are trying to measure? If you are creating a measurement (e.g., a survey, rubric, test, etc.) then also design a testing regime for your measurement system before deploying it. Think ahead to reporting your results: how will you explain the alignment with your research question? Plan out your method thoughtfully: how will you deploy this measurement? Think about the ways you can improve the reliability of your results, and report what you did to improve reliability and any evidence that can demonstrate their reliability. Not all aspects of reliability are under your control, but the design of your study methods can improve the chances of enhancing reliability.

Next, check the claims you are making about the results. Many people think about validity in terms of the results: are the data valid given the design of the study, and what happened during the study? The validity of the results is strengthened when the research question and measurement method are well-aligned; an appropriate, validated instrument (measurement approach) is used; you managed internal and external threats to validity during the study, and the interpretation of the results is aligned with what the instrument measures.

Then, use the limitations section of your write-up (in your thesis, or paper) to explain the steps you took to enhance reliability and validity and the limitations in the study design and deployment. Maybe a pandemic hit in the middle of your study. Maybe you had to use convenience sampling because it was the only feasible option. Also clearly explain the limitations of your results and the generalizability of your conclusions. Readers understand that real-life research has real limitations, and they want to hear how these limitations impact the data and interpretation of your results.

One common question: I know there are limitations in my study, but I'm not sure whether to call it an issue of validity or reliability. How do I explain this? Answer: sometimes it is a matter of interpretation whether an issue is one of validity or reliability. Instead of trying to label it, consider simply explaining the issue, and pointing out how you accounted for it in your results/discussion, or how it may impact interpretation or generalizability of your work.

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[3] https://www.ets.org/Media/Research/pdf/RM-18-01.pdf

More on Validity

In the "Validity and Reliability: Quantitative Research Study Buddies" Research Snack, we made the point that validity relates to the accuracy of a research study and the appropriate interpretation of the results. The essential question that underpins validity is: are you measuring what you purport to measure, and appropriately interpreting the results?

The term validity is used in a couple of distinct ways in engineering education research:

1. To describe the quality of <u>an instrument or items in the instrument</u>. An instrument could be a survey, rubric, test or other measurement system. There are several types of validity that relate to instrument design, development and testing (see table below). These types of validity are most frequently associated with instruments used for observational (correlational) studies.
2. To describe the quality of <u>a study design</u> (typically an experiment or quasi-experiment) and the way it is run. Most often explained as "threats" to validity, these are internal and external factors in the research that may impact the interpretation, or generalizability, of the results.

1. Types of validity used in instrument development	
Face validity	Do the participants interpret the items and instructions on the instrument as intended?[1] Is your instrument clear and transparent to the population of interest?
Construct validity	Do the items in your instrument reflect key dimensions of the construct as characterized by the research on this topic? This type of validity is substantially related to the conceptual framework used in your research and builds on a literature review. An instrument that has construct validity is tuned to the conceptual or theoretical framework you are using, and it is clear in your reporting how it relates to the framework and covers the major aspects of the constructs you are purporting to measure.
Content validity	Do the items measure the intended content/construct? Does the instrument cover the key aspects of the content/construct? If an instrument does not cover the major aspects of the construct effectively, the result is "construct underrepresentation" or "construct deficiency".
Criterion validity	Sometimes this type is split into two: predictive validity and concurrent validity. Both are related to the concept of triangulation: do you have other evidence that suggests your instrument is accurate? Or is there some objective criterion you can use for comparison with your results to strengthen confidence in your instrument? <u>Predictive validity</u>: Do the results from your instrument accurately predict some other independent measure? For example, if you design a tool to measure students' design ability, do the results predict their grades in a subsequent design course? <u>Concurrent validity</u>: Do the results from your instrument concur with another, independent measurement of the same population (i.e., convergent evidence)? Or, possibly, do your results diverge from results from some other, independent measurement in an expected way (i.e., discriminating evidence)?

[1] An "item" may be a question on a survey or test. But not all items are questions. For example; an item may be a criteria on a rubric, or a statements on a survey that you are asking participants to rank.

2. Types of validity related to the context and participants, typically in an experiment (Creswell has an excellent section on this (p. 169-172), which I highly recommend reading)	
Internal validity	Relates to the selection of the participant group and their experiences, feelings, and so on, and how these may affect (i.e., threaten) an "objective" measure.
External validity	Relates to external factors that limit the generalizability of the results or interpretation of the results: - Ecological validity: is the context you used for observations or other aspects of the study authentic (e.g., observations in a real class or a mock class)? Can you generalize your results to other contexts, or are the results highly context specific? - Historical validity: are the results generalizable to future situations? Or will changes that occur over time mean your findings become less meaningful/accurate? - Population validity: are your results generalizable to other populations? Or specific to the specific group who participated (e.g., at one university, one discipline, etc.)

There are other types of validity discussed in the literature, and sometimes they are organized somewhat differently, but this table covers the ones mentioned most frequently.

Common question: Do I need to address every type of validity in my study design and write-up? Answer: No, not necessarily. Most studies and write-ups do not address every type of validity explicitly. However:

1. Even if you don't include a write-up on every aspect of validity, think through these types, and the overall question of validity in your study. Reflect, document (make notes) and talk with collaborators about the validity of your study. This will help you design and conduct better research. It will also help you answer questions about your research when you present it.
2. Do include the most critical aspects of validity in your write-up. This is an important aspect of research and something that reviewers will look for in your work.

The table shows types of validity that are relevant for instrument development and types of validity relevant for experiments. You might ask: these all seem relevant for both observational and experimental work – Is this categorization really so distinct? Answer: No. This is the categorization used by Creswell, but in fact these types of validity are important considerations in all types of research. That said, some types will be more important to a particular study than others; so identify which ones best align with your work.

It is worth noting that not every source uses "types of validity". The AERA Standards for Testing, which specifically pertains to the development and use of educational and psychological tests, discourages the use of "types of validity". Rather they make the point that validity resides in the interpretation of the results. That said, their description of the development of tests references many of the concepts identified in the table.

No matter how it is framed, validity is a critical aspect of engineering education research.

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Selecting a Sample for a Quantitative Research Study

Chances are that when you took social studies in high school you were taught how to look up information, but not how to design a research study. You probably learned how to do research in your science classes and learned more about it in engineering and in grad school. However, the type of research you learned was probably experimental research, not observational, and it probably didn't involve people. So how do we design a study in engineering education research (EER)?

In EER there are essentially, broadly speaking, three categories of methodologies: qualitative, quantitative, and mixed methods. In this research snack, let's consider one of the most basic decisions that needs to be made in a quantitative research study: Sampling.

First, we need to decide on our population. What is the population of interest? A single person, a group of students, instructors, a population in a course(s), a curriculum/a, or other groups? Maybe it is all full-time students in 3rd-year chemical engineering, for example. Ideally, we would have the whole population of interest participate in our study, but this may not be practical. So how do we pick a sample? Here are a few common ways that samples are selected:

Simple random sampling: randomly pick a sample from the population. You could draw out of a hat, roll a dice, use a random number generator, etc. (yes, real professional researchers use names in hats).

Stratified sampling: the population is divided into groups (e.g., by engineering discipline) and then a fraction of each group is randomly included in the study. This could be an equal number from each group, or a fraction that is proportionate to the distribution of groups in the population.

Clustered sampling: If the population is clustered (e.g., students in courses), we might choose to include every person in a random set of clusters, (e.g., every student in a randomly selected set of courses – if the courses do not have overlapping enrolments, or the overlap is very small).

Beware of convenience sampling! Convenience sampling is choosing a sample because it is convenient. For example, choosing the students in your own class to survey. This is certainly easy, but it isn't necessarily the best choice. The students in your own class may not be representative of the population of interest that you have identified. They certainly aren't random in any sense, unless your class is the only population of interest.

Identifying your population of interest and a sampling strategy is one step in designing your research study. In future snacks we will explore questions like:

- Do you need the people in your sample to consent to participate? (the answer is "usually, but not always")
- What are some strategies to encourage participation?
- What if only a fraction of people in your sample agree to participate?

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Human Research Ethics: Can I Use My Own Class for My Research Study?

The short answer is **yes**. In Canada, if we want to do research that involves humans (like our students), we need to run our study by a behavioural research ethics board (REB) for approval. Every university has such a Board. Some may also have Biomedical and/or Veterinary REBs. For engineering education research though, you'll usually be dealing with your Behavioural REB.

Referring to the Snack on Statistical Studies, a sample study that involves a survey, for instance, will require a simple ethics application which will likely be approved quickly (minimal risk). An observational study will require more safeguards, usually to address issues of free and informed consent, coercion to participate, and/or conflicts of interest. This is especially true for experimental studies in engineering education, where fairness can also be a major consideration.

The good news is that you can generally do whatever study you have in mind. It's just that some studies will require more logistical complexity to ensure that the research is carried out ethically. If you are teaching a class that you want to study, such as in the scholarship of teaching and learning (SoTL), **you have an inherent conflict of interest as a teacher and as a researcher** i.e. sometimes the objectives of those two roles will differ. When recruiting, you usually can't directly recruit your own students due to perceptions of coercion and you can't see who has participated and what they have said, until your position of influence over them has expired. To address this issue, it is best to have a colleague, or grad student, do the recruitment and hold the information about who is in, or not in, the study until after you submit your grades for the term.

If you do an experimental study, **you usually need to ensure that those getting the experimental treatment will not be able to get more benefit than the "control group"**, if benefits turn out to be evident. There are good methods to deal with all of these issues and more. Look for future research snacks on cross-over studies, and so on, and talk to your colleagues who have experience in SoTL – your teaching centre may be a good source for information on this too.

While some may lament the need for ethics approval, it can be a helpful experience. Procedurally, you'll want to plan out how you will execute your study, in great detail. The devil (and the ethics) is typically in the details. Once you have your plan, you can then find your Board's forms and fill them out. Typically, you will need to prepare the basic application, along with a consent form and a participant recruitment narrative. Then the Board will review your application. This can take anywhere from 2-8 weeks, depending on how complex your application is, and how busy your Board may be. REBs will evaluate your application against the criteria laid out in the latest (2018) version of the Tri-Council Policy Statement (or TCPS-2). You and anyone else involved in carrying out your study will need to complete the TCPS-2 tutorial, which can be found at https://ethics.gc.ca/eng/education_tutorial-didacticiel.html. Much like graduate theses, it is rare for an application to fail (be rejected) and it is also fairly rare for no modifications to be required. Usually, the Board will require you to clarify a few points and/or add an extra safeguard or two for your participants (like minor revisions on a thesis).

The point of the ethics review is to make sure that human research is conducted ethically. This ensures that participants can offer free and informed consent, that participants are treated with fairness and respect, that participants are not pressured to participate, that conflicts of interest are well handled, that risks are minimized while benefits are maximized, that data is protected, and that no systemic discrimination takes place during the study.

While the TCPS-2 gives you the ethical framework for your research, don't hesitate to reach out to your REB for advice and assistance. As well, it is often helpful to consult with peers who have done similar studies either at your institution or at others. Not every REB will have exactly the same procedural requirements (they all interpret the TCPS-2 slightly differently), but they should be fairly similar.

As a final note, if your "research" is really an internal quality assurance study, accreditation, institutional quality assurance, program evaluation or simply wanting to know more about the effectiveness of your own teaching then you may not need to complete an ethics application at all. Best to check with your REB about that. Even if you don't need formal REB approval, you still need to do your QA study ethically! Indeed, it's best to pretend that you need ethics approval regardless, so that you'll continue to treat your students ethically.

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Interdisciplinary Research

Interdisciplinary Research as an Iterative Process of Teaching and Learning
Engineering Education is a product of two fields: engineering and education, both of which include multiple sub-fields. For this reason, and because our response to complex social realities requires researchers to transcend disciplinary silos, we must learn to work and thrive in interdisciplinary teams. We recognize this work can be difficult. Working across disciplinary boundaries requires intensive listening, humility, and the recognition that each of us is (de)limited in some ways. In this research snack, six members of the EER community share lessons we learned while working in interdisciplinary teams.

Defining terms: Multi? Inter? Trans?
There are at least three ways of characterizing collaboration across disciplines: multidisciplinary, interdisciplinary, and transdisciplinary. Stock and Burton[1] distinguish the terms as follows:

- **Multidisciplinary:** *coexistence of academic disciplines*
- **Interdisciplinary**: *bridging disciplinary viewpoints and methods*
- **Transdisciplinary:** *redrawing a disciplinary map*.

We present these definitions in ascending order of integration without attaching virtue to any one. For this snack, we have landed on the term *interdisciplinary* because our growing body of research bridges rather than transcends or simply co-exists with disciplinary viewpoints and methods. That is, our investigation involves an active process of teaching and learning from one another as we each draw on distinct disciplinary roots.

Teaching as Learning
The six contributors to this snack have completed graduate training in engineering, education, and the humanities. In addition to these distinct disciplinary roots, we have also worked in a range of institutional contexts including K-12 education, higher education, and industry. Each of these experiences has sensitized us to different epistemologies, methodologies, and audiences, allowing us to contribute to interdisciplinary EER teams in unique ways. At the same time, our experiences on these teams has enabled us to learn important lessons from our colleagues rooted in other disciplines. At the risk of reducing our experiences to categories, authors with engineering degrees have drawn primarily on our experiences with quantitative methods and design, while those with degrees in education and the humanities have drawn primarily on our experiences with qualitative methods, theoretical frameworks, and communication. EER flourishes when we find ways to bridge these two bodies of professionally-rooted expertise. Please see Table 1 for a summary of our contributions, learning, and experientially derived tips for the next generation of EE researchers.

While it is both possible and admirable to conceptualize interdisciplinary research in other ways,[2] we have chosen to characterize it as an iterative process of teaching and learning to highlight the unfinished nature of our own development as researchers. In the spirit of lifelong learning, we wish to honour the many lessons we have learned and continue to learn from our colleagues in other disciplines while engaging in EER. Our inquiry is not only unfinished, but also reciprocal. The next generation continues to teach us through their curiosity, questions, and insights. In the words of Paulo Friere[3] "whoever teaches learns in the act of teaching, and whoever learns teaches in the act of learning" (p.31).

Table 1: Teaching and Learning from other Disciplines

Name	Background	Contributions to EER	Learning from Others	Tips for EER Researchers
Susan McCahan	Mechanical Engineering	Seeding a field by designing and allocating resources to SOTL	Diversifying methodological and theoretical base	Start with a small SOTL project, learn from the experience, and consult with others
Brian Frank	Electrical Engineering	Building bridges between faculties, departments, and institutions	Complexity of large-scale, multi-institutional assessments of student learning, in a changing context	Reflect on student experiences, collaborate, and read the literature related to your interests
Emily Moore	Chemical Engineering; Industry	Reciprocal translation between industry and academic audiences	Use of theoretical & conceptual frameworks to pose social science questions in engineering	Get ready to be uncomfortable; it's a sign that you are learning; scoping is iterative; there is value in making the implicit explicit
Lisa Romkey	Curriculum, Teaching & Learning; Higher Education	Epistemological considerations & theoretical frameworks in educational research design; K-12 STEM education	Design-based research; pedagogical content knowledge in engineering	You belong here; there is room for many voices & pathways; take advantage of every learning opportunity you have in research methods; ask the authors of this snack for their top research methods text! Make sure you can clearly articulate your own research goals/purpose; this can open doors to collaboration.
Deborah Tihanyi	Drama; Theatre; Humanities	Bringing performance training & humanities lens to EER; experience conducting narrative research; work across disciplines integrating communication	Social science methods, particularly quantitative; an appreciation of engineering cultures and ways of knowing	Immerse yourself in the discipline you're studying; engage in individual and interpersonal reflective practice; understand your strengths; work to develop a common language around shared objects
Cindy Rottmann	Educational Leadership & Policy	EER project framing drawing on a diversity of theoretical frameworks, methods & paradigms; social & policy implications of EER research	Professional engineers & professors are active participants, not passive recipients of findings; Iteration is part of the analytic process	We may use the same words in different ways, so listen to others and check in to make sure you are respecting perspectives that differ from your own

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Engineering Education Research Snacks

CEEA ACEG
CANADIAN ENGINEERING EDUCATION ASSOCIATION
ASSOCIATION CANADIENNE DE L'ÉDUCATION EN GÉNIE

Reporting your Quantitative Research

Author guidelines or toolkits for dissertations, conferences and journals often provide meticulous detail on font sizes and margins, but are silent on the content you should include in a well written report on your research. Obviously, reading other people's work in journals or conferences is critical to understanding the norms in the field, and for years I relied on this approach to advise students on their research reporting. However, there are also some useful (possibly even essential) references that are extremely helpful. Many EER journals, including JEE, point authors to resources published by AERA and APA[1]. Using these as a starting point, what changes when you are designing an EER study or writing about EER work?

Let's start with "*Reporting Quantitative Research in Psychology: How to Meet APA Style Journal Article Reporting Standards*"[2]. READ THIS BOOK! This short little book describes in flowchart and checklist style the information that should be reported in a paper, report or dissertation. It includes key differences for research that is observational versus experimental, or quasi-experimental, and it has information on reporting studies where N = 1, and other types of situations. It also has some critical information such as how to report that the data in your paper was also published in your thesis, or how to use your abstract to optimize findability for people looking for literature in your field. There are a few key differences between EER reporting and APA reporting, as it is described in this text. For example, the information they suggest putting in an "Author Note" in an APA style report is often handled very succinctly in the "Acknowledgement" in EER papers.

While this APA book is a great starting point, it is not complete for EER work. For example, it does not mention the importance of including your research paradigm (e.g. theoretical and conceptual framework(s)) in your reporting. Instead, JEE recommends using the AERA work "*Standards for Reporting Empirical Social Science Research in AERA Publications*", which mentions theoretical orientation as an important part of a research report. This AERA Standards guide is one of many AERA publications available online. While useful, this particular publication is relatively short, and does not include as much detail as the APA book, unfortunately.

So, what do both of these publications miss in EER reporting? There are a couple of critical pieces (see table below). First, many EER publications, and particularly dissertations, contain a more fulsome description of the theoretical orientation and conceptual frameworks used by the authors in situating and designing their research study. This is true for both quantitative and qualitative EER studies. These concepts have been discussed in other research snacks.

Second, many EER studies benefit from a description of the "context" or "setup" in the Introduction, or early in the Methods section. APA calls this "setting, exposure and time span". For example, the research may revolve around a specific course, a program (curricular or co-curricular), a particular classroom or space, a specific pedagogical approach or teaching method, or a specific type of assessment. It is the context in which you either are doing your observations or your manipulation (in the case of an experimental or quasi-experimental study). The reader needs to understand this "setup" before you explain the method you are employing to investigate some aspect of the educational experience, or the experiment you are running in the context. And finally, it is

[1] AERA (American Education Research Association) and the APA (America Psychological Association) are both enormous compared to EER groups. It is worth attending an AERA conference, if you have the chance, just to see the wide, wide world of education research.
[2] There is a similar guide for Qualitative Research published by APA.

increasingly common for EER dissertations (both qualitative and quantitative) to include a positionality statement that describes the way the author identifies themselves and their perspective as part of the research work. Positionality generally appears in the Introduction.

As the APA points out, the content list they provide is too expansive to be covered in most papers given word or page limits. However, reading through the checklist is invaluable for would-be authors, including students who are planning out their research program.

What to include in reporting – extending the APA guidance	
APA guides provide helpful checklists for publication content	https://apastyle.apa.org/jars https://apastyle.apa.org/jars/quantitative quick checklist: https://apastyle.apa.org/jars/quant-table-1.pdf (Similar guides are available for qualitative research)
Author Note	In EER this information (in short form) is generally found at the end of a paper in the acknowledgement rather than an author note.
Theoretical & Conceptual frameworks	See the research snacks on these topics. (https://ceea.ca/resources-2/)
Setting, exposure and time span; i.e., context and setup	Very frequently an EER study is taking place in a specific context (e.g. a third year design course, first year orientation programming, etc.). For a course, this description might include a summary of the intended learning outcomes, the student population taking the course, the assessment plan, the pedagogical approach, the length/structure of the course and how it fits in curriculum, for example.
Positionality statement	How the author positions themself: who they are and how this may impact their perspective on the research. It may also include the researcher's relationship to the participants (e.g., instructor for the course being studied). This is recommended by the APA for qualitative studies and is increasingly common in EER in all types of dissertations/reports.

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