MAKING THE MOVE:

NAVIGATING A TRANSITION FROM DISCIPLINARY ENGINEERING INTO ENGINEERING EDUCATION RESEARCH

Sindia M. Rivera-Jiménez
Assistant Professor
Engineering Education
University of Florida

Sarah Wilson
Assistant Professor
Chemical and Materials Engineering
University of Kentucky

1. **RESEARCH IN ENGINEERING EDUCATION**

We will walk you through a brief history of engineering education. You will talk about your research goals.

2. **IDENTIFYING YOUR RESEARCH AREA**

We will talk about sources of research ideas. You will take time to identify an area of interest.

3. **DEVELOPING YOUR RESEARCH METHODS**

We will introduce you to the importance of theory and research methods. You will brainstorm strategies for data collection.

RESEARCH IN ENGINEERING EDUCATION

EARLY HISTORY

1802 1st engineering program (Civil) established in the U.S.

1852 First professional organization established (ASCE)

1862 Morrill's Act (Land Grant Act)

1802 Society for Promotion of Engineering Education (SPEE) formed. Later became ASEE

1802 1st SPEE periodical focused on "technical education". Later became JEE

Froyd & Lohmann, 2013

TOTODAY

1950 — NSF was established, transforming colleges into research-based institutions, mostly in science and engineering

1955 — ASSE issued the Grinter Report. Outlined S&E research oriented curriculum which still exists in most of US engineering programs.

1986 — National Science Board was issued. Instrumental to ignite NSF supper to S&E education programs and shaped national dialogue on the role of scholarship

1988 — First NSF grant related to engineering education is funded

1990 — Boyer' influential report "Scholarship Reconsidered: Priorities of the Professoriate" offered a new taxonomy to describe academia's forms of scholarship.

1990 — Introduction to EC 2000 by ABET. Introduced outcomes based on observation, evaluation, and improvement.

2006 — National EER Colloquies produced 1st organized taxonomy

2009 — NSF funded ASEE Study: "Creating a Culture of Scholarly and Systematic Innovation in Engineering Education"

Froyd & Lohmann, 2013

LEVELS OF INQURY

1

EXCELLENT TEACHING

- Involves the use of good content and teaching methods

2

SCHOLARLY TEACHING

- Good content and methods and classroom assessments and evidence gathering
- Informed by best practices and best knowledge, inviting of collaboration and review.

3

SCHOLARSHIP OF TEACHING & LEARNING (SoTL)

- The question is tied to learning, pedagogical, or social theory and interpreting can increase significance of findings
- Close attention to design of study and methods used, which will have greater impact of results

4

RIGOROUS ENGINEERING EDUCATION RESEARCH

Same as SoTL plus including unique components:

- Research question (why or how) and not assessment (what or how much)
- The question is tied to learning, pedagogical, or social theory and interpreting can increase significance of findings
- Close attention to design of study and methods used, which will have greater impact of results

Borrego 2007

ENGINEERING EDUCATION RESEARCH AREAS

The Research Agenda for the New Discipline of Engineering Education. (2006).

01 - EPISTEMOLOGIES (THEORY OF KNOWLEDGE)

02 - LEARNING MECHANISMS

03 - LEARNING SYSTEMS

04 - SOCIALLY-RELEVANT ENGINEERING

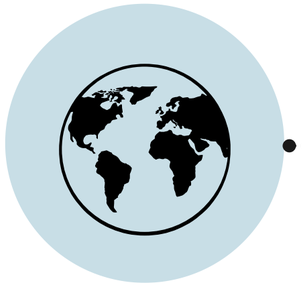
05 - ASSESSMENT METHODOLOGIES

IDENTIFYING YOUR RESEARCH SPACE

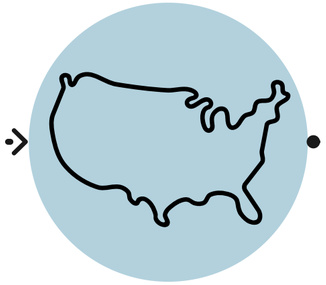
IDENTIFYING YOUR RESEARCH TOPIC

Defining your research topic and the scope of your project is crucial to getting started.

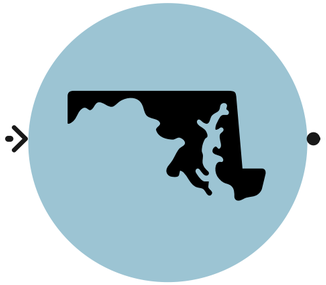
How is chemical engineering taught at universities across the world?



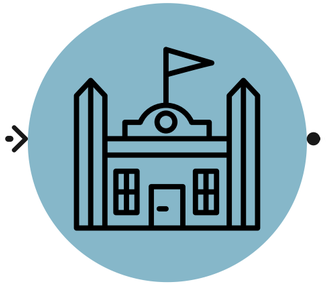
How is chemical engineering taught at universities across the country?



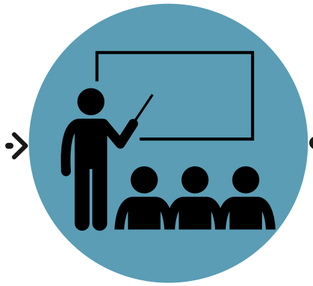
What specific skillsets do chemical engineers in industry need in the state of Maryland?



Where are the gaps in learning for chemical engineering students at my institution?



How can I effectively incorporate communication into a thermodynamics course?



How do students perceive the importance of communication in chemical engineering?

SOURCES OF IDEAS

01 - REPORTS

02 - OWN EXPERIENCES

03 - COMMUNITIES

What are you interested in learning more about in terms of your teaching or your students' learning?

Thinking about the teaching and learning issue you've identified in previous workshops, briefly state this issue as a research question

UNDERSTANDING THE PHENOMENA

Examples of Realites in Education

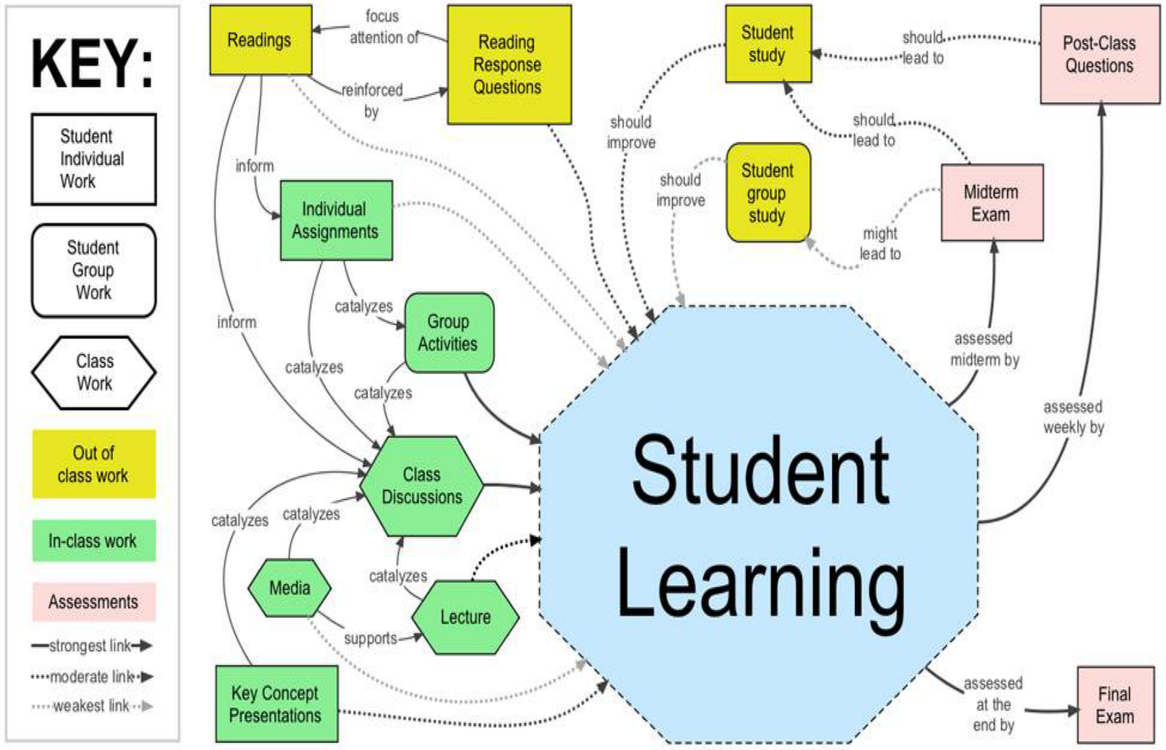
Behavioral phenomena: the observable actions of individuals or groups and to mental phenomena such as knowledge, attitudes, beliefs, motivations, perceptions, cognitions, and emotions.

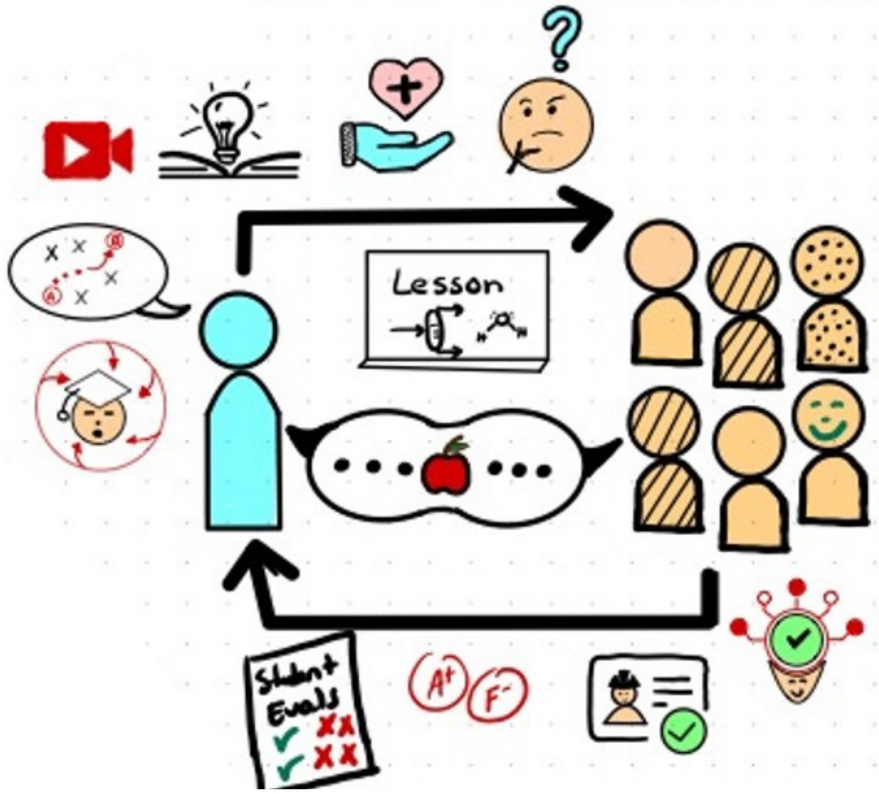
Social phenomena: the interactions between and among individuals, and to the characteristics, structures, and functions of social groups and institutions, such as families, communities, schools, and workplaces, as well as the physical, economic, cultural, and policy environments in which social and behavioral phenomena occur.

UNDERSTANDING THE PHENOMENA

Pictorial Maps for Research Ideation

- Visual representation of a behavioral or social phenomenon in education.
- Illustrates elements, relationships, and interactions using graphics, symbols, and diagrams.
- Simplifies complex information, aids visualization of factors, and supports analysis and decision-making in education.





LITERATURE REVIEW

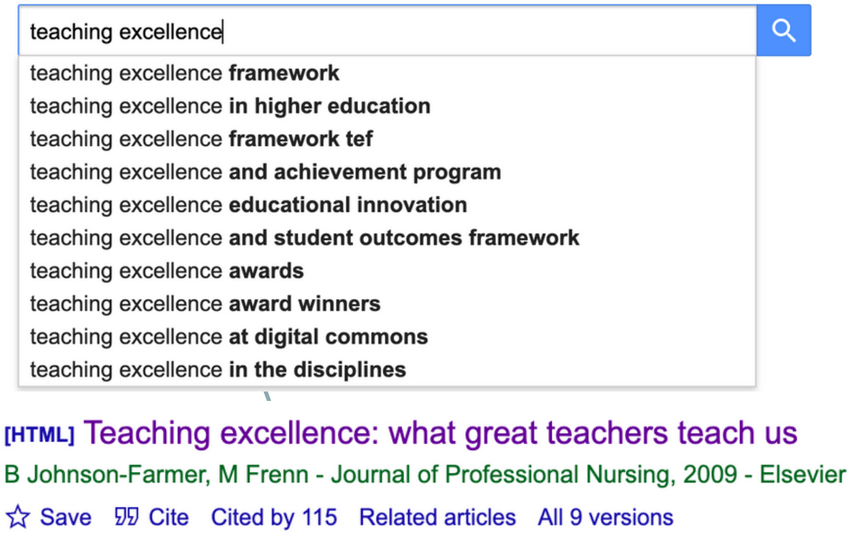
What do you already know about this topic/question?
Where might you go to look for literature for your review?

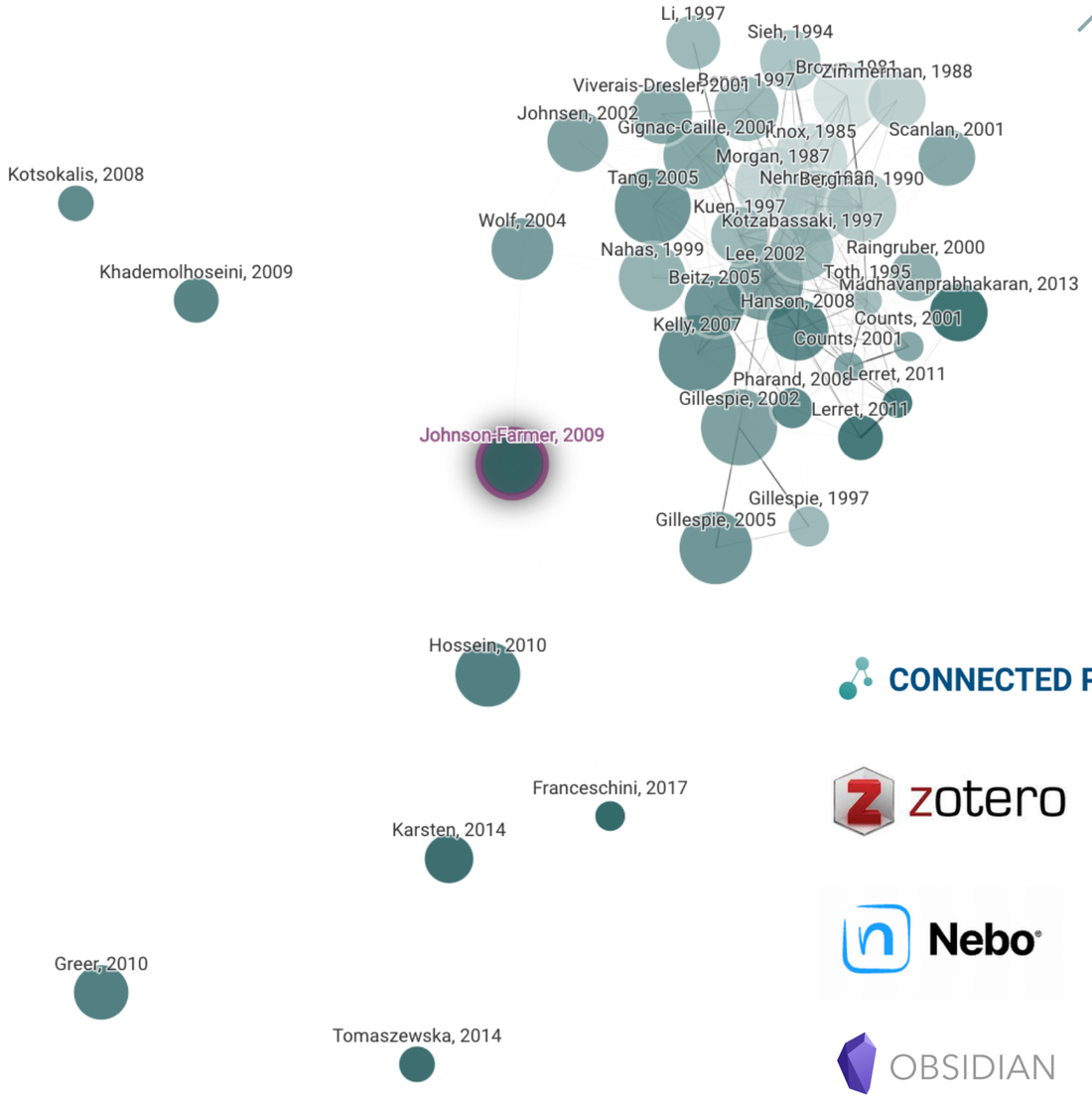
01 - NARRATIVE LITERATURE REVIEW

02 - SCOPING REVIEW

03 - SYSTEMATIC REVIEW

Google Scholar





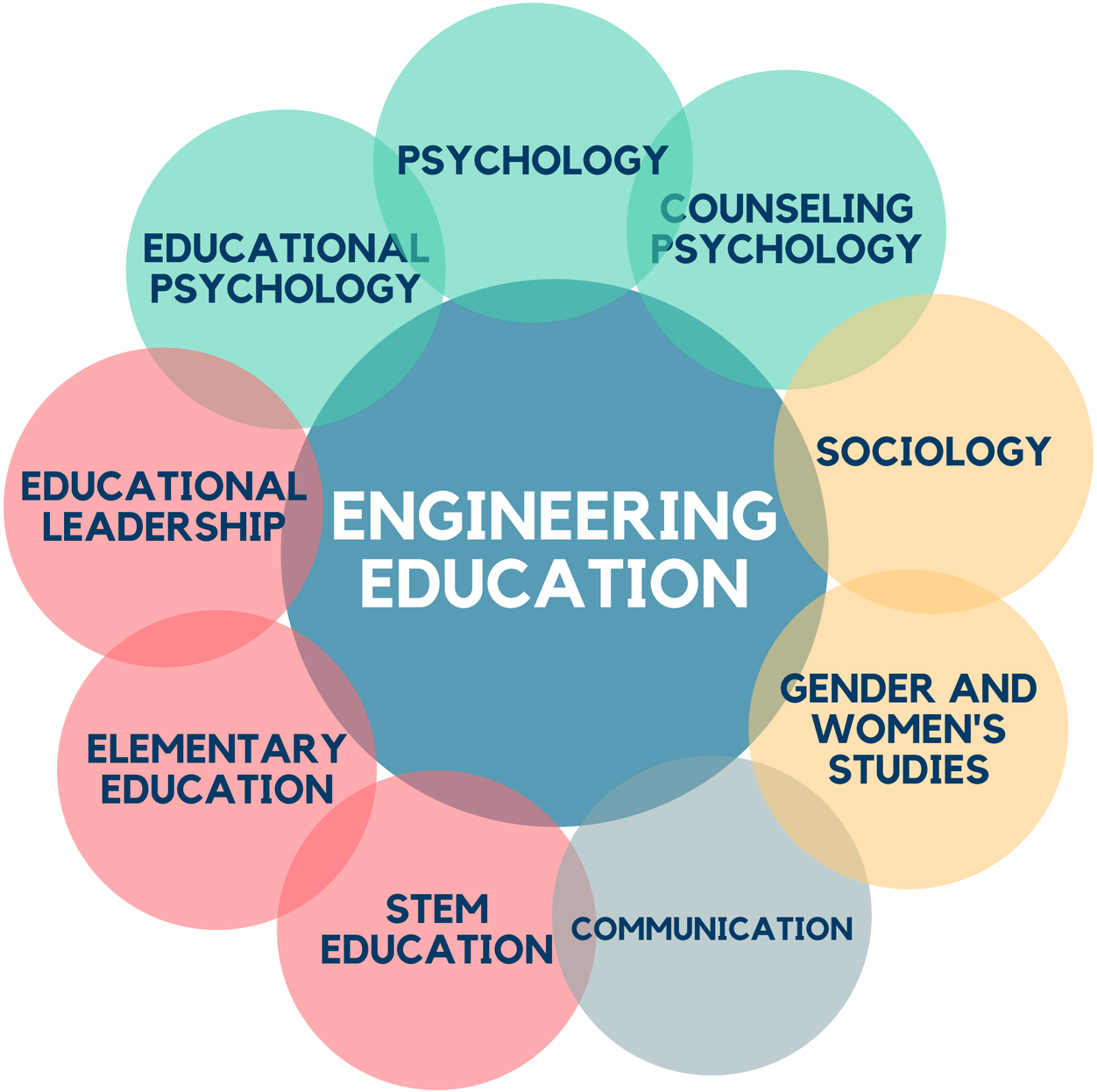
CONNECTED PAPERS

zotero

Nebo

OBSIDIAN

ESTABLISHING OUTSIDE COLLABORATIONS



ACTIVITY #1:
CREATING A PICTORIAL MAP FOR EXPLORING PROBLEM SOLVING SKILLS IN THE CLASSROOM

Why this is important?

- **ABET Criteria 1 :** "an ability to **identify, formulate, and solve** complex engineering problems by applying principles of engineering, science, and mathematics."
- "The ideal of being a lifelong learner is no longer a platitude. It has become economic necessity, and the academic community is only beginning to **understand that traditional teaching methods and curricula must be adapted to develop a twenty-first-century workforce and citizens of an increasingly complex world.** – Buck Goldstein and Holden Thorp, Editor, Science, Boyer 2030 Commissioner

What is the phenomenon?

- Problem solving: a process, used to obtain a best answer to an unknown, or a decision subject to some constraints.

What does the literature says?

- Problem solving is not the same as exercise solving
- Students who train mostly in exercise solving tend rely heavily on solutions they have seen before, rather than working directly from first principles.
- Thus, a problem with brand new context presents a formidable challenge to them.

Mourtos, et. al. (2004); Boyer 2030 Commission. (2022); ABET (2022)

ACTIVITY #1:
CREATING A PICTORIAL MAP FOR EXPLORING PROBLEM SOLVING SKILLS IN THE CLASSROOM

Groups 3-4 participants

Brainstorm and discuss 1-2 KEY problem solving skills you believe are important for students in the classroom. Think broadly and consider both cognitive and interpersonal skills.

3 m

ACTIVITY #1:
CREATING A PICTORIAL MAP FOR EXPLORING PROBLEM SOLVING SKILLS IN THE CLASSROOM

Groups 3-4 participants

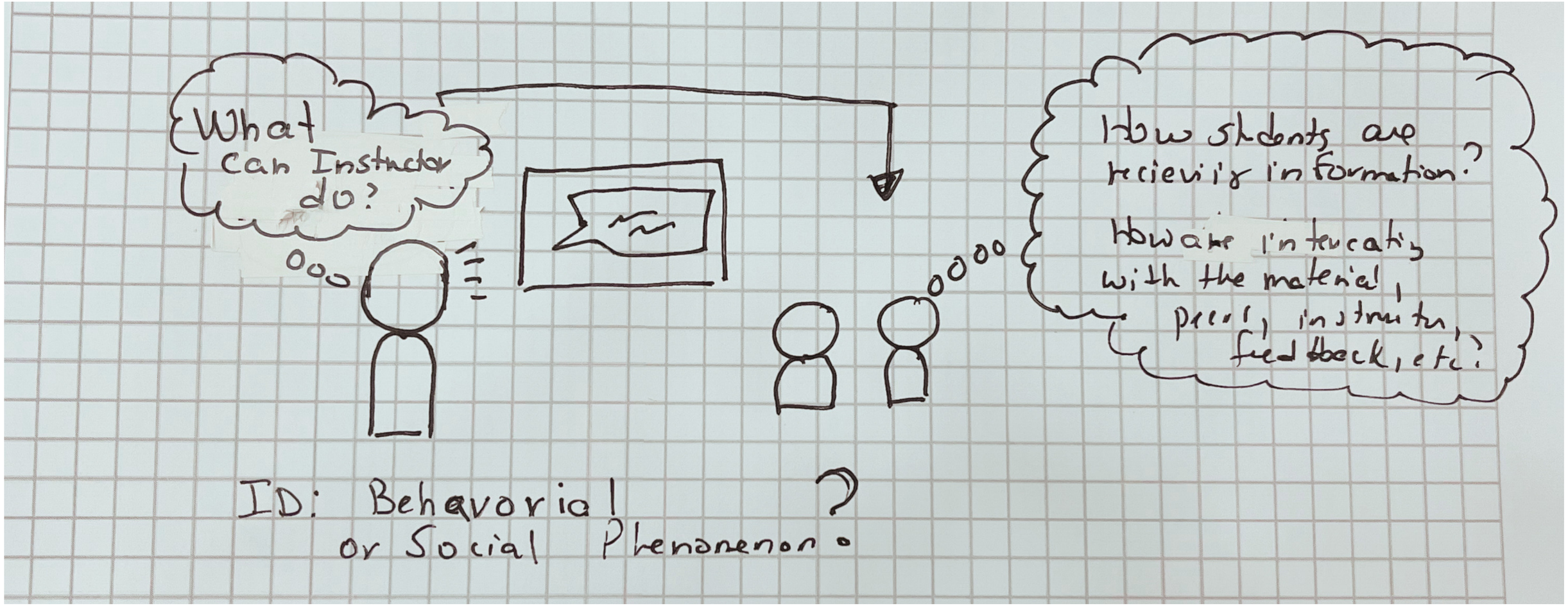
Brainstorm and discuss 1-2 KEY problem solving skills you believe are important for students in the classroom. Think broadly and consider both cognitive and interpersonal skills.

3 m

As a group, create a pictorial map that represents these skills acquisition as a social phenomena between you and the students. You can use symbols, diagrams, illustrations, or any other graphical elements to depict the skills and their interrelationships.

8 m

GETTING STARTED ON YOUR PICTORIAL MAP



ACTIVITY #1:
CREATING A PICTORIAL MAP FOR EXPLORING PROBLEM SOLVING SKILLS IN THE CLASSROOM

Groups 3-4 participants

Brainstorm and discuss 1-2 KEY problem solving skills you believe are important for students in the classroom. Think broadly and consider both cognitive and interpersonal skills.

3 m

As a group, create a pictorial map that represents these skills acquisition as a social phenomena between you and the students. You can use symbols, diagrams, illustrations, or any other graphical elements to depict the skills and their interrelationships.

8 m

Compare and contrast the different maps to identify common themes and patterns across the maps. Discuss the insights gained.

3-5 m

ACTIVITY #1

LESSONS LEARNED

Pictorial maps can help generate ideas for research in engineering education in several ways

Identification of Gaps: reveal areas where the phenomena is not adequately represented or explored in educational settings.

Relationship Exploration: spark ideas for research on how various variables, such as instructional methods, assessment strategies, or classroom dynamics, impact the development and application of the phenomena

New Perspectives: visual representations of complex concepts, allowing researchers to investigate unconventional angles or alternative approaches to addressing the phenomena.

Comparative Studies: Comparing maps generated by different groups or across different contexts can highlight variations in the phenomena stimulating research focused on understanding the cultural, disciplinary, or contextual factors.

Intervention Design: Researchers can use the maps as a basis for designing and testing interventions, exploring their effectiveness, and contributing to evidence-based practices

Data Collection Types: Analysis of elements and relationships can guide in selecting appropriate data collection methods sources like surveys, observations, interviews, or existing educational records for gathering relevant data.

DEVELOPING YOUR RESEARCH METHODS

A CALL FOR RIGOROUS RESEARCH IN ENGINEERING EDUCATION

QUESTION

Pose significant questions that can be investigated empirically.

THEORY

Link research design to relevant theory.

METHODS

Use methods that permit direct investigation of the question.

REPRODUCIBILITY

Replicate and generalize across studies.

DISSEMINATION:

Disclose research to encourage professional scrutiny and critique

Borrego (2007); Felder, (2007); Shavelson (2002).

THINKING ABOUT GENERALIZABILITY

Exploring a problem of broad appeal

Need to think about the distinction between local and transferable studies

"If you do something in your classroom, isn't it automatically generalizable?"

Need to go against your training

Scientists and engineers are trained to expect that once a fact is proven or discovered, it is universally true. Reproducing the exact same experimental conditions with humans (e.g., classroom) is impossible.

What contributes to the low retention rates of chemical engineering students at the University of Kentucky?

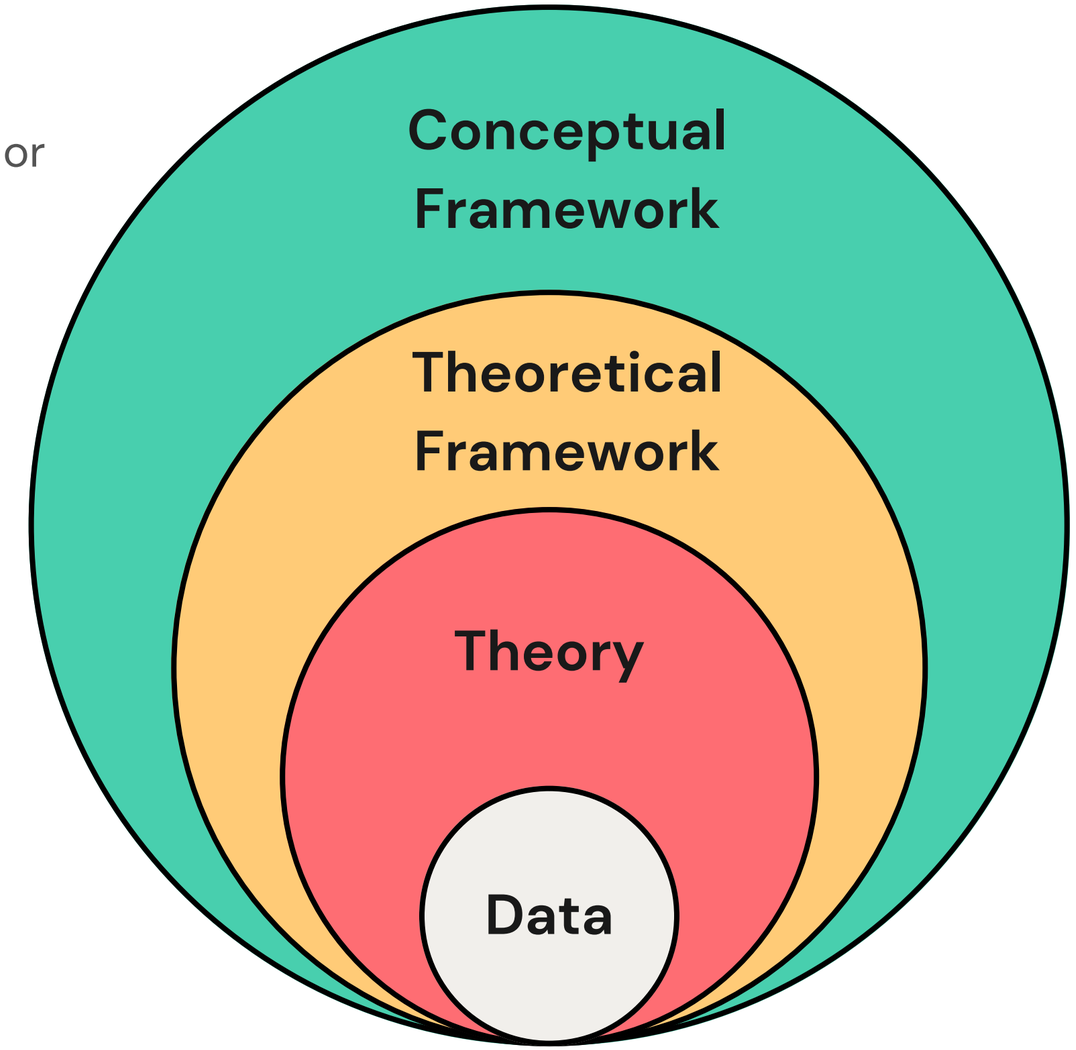
What contributes to the low retention rate of first generation students at public universities?

Borrego (2007)

FRAMEWORKS (LENSES, FILTERS, ANGLES)

THEORY

Description of relationship between concepts and ideas that help us understand the world. It can be supported by preliminary data or by a vast body of research—the more data supporting the theory, the stronger it becomes



Varpio, L., Paradis, E., Uijtdehaage, S., & Young, M. (2019). The Distinctions Between Theory, Theoretical Framework, and Conceptual Framework. Academic medicine: journal of the Association of American Medical Colleges.

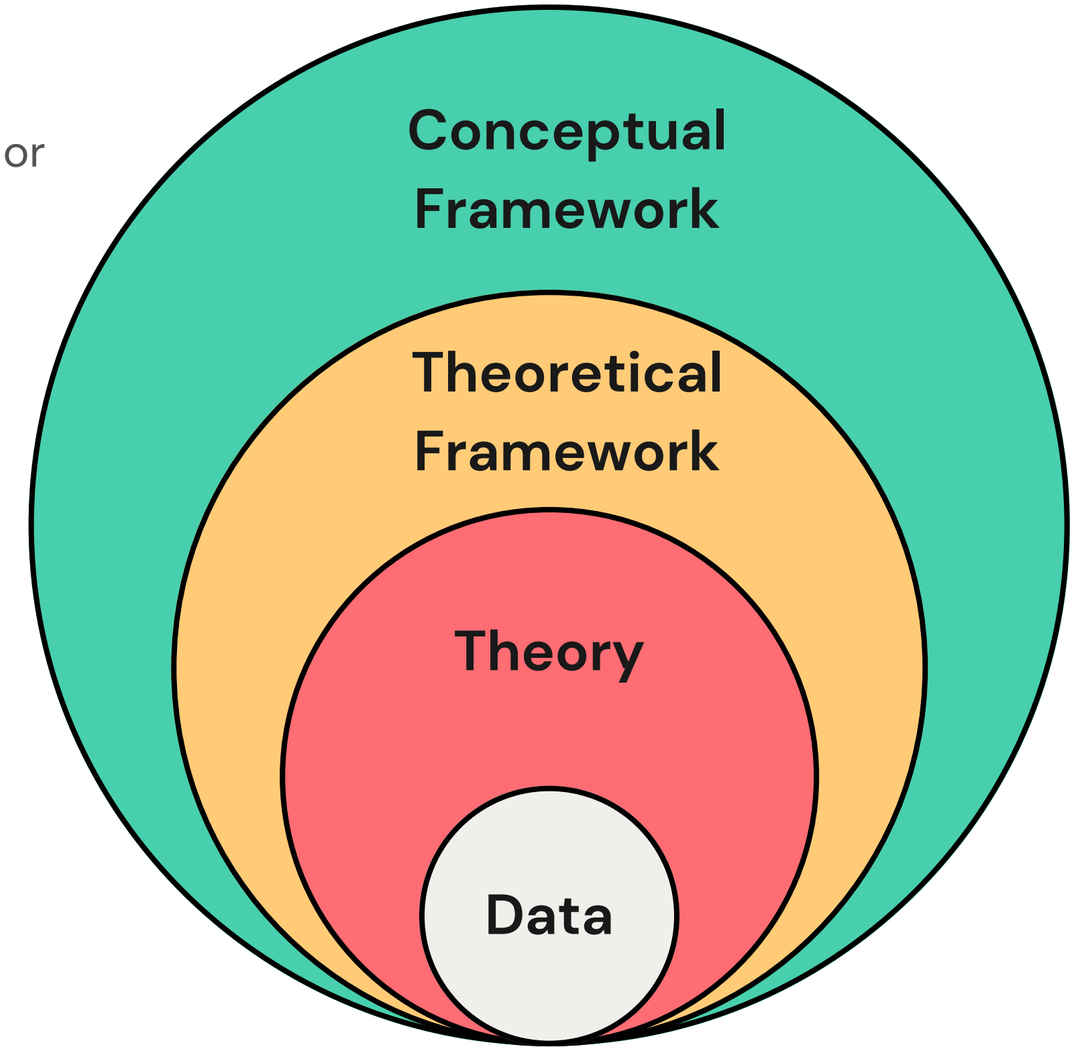
FRAMEWORKS

THEORY

Description of relationship between concepts and ideas that help us understand the world. It can be supported by preliminary data or by a vast body of research—the more data supporting the theory, the stronger it becomes

THEORETICAL FRAMEWORK

Explanation of how a theory (theories) shaped the study. It includes the fundamental assumptions, concepts, and principles that underpin the theory of learning being studied.



Varpio, L., Paradis, E., Uijtdehaage, S., & Young, M. (2019). The Distinctions Between Theory, Theoretical Framework, and Conceptual Framework. Academic medicine: journal of the Association of American Medical Colleges.

FRAMEWORKS

THEORY

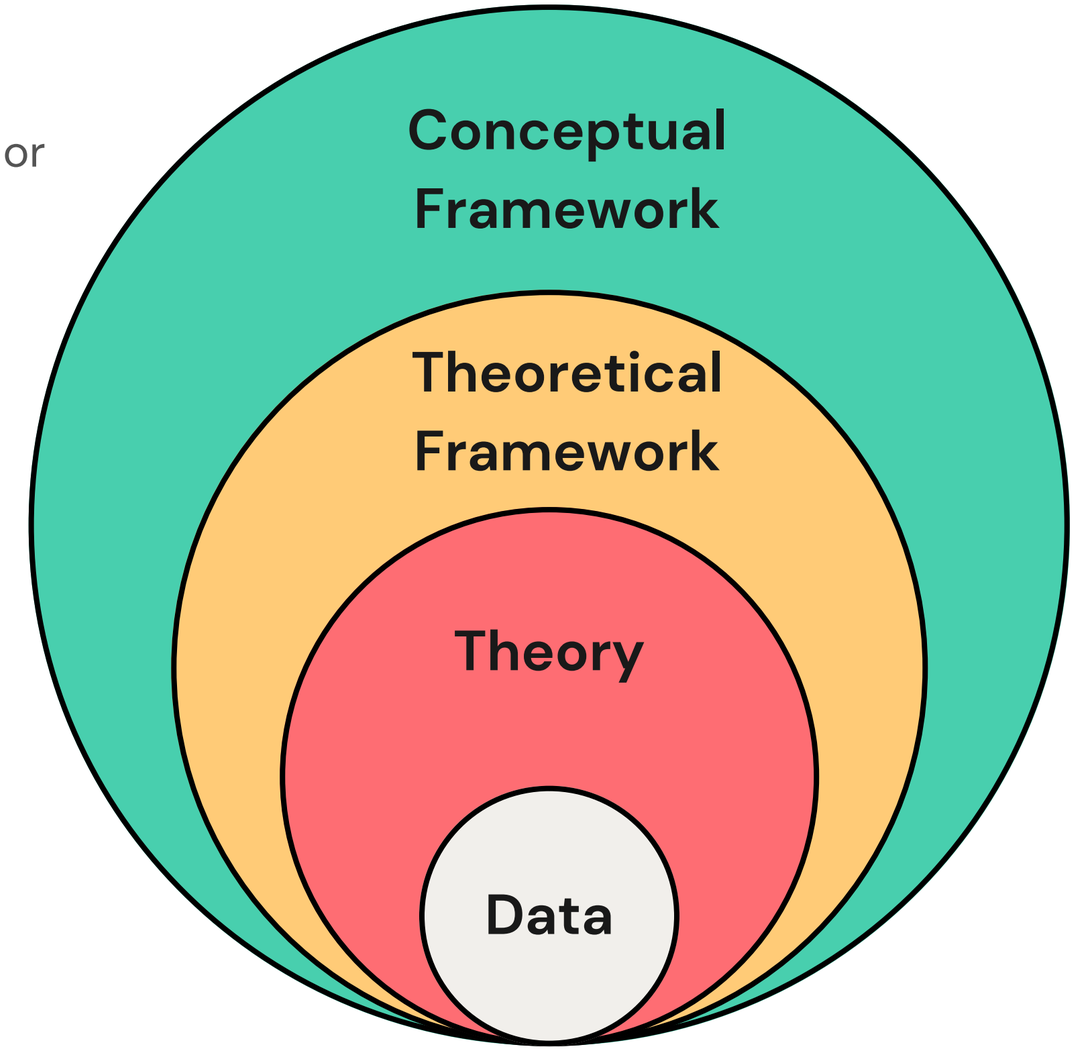
Description of relationship between concepts and ideas that help us understand the world. It can be supported by preliminary data or by a vast body of research—the more data supporting the theory, the stronger it becomes

THEORETICAL FRAMEWORK

Explanation of how a theory (theories) shaped the study. It includes the fundamental assumptions, concepts, and principles that underpin the theory of learning being studied.

CONCEPTUAL FRAMEWORK

Logical argument justifying all aspects of the research: why it is important and why the methodology is appropriate. Specific concepts and ideas used to explain a particular phenomenon within the broader theoretical framework.



Varpio, L., Paradis, E., Uijtdehaage, S., & Young, M. (2019). The Distinctions Between Theory, Theoretical Framework, and Conceptual Framework. Academic medicine: journal of the Association of American Medical Colleges.

FRAMEWORKS

THEORY

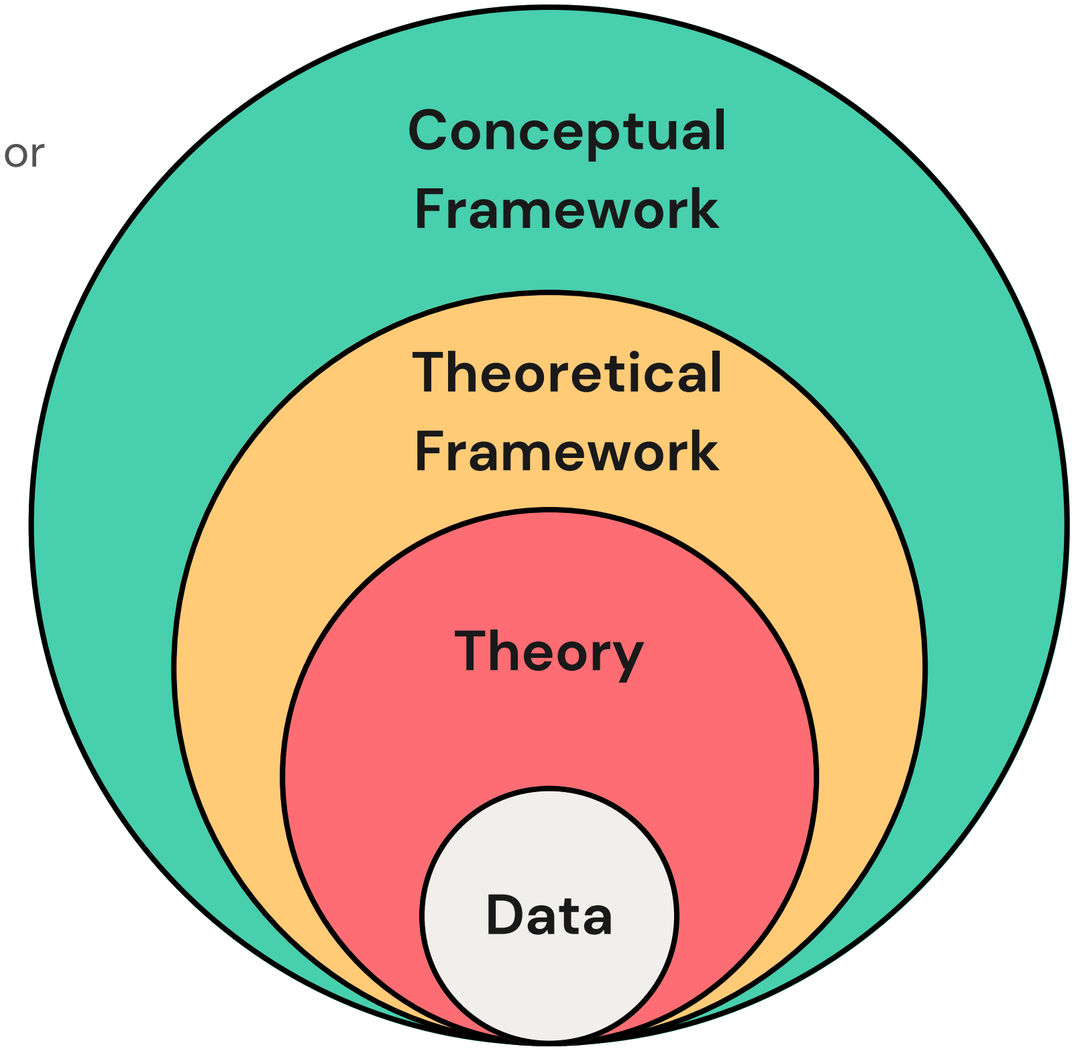
Description of relationship between concepts and ideas that help us understand the world. It can be supported by preliminary data or by a vast body of research—the more data supporting the theory, the stronger it becomes

THEORETICAL FRAMEWORK

Explanation of how a theory (theories) shaped the study. It includes the fundamental assumptions, concepts, and principles that underpin the theory of learning being studied.

CONCEPTUAL FRAMEWORK

Logical argument justifying all aspects of the research: why it is important and why the methodology is appropriate. Specific concepts and ideas used to explain a particular phenomenon within the broader theoretical framework.



Varpio, L., Paradis, E., Uijtdehaage, S., & Young, M. (2019). The Distinctions Between Theory, Theoretical Framework, and Conceptual Framework. Academic medicine: journal of the Association of American Medical Colleges.

COMMONLY USED THEORIES ACROSS DISCIPLINES

University of Colorado-Denver, Grant, C., Osanloo, A., & New Mexico State University. (2014). Understanding, Selecting, and Integrating a Theoretical Framework in Dissertation Research: Creating the Blueprint for Your "House." *Administrative Issues Journal Education Practice and Research*, *4*(2). https://doi.org/10.5929/2014.4.2.9

- Transformational/relational theories
- Transactional/management theories
- Servant leadership/moral theories
- Trait theories
- Situational theories
- Behavioral theories
- Systems theory
- Cognitive theory
- Sense of community theory
- Behavioral theory

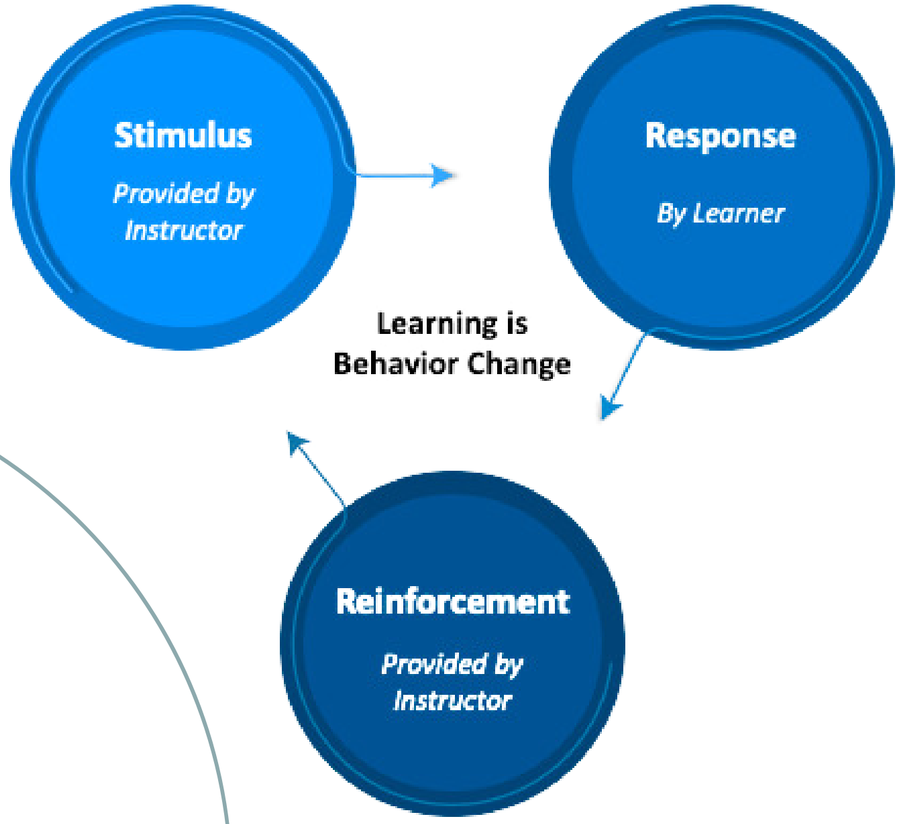
- Queer theory
- Feminist Theory
- Critical race theory
- Self-efficacy theory
- Functionalist theory
- Relational theory
- Gender theory
- Change theory
- Identity formation
- Community of Inquiry
- Transformational theory

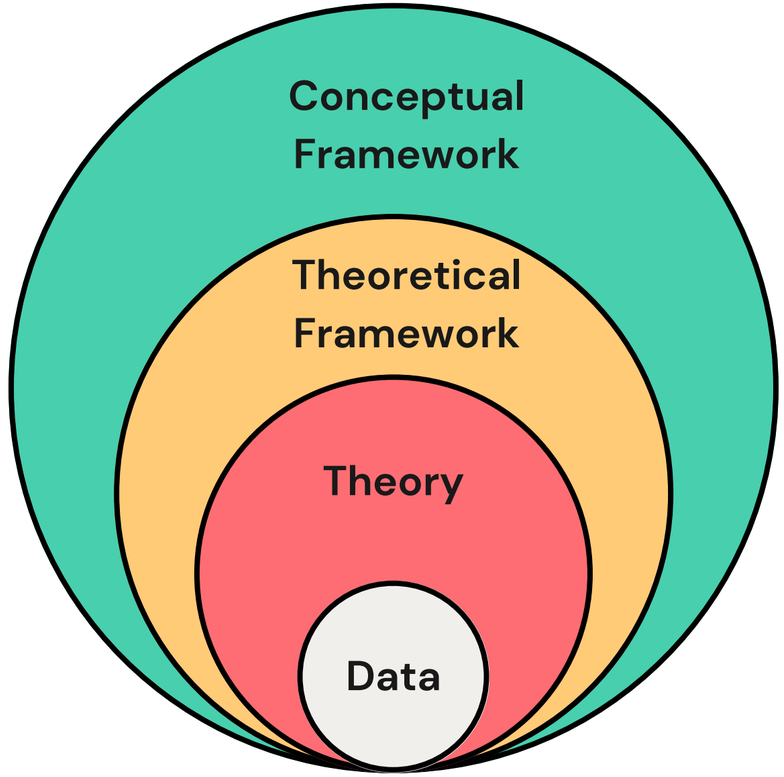
GROUNDING YOUR RESEARCH DESIGN

THEORY

Example: Behaviorism:

- All learning occur through interactions with the environment
- The environment shapes behaviors





GROUNDING YOUR RESEARCH DESIGN

THEORETICAL FRAMEWORK

Example: Behaviorism:

- All learning occur through interactions with the environment
- The environment shapes behaviors

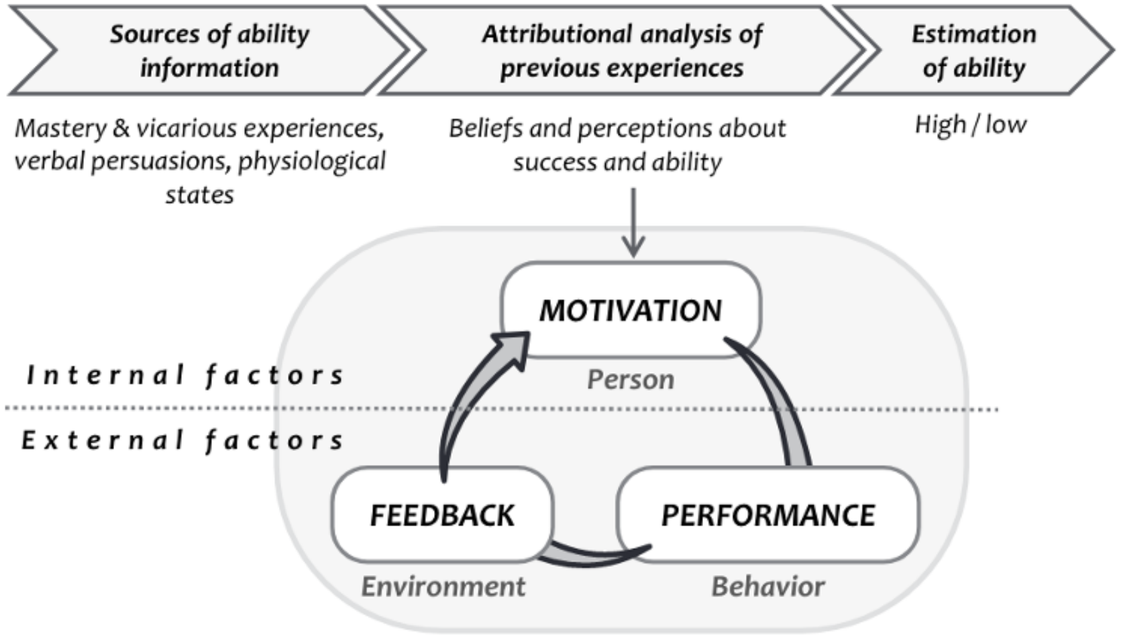
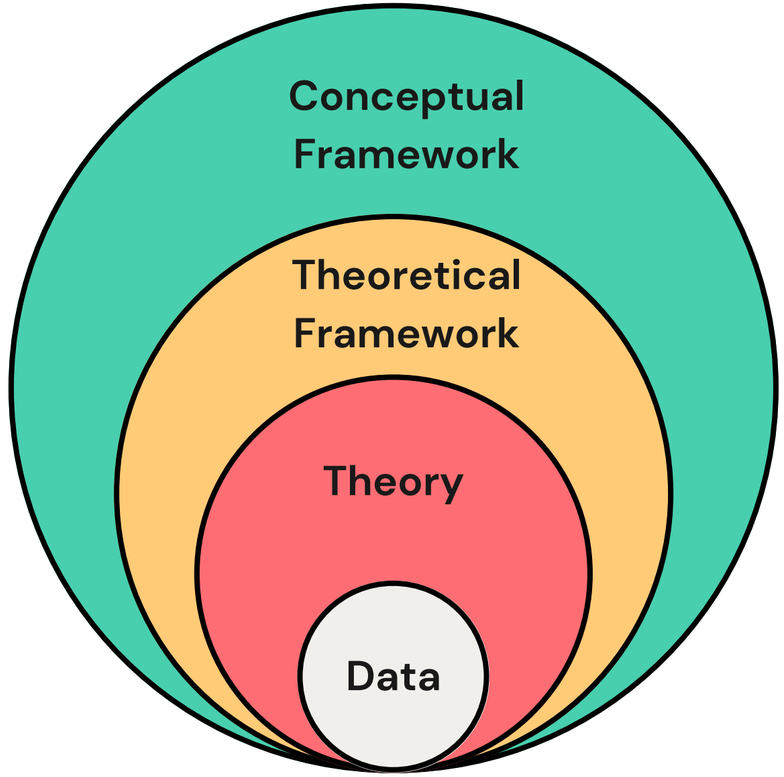


Fig. 1. Summary of the theoretical framework: Interplay between motivation, performance, and environment.

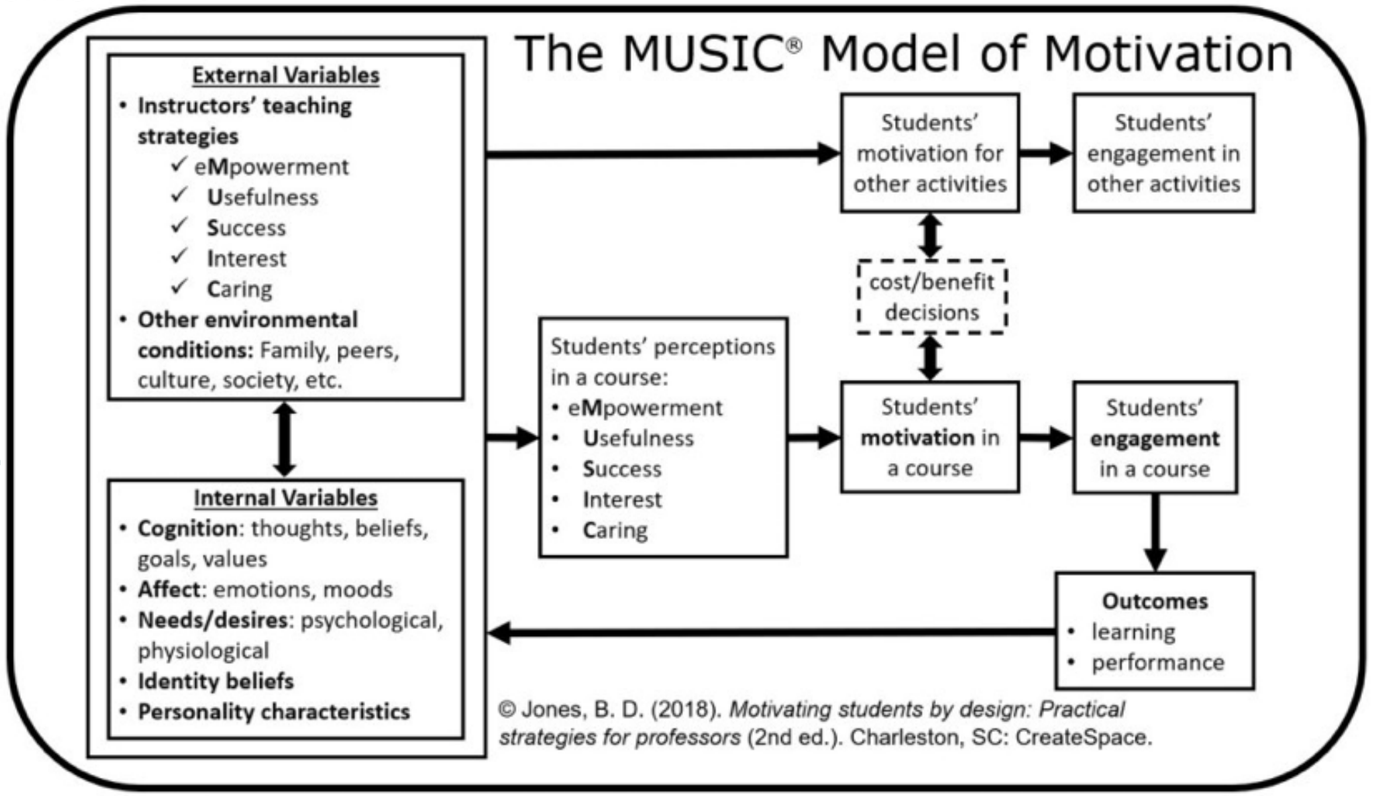


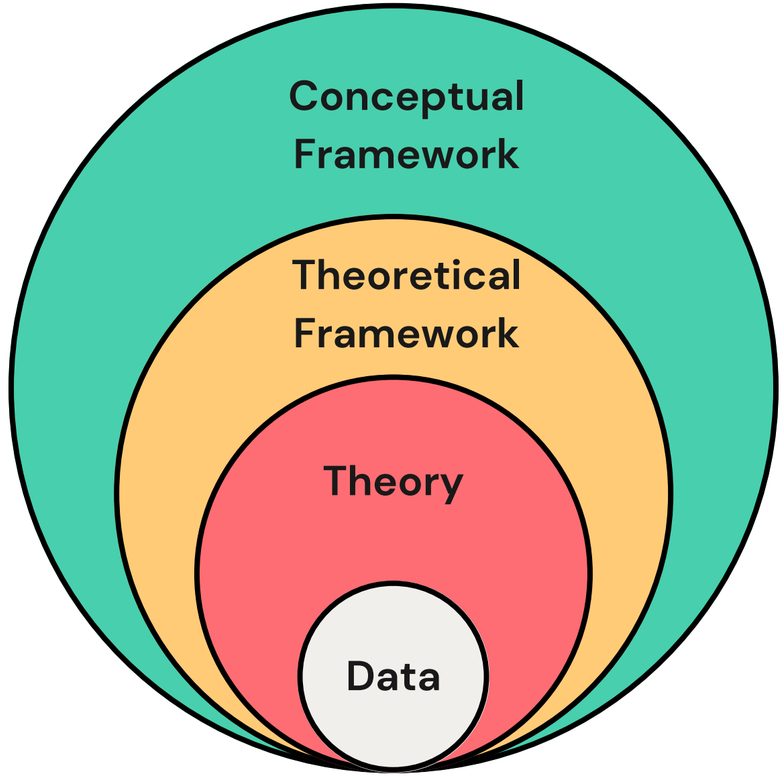
Määttä, E. "Setting young children up for success. Approaching motivation through children's perceptions of their ability." Acta Universitatis Ouluensis 155 (2015).

GROUNDING YOUR RESEARCH DESIGN

CONCEPTUAL FRAMEWORK

The MUSIC Model of Motivation was developed by Dr. Brett D. Jones (2009, 2018) as a research-based model to explain factors in the motivational climate that affect people's motivation to engage in activities, such as courses and class assignments.





https://www.themusicmodel.com/music_model/

WRITING RESEARCH QUESTIONS

QUALITATIVE

1. Try to evolve during the research and be open-ended without referencing the literature
2. Begin with “How” or “What”. Avoid “Why” [this is a quantitative term that implies cause and effect]
3. List the central phenomenon you plan to explore
4. Specify the research site and participants
5. Avoid using words such as “impact” or “effect” and directional phrases

What is (the central phenomenon) of/for (participants) at/in (research site)?

What is the process of the curriculum committee in making decisions about courses?

WRITING RESEARCH QUESTIONS

QUANTITATIVE

1. They Begin with “How”, “What”, or “Why” and can NEVER be answered by a simple Yes or No
2. Specify the independent and dependent variables
3. IF your questions deal with connections among multiple variables, you will again - use relate or compare – just as you did in the purpose statement

General Descriptive Examples:
What factors positively impact (phenomenon) of (participants)?
Relationship Script:
How does (Ind Var) relate to (Dep Var) for (participants)?
Comparison Script:
How does (group 1) compare with/differ from (group 2) in terms of (Dep Var) for (participants)?

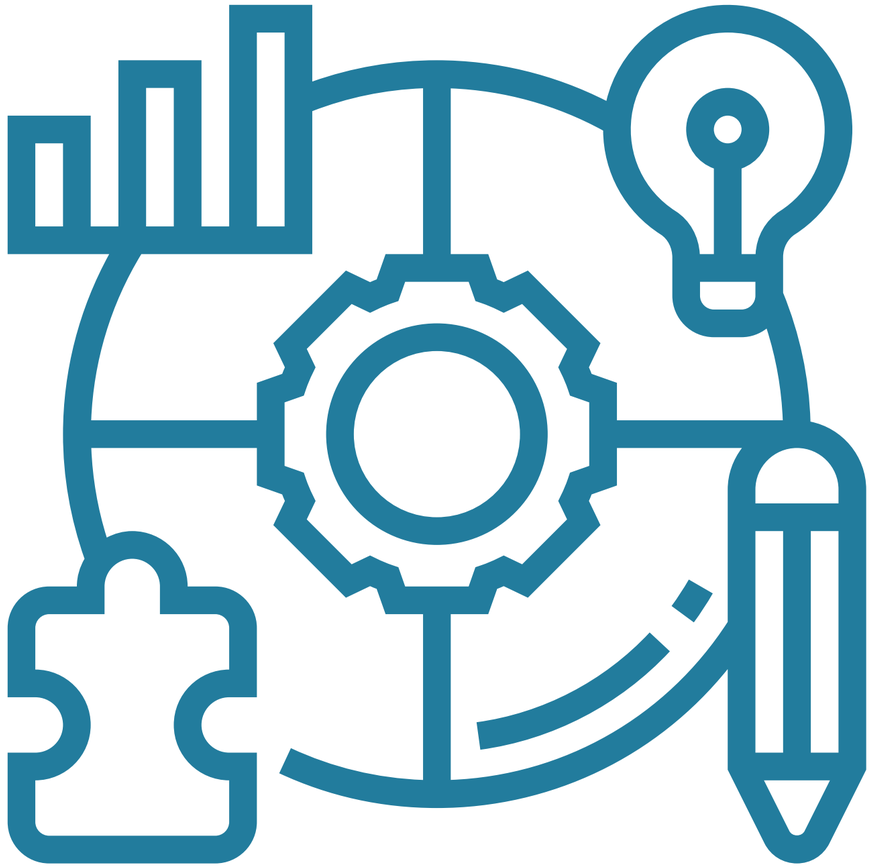
TYPES OF DATA COLLECTION

The type of methods that are using should be connected to your research question and theoretical framework.

01 - QUANTITATIVE

02 - QUALITATIVE

03 - MIXED METHODS



QUANTITATIVE METHODS

Utilizes numbers to test hypotheses and make predictions by using measured amounts, statistics and ultimately describe an event by using figures.

Advantages

- Can collect and analyze a lot of information.
- With good design, that means you can make general statements about what is likely to be true overall.

Disadvantages

- Lack of depth in understanding (e.g. reasons why, context, emotions or feelings).
- It requires mathematical and/or statistical knowledge to be able to analyze the data effectively.
- Measurement instruments (e.g., surveys) must be properly validated through a time-consuming processes before using it.

Important considerations

- All measurements must be validated: Use instruments that others have developed!
- Must know required sample sizes for desired statistical methods

QUALITATIVE METHODS

Utilizes words to understand people's beliefs, experiences, attitudes, behavior, and interactions

Advantages

- Provides significant detail about specific cases, people or group
- Allows for understanding of the driving forces behind a phenomena

Disadvantages

- Can’t make general statements due to small sample sizes
- Analysis is time consuming
- Some argue that the analysis is very subjective, but this depends on your approach.

Important considerations

- Sample sizes must be considered and matched to the type of qualitative analysis
- Be careful about generalizing findings that aren't supported by the literature

MIXED METHODS

Combines quantitative and qualitative methods to provide deeper context into the phenomenon

Advantages

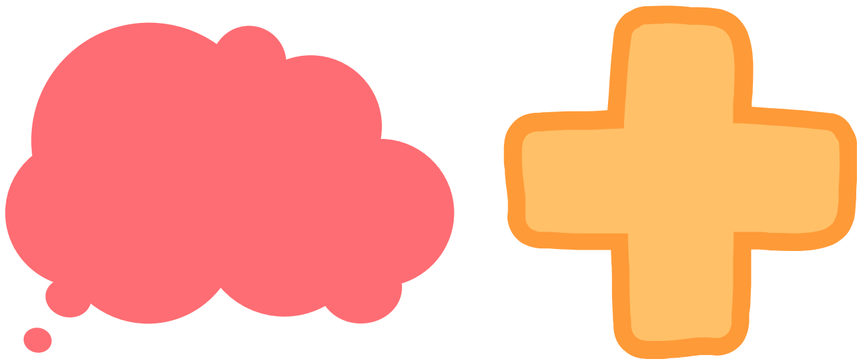
- Amplifies understanding of the phenomenon through combining different data types together

Disadvantages

- Can be significantly time consuming to apply both quantitive and qualitative methods
- Requires expertise in both quantitative and qualitative analysis techniques

Important considerations

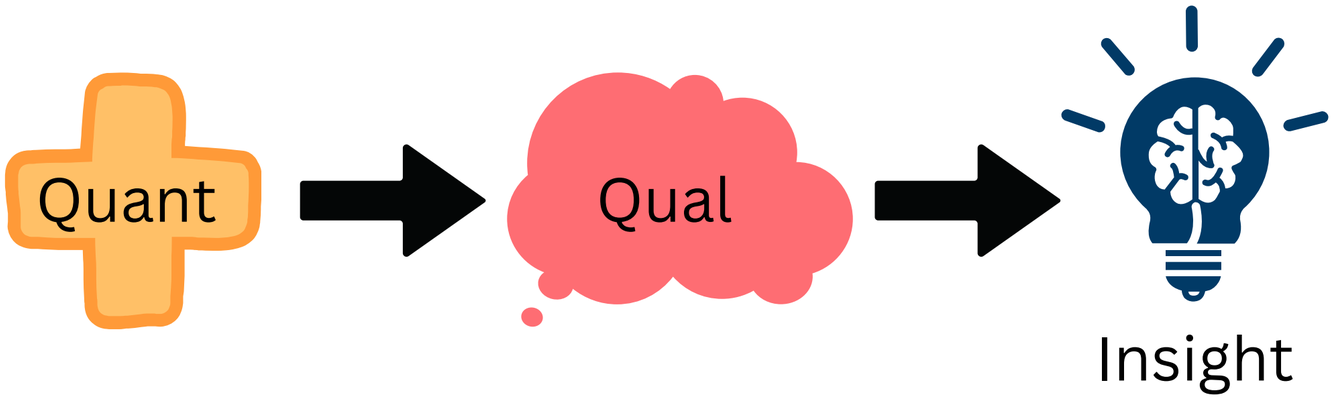
- Important to consider the ordering of your quantitative and qualitative approaches
- Mixed-methods should be used to strengthen understanding



MIXED METHODS

Applications of mixed methods

Exploratory Research

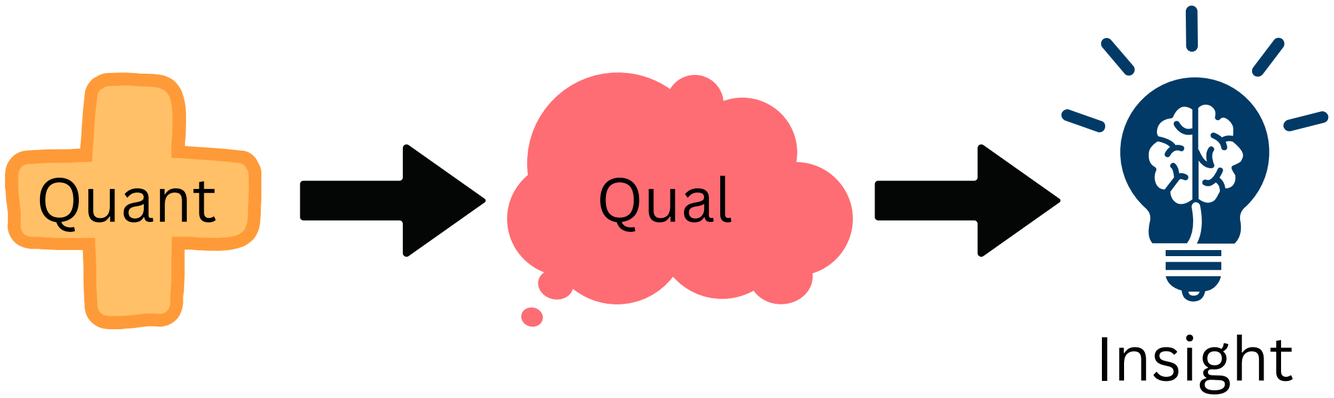


https://www.opinionx.co/blog/mixed-methods-research

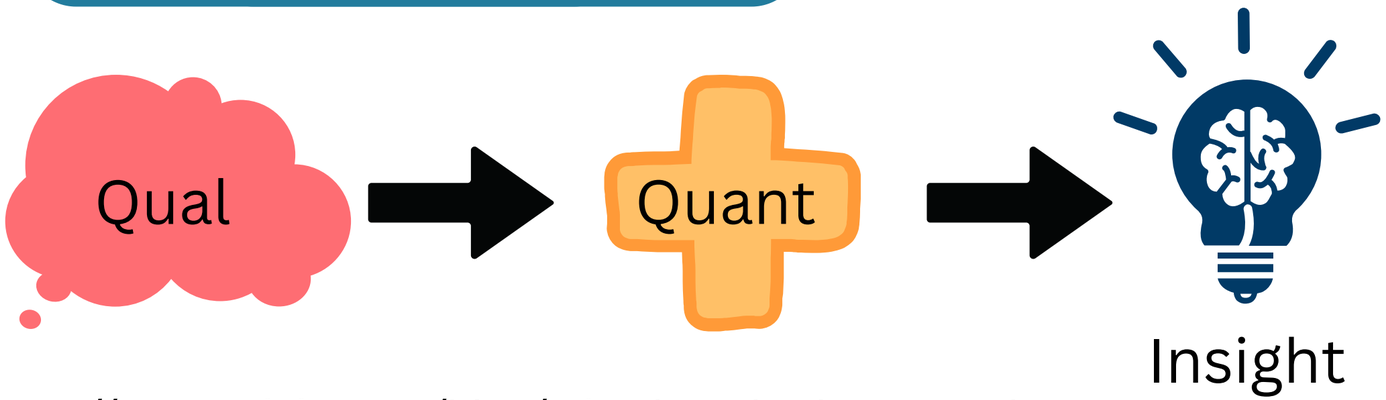
MIXED METHODS

Applications of mixed methods

Exploratory Research



Explanatory Research

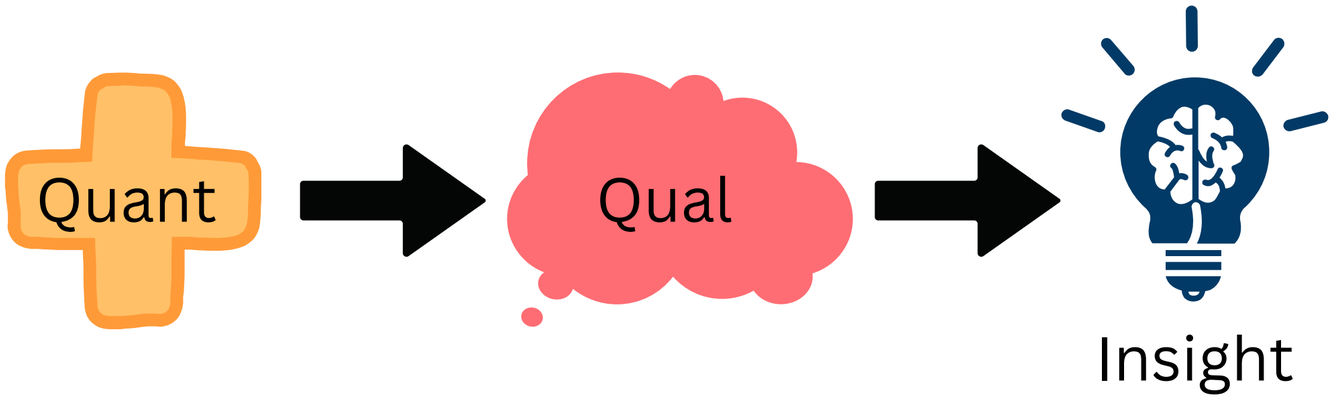


https://www.opinionx.co/blog/mixed-methods-research

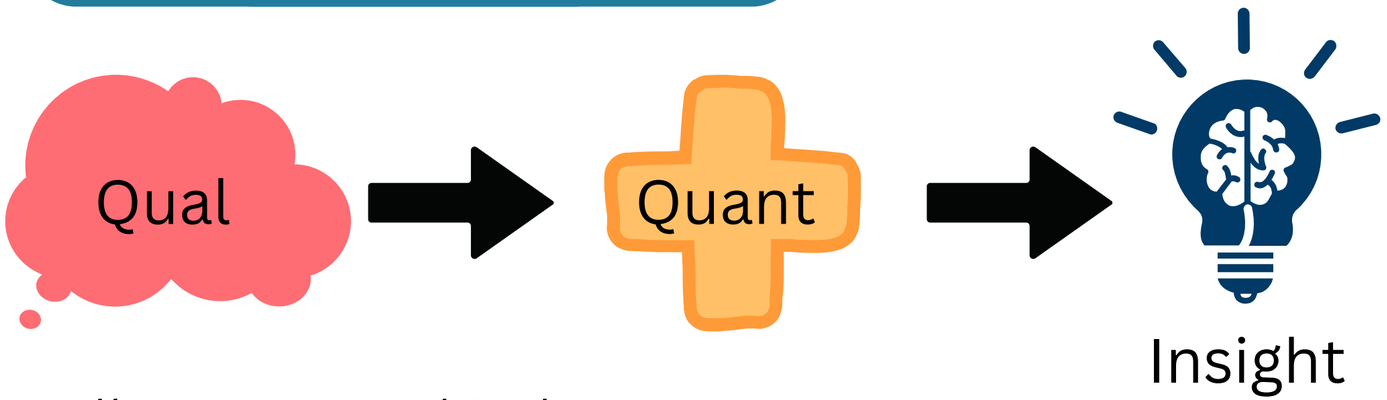
MIXED METHODS

Applications of mixed methods

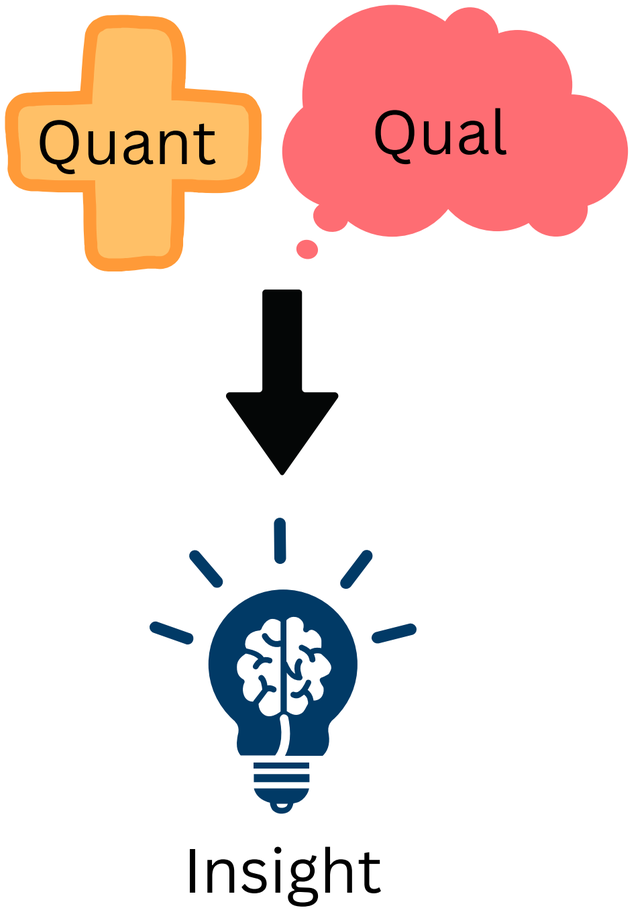
Exploratory Research



Explanatory Research



Dynamic Research



https://www.opinionx.co/blog/mixed-methods-research

ACTIVITY #2: THINKING ABOUT DATA

What is the phenomenon?

- Problem solving: a process, used to obtain a best answer to an unknown, or a decision subject to some constraints.

What does the literature says?

- Problem solving is not the same as exercise solving
- Students who train mostly in exercise solving tend rely heavily on solutions they have seen before, rather than working directly from first principles.
- Thus, a problem with brand new context presents a formidable challenge to them.

Mourtos, et. al. (2004); Boyer 2030 Commission. (2022); ABET (2022)

ACTIVITY #2: THINKING ABOUT DATA

Find your group

Brainstorm

15 m

1. **Identify the research question(s) that make the most sense to you and ask your colleagues to review them.**
2. **Given your question(s), do you have access to existing data/artifacts that you're aware of that can help you address your research question?**
3. **What other types of data/artifacts/information and methods (e.g., student reflections, assignments, interviews, focus groups, questionnaires/tests, observations, quasi-experiments) might you need to collect to best address your research question? What do you hope to learn from each?**
4. Given your question and the information you are seeking to collect; what strategies or methodologies might you use to analyze data/artifacts you plan to collect as part of your study?
5. Might it be a good idea to use multiple/mixed methods to address your research question?
6. What time frame is optimal for your study? Multi-institutional? Longitudinal? Short or long-term? One semester or multiple semesters? How many data points do you need to best answer your question? How many participants?

Discussion

3-5 m

ETHICAL CONSIDERATIONS

Educational research = studies on human beings. Therefore, you must consider the ethical impact of the research that you are conducting.

- All studies that you plan to publish must be approved by the Institutional Review Board (IRB) of your institution

- The IRB considers the ethical impacts of your research and ensures that your research participants are protected.

Important ethical considerations:

- Positionality: how does your own worldview impact your research and interpretation of the data?
- Consent: How will you ensure that participation in your research is voluntary and informed?
- Do no harm: How will you ensure that your research participants are protected and valued through the research process?

Example IRB documents can be found on the resources page.

DISSEMINATION

When designing your research, you want to think about the end goal. Dissemination allows you to share your findings but also helps to improve rigor in research methods.

Increasing expectations for rigor ⟶

Disciplinary conferences

AIChE The Global Home of Chemical Engineers

BMES BIOMEDICAL ENGINEERING SOCIETY™

NSBE NATIONAL SOCIETY OF BLACK ENGINEERS

swe™ Society of Women Engineers

DISSEMINATION

When designing your research, you want to think about the end goal. Dissemination allows you to share your findings but also helps to improve rigor in research methods.

Increasing expectations for rigor •-------->

Disciplinary conferences

Educational conferences

AIChE The Global Home of Chemical Engineers

ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

BMES BIOMEDICAL ENGINEERING SOCIETY™

frontiers in Education

NSBE NATIONAL SOCIETY OF BLACK ENGINEERS

SEFI European Society for Engineering Education

swe™ Society of Women Engineers

AERA FOUNDED 1916 AMERICAN EDUCATIONAL RESEARCH ASSOCIATION

DISSEMINATION

When designing your research, you want to think about the end goal. Dissemination allows you to share your findings but also helps to improve rigor in research methods.

Increasing expectations for rigor •-------->

Disciplinary conferences	Educational conferences	Disciplinary journals
AIChE The Global Home of Chemical Engineers	ASEE American Society for Engineering Education	CEE
BMES Biomedical Engineering Society™	frontiers in Education	JMEE International Journal of Mechanical Engineering Education
NSBE National Society of Black Engineers	SEFI European Society for Engineering Education	Computer Science Education
swe Society of Women Engineers	AERA Founded 1916 American Educational Research Association	Journal of Civil Engineering Education

DISSEMINATION

When designing your research, you want to think about the end goal. Dissemination allows you to share your findings but also helps to improve rigor in research methods.

Increasing expectations for rigor •-------->

Disciplinary conferences	Educational conferences	Disciplinary journals	Educational journals
AIChE The Global Home of Chemical Engineers	ASEE American Society for Engineering Education	CEE	JEE Journal of Engineering Education — The Research Journal for Engineering Education
BMES Biomedical Engineering Society™	frontiers in Education	IJMEE International Journal of Mechanical Engineering Education	Studies in Engineering Education
NSBE National Society of Black Engineers	SEFI European Society for Engineering Education	Computer Science Education	Journal of Women and Minorities in Science and Engineering
swe Society of Women Engineers	AERA American Educational Research Association — Founded 1916	Journal of Civil Engineering Education	International Journal of Engineering Education

DISSEMINATION

When designing your research, you want to think about the end goal. Dissemination allows you to share your findings but also helps to improve rigor in research methods.

Increasing expectations for rigor •-------->

Disciplinary conferences

AIChE The Global Home of Chemical Engineers

BMES BIOMEDICAL ENGINEERING SOCIETY™

NSBE NATIONAL SOCIETY OF BLACK ENGINEERS

swe Society of Women Engineers

Educational conferences

ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

frontiers in Education

SEFI European Society for Engineering Education

AERA AMERICAN EDUCATIONAL RESEARCH ASSOCIATION FOUNDED 1916

Disciplinary journals

CEE

JMEE International Journal of Mechanical Engineering Education

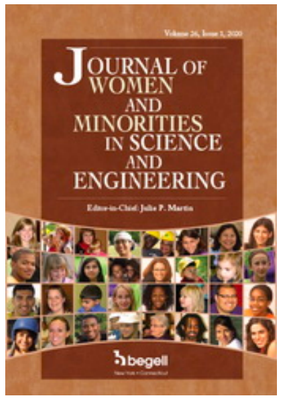
Computer Science Education

Journal of Civil Engineering Education

Educational journals

JEE Journal of Engineering Education THE RESEARCH JOURNAL FOR ENGINEERING EDUCATION

Studies in Engineering Education



International Journal of Engineering Education

LESSONS LEARNED TODAY

1. RESEARCH IN ENGINEERING EDUCATION
2. IDENTIFYING YOUR RESEARCH AREA
3. DEVELOPING YOUR RESEARCH METHODS

"Research is formalized curiosity. It is poking and prying with a purpose."

Zora Neale Hurston

THANK YOU!

"This material is based upon work supported by the National Science Foundation under Grant No. (RIEF 2106206; RIEF 2024394; and RFE 2225567)"

RESOURCES

https://bit.ly/43Qiace

QUESTIONS?

Sindia M. Rivera-Jiménez, Ph.D.
rivera.jimenez@eng.ufl.edu

Sarah Wilson, Ph.D.
s.wilson@uky.edu

REFERENCES

Froyd, J. E., & Lohmann, J. R. (2013). Chronological and Ontological Development of Engineering Education as a Field of Scientific Inquiry. In A. Johri & B. M. Olds (Eds.), Cambridge Handbook of Engineering Education Research (pp. 3–26). Cambridge University Press

Finelli, C. J., Borrego, M., & Rasoulifar, G. (2015). Development of a Taxonomy of Keywords for Engineering Education Research. Journal of Engineering Education, 104(4), 365–387. https://doi.org/10.1002/jee.20101

Haghighi, K. (2005). Quiet No Longer: Birth of a New Discipline. Journal of Engineering Education, 94(4), 351–353. https://doi.org/10.1002/j.2168-9830.2005.tb00862.x

Radcliffe, D. F. (2006). Shaping the Discipline of Engineering Education. Journal of Engineering Education, 95(4), 263–264. https://doi.org/10.1002/j.2168-9830.2006.tb00901.x

The Research Agenda for the New Discipline of Engineering Education. (2006). Journal of Engineering Education, 95(4), 259–261. https://doi.org/10.1002/j.2168-9830.2006.tb00900.x

Borrego, M. (2007). Conceptual Difficulties Experienced by Trained Engineers Learning Educational Research Methods. Journal of Engineering Education, 96(2), 91–102. https://doi.org/10.1002/j.2168-9830.2007.tb00920.x

Felder, R. M. (2007). Research on teaching and learning in engineering. Academy of Chemical Engineers Award Lecture, Department of Chemical and Biological Engineering, University of Missouri-Rolla.

Mourtos, N. J., Okamoto, N. D., & Rhee, J. (2004, February). Defining, teaching, and assessing problem solving skills. In 7th UICEE Annual Conference on Engineering Education (pp. 1-5).

Boyer 2030 Commission. (2022). Report: EQUITY/EXCELLENCE IMPERATIVE: a 2030 blueprint for undergraduate education at u.s. Research… Universities. The Association for Undergraduate Education at Research Universities (UERU). https://ueru.org/boyer2030

Shavelson, R., and L. Towne, Scientific Research in Education, Washington, D.C.: National Academies Press, 2002.