Research communication

A 90-minute guided review

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This text matches the spoken narration slide by slide. The recording lasts **1:33:38**, including 10 minutes of practice pauses. Use the slide deck to see the figures and tables. The examples draw on Weeks 1, 3, 4, 5, 6, 8, 9 and 10.

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1. Research communication

Slide 1 · Starts 00:00

Welcome to this review of Research Communication Skills for Chemical Engineers. We will revisit eight teaching sessions, beginning with the purpose of a research contribution and ending with a defensible conclusion. The connection throughout the review is the relationship between a question, the evidence collected to answer it, and the claim that the evidence can support.

Keep a pen and a sheet of paper nearby. Several short activities invite you to make a decision before seeing a worked answer. You can pause the recording whenever you need more time. The figures use synthetic teaching data, and each example states its own experimental setting. We will use printed tables and explicit plotting steps, so you can follow the reasoning without a programming background.

2. The 90-minute review

Slide 2 · Starts 00:50

The review follows the same decisions that a researcher makes while developing a paper. First, we decide what the contribution is and which readers need it. That decision helps us choose an article type and a suitable publication venue. We then examine how to retrieve relevant literature, document a search, screen records and compare studies in an evidence matrix. These topics draw on Weeks One and Three.

Next, we examine the argument within a manuscript. We will assign a function to each part of the Introduction, Methods, Results and Discussion, and use a reverse outline to find a missing connection. A gap becomes useful when its consequence is clear. An aim becomes testable when the Methods can produce the quantity needed to answer it. Those connections draw on Weeks Four and Five, together with the reporting checks introduced in Week Six.

The second half connects numerical reporting with figure construction. We will count independent experimental units, distinguish variation from precision, state percentage changes correctly and choose a display that answers a reader's question. The Matplotlib material is reviewed through its general workflow: original data, a checked summary, a figure, an exported file and the materials needed to reproduce the result. We will inspect the outputs without asking you to write code.

Finally, we will interpret a conversion and selectivity trade-off, compare explanations and design a useful follow-up test. We will finish by revising a conclusion so that its numerical evidence, experimental scope and implication agree. Treat the worked answers as explanations of a reasoning process. When your wording differs, check whether your evidence and limits still support your claim.

3. Choose the genre for the contribution

Slide 3 · Starts 02:51

Before choosing a journal or opening a manuscript template, identify the contribution you want to give the reader. The same experimental project can produce several kinds of documents. What changes is the reader's purpose and the evidence the document must organize.

A research paper presents a new claim and supports that claim with evidence. Its main task is to make the argument convincing and checkable. A communication presents a focused finding in a shorter form, often with a reason to communicate the finding promptly. A short format still needs enough methodological information for the work to be checked, sometimes through supporting information.

A review makes a contribution through synthesis. It organizes what is known, compares the strength and limits of the evidence, and helps readers understand the field differently. A sequence of separate paper summaries does not yet provide that synthesis. A data paper makes a dataset usable. Readers need to understand what the variables mean, how the observations were collected, and what limits apply to reuse.

A technical report serves a client or institution. It may emphasize a practical decision and present its main message in an executive summary. A thesis demonstrates research competence. It can include detailed reasoning, unsuccessful approaches, and derivations that a journal article might shorten.

These categories are useful because they connect structure to purpose. They are not labels to apply only after the writing is finished. Complete this sentence before drafting: the reader will gain something specific from this document. If the answer is a reusable dataset, build around reuse. If the answer is a supported scientific claim, build around the claim and its evidence.

4. Read structure as evidence of purpose

Slide 4 · Starts 04:54

You can learn a great deal about a document by looking at its structure before reading every scientific detail. Headings, proportions, and the location of evidence all provide clues about what the document is trying to accomplish.

The familiar Introduction, Methods, Results, and Discussion structure connects a question to an answer. It first establishes the problem, then explains how the work was done, reports the observations, and interprets them. Thematic headings suggest a different organization. For example, sections on degradation mechanisms, prevention strategies, and remaining limitations may organize evidence across many studies rather than describe one experimental sequence.

A document that devotes substantial space to variable definitions, collection procedures, file formats, and data quality may be designed for dataset reuse. An executive summary near the front suggests that a decision maker needs the main conclusion before the technical detail. In each case, the structure tells you something about the reader's needs.

Use these clues together. Length alone cannot identify a genre reliably. A short paper may provide extensive methods in its supporting information. A systematic review may include a Methods section explaining how studies were searched and selected. A technical report may contain a substantial experimental study. One feature does not settle the classification.

This way of reading is also a way of checking your own writing. If you claim that a new method is the contribution, readers need a clear description of that method. If the contribution is a synthesis, the headings should help readers see relationships across the literature. The question is whether the document's shape helps it perform its intended job. A suitable structure makes the purpose easier to recognize and the evidence easier to inspect.

5. Fit the venue and the reader

Slide 5 · Starts 07:03

Publication fit begins with the people who need your contribution. Ask who will use the finding, what problem they are trying to solve, and what evidence they will expect. The choice of venue follows from those questions as well as from the scientific topic.

Two journals may both publish membrane research but serve different conversations. One may emphasize surface mechanisms. Another may emphasize device performance or process design. A paper can concern the same material while answering a question that is more relevant to one audience than another. Topic overlap is therefore useful, but it is only the beginning of a fit assessment.

Check the venue's scope, the article types it accepts, and the kind of contribution your manuscript actually makes. Then compare the scope of your claim with the scope of your evidence. Suppose a short laboratory experiment measures membrane degradation in a clean feed. That study may support a useful claim about behavior under those controlled conditions. It does not automatically support a prediction of service life in an industrial plant with a complex feed.

The work does not become worthless because its boundary is narrow. The task is to state that boundary accurately and choose readers who need the answer you can provide. Expanding the claim beyond the evidence usually creates a larger problem than stating a precise, limited contribution.

Before drafting, write one sentence describing the central claim. Write a second sentence identifying the evidence that warrants it. Then identify the reader who needs that combination. This simple exercise connects venue selection to scientific reasoning. It also helps you decide which details belong in the main argument and which details can be placed elsewhere.

6. Build a search from concepts

Slide 6 · Starts 09:05

A reproducible literature search starts with concepts rather than a long conversational sentence. For many chemical engineering questions, three useful concept blocks are the system, the process or phenomenon, and the property or metric.

Consider the zinc example. The system is the zinc anode. The phenomenon is dendrite growth or its suppression. The metric may be cycle life or coulombic efficiency. These blocks turn a broad interest into a structure that you can inspect and revise.

Within one block, use OR to connect alternative terms for the same concept. Between blocks, use AND to connect the concepts required by your question. OR usually broadens a block because either term can qualify. AND asks for the combination, so it can narrow the result set. Parentheses help preserve the intended grouping.

Good alternatives include abbreviations, expanded names, spelling variants, older terminology, and trade names when relevant. Researchers do not always describe the same material in the same way. If you search only the name you personally prefer, you may miss a useful part of the literature and mistake a vocabulary problem for a research gap.

The blocks on the slide are a conceptual plan, not a query that will run unchanged in every database. Check the database's rules for phrase searching, truncation, and fields such as title, abstract, and keywords. Use exclusions carefully because they can remove relevant papers you have not inspected.

If the result set is unexpectedly small, inspect which block is restricting it. If it is too broad, refine one part at a time. Keep a record of each meaningful change. That record lets you explain both how you searched and why the final set of papers has the boundaries it does.

7. Keep a search log and repair metadata

Slide 7 · Starts 11:12

A search becomes inspectable when you record enough information to reconstruct it. Keep the database name, the search date, the full query, all filters, and the number of hits. If you refine the search, retain the earlier version and explain the change. A result count without the query and filters does not tell another reader how the collection was produced.

A search log and a reference record answer different questions. The log explains how you found the literature. The reference record identifies a particular document. Both matter, but neither replaces the other.

In Zotero, you might capture a record from a journal page, import a PDF, or add a paper using an identifier such as a DOI. Capture is the first step. It is followed by checking the metadata against the source. Verify the authors, title, publication year, journal, and identifier. An incomplete or incorrect record can produce a beautifully formatted but incorrect reference.

Formatting software cannot decide whether a citation actually supports your sentence. That requires checking the source itself. Likewise, changing the citation style will not repair an incorrect author name or a wrong year already stored in the record.

A practical sequence is capture, check, organize, and cite. Collections can help you group items by project. Tags can describe their roles, such as a key method, evidence supporting a claim, or evidence reporting a different outcome. Notes can preserve the relevant measurement and its conditions.

The benefit is more than a tidy bibliography. A dependable library keeps the path from your sentence back to the original evidence visible. It also reduces the need to reopen the same paper repeatedly because you cannot remember what it actually established.

8. Screen first, then map the evidence

Slide 8 · Starts 13:17

Once a search returns papers, write down the inclusion criteria before screening them. The criteria should follow the research question. They might specify the material system, a range of operating conditions, or a metric needed for the comparison. Stating them early helps prevent the collection from drifting toward papers that merely agree with your expectations.

Use two passes. First inspect titles and abstracts and classify records as include, exclude, or unsure. Unsure is a useful category. An abstract may simply lack enough information for a decision. In the second pass, read the full texts that remain and record exclusion reasons against the criteria.

Next build an evidence matrix with one row per study. Record the claim, system, conditions, metric with units, and limitation. The purpose is comparison, not copying an abstract into a table. A concise row should let you understand what the study actually contributes without reading it again from the beginning.

Conditions are especially important when results appear to differ. For a cell lifetime comparison, current density, areal capacity, temperature, cell configuration, and the definition of failure can all change the meaning of a reported number. Two quantities with the same label are not necessarily comparable measurements.

When a detail is missing, write that it was not reported. Do not fill the gap from what seems typical in the field. A visibly incomplete matrix is more useful than an apparently complete one built from assumptions.

The matrix then becomes a reasoning tool. It can show genuine disagreement, a measurement missing from the selected literature, or a field tested in only one regime. Those patterns help formulate a specific question, provided that your conclusion stays within the coverage of your search.

9. Compare the conditions before the claims

Slide 9 · Starts 15:25

Try that reasoning with two synthetic studies. Both compare additive X with their own control.

Study A uses a current density of one milliampere per square centimeter and an areal capacity of one milliampere hour per square centimeter. It reports a lifetime gain of one hundred cycles.

Study B uses ten milliamperes per square centimeter and five milliampere hours per square centimeter. It reports a lifetime gain of zero cycles. Neither study reports uncertainty here.

Do these outcomes establish a contradiction? Discuss the question with a partner. Identify the conditions that matter, and prepare one sentence giving your answer and its reason. Consider what else you would need to know before combining the two outcomes into a general claim. These are invented teaching data, not published studies. Take two minutes for the comparison.

> Practice pause after this narration: 02:00. Pause the recording for longer whenever you need.

10. Worked answer: the regimes differ

Slide 10 · Starts 18:25

These outcomes do not establish a contradiction. They report different results, but the experiments were performed in different regimes. Both current density and areal capacity change between A and B. We cannot isolate the reason for the difference from this comparison alone.

There is another limit. Uncertainty is unreported. We do not know how much variation occurred between independent preparations, how precise the lifetime estimates are, or whether the studies used the same failure definition. A reported gain of one hundred cycles is a descriptive outcome. It is not enough by itself to establish a general treatment effect under all operating conditions. A reported gain of zero also does not establish that the additive has no possible effect anywhere.

A careful summary keeps each outcome inside its tested conditions. Study A reports a gain under the conditions it used. Study B reports no gain under another set of conditions. That is more informative than saying one paper supports the additive and the other rejects it. It also avoids selecting a preferred result simply because its number is larger.

What question remains? We want to know whether the additive's effect depends on operating conditions when the comparison is made under a matched protocol. A useful next study would include treatment and control at each condition, use the same measurement and failure definitions, and vary the factor of interest systematically. For example, hold areal capacity fixed while varying current density. Then report the uncertainty as well as the point estimates.

Notice that the control comparison exists within each study, but the conditions differ between studies. Comparing the reported gains across studies introduces another level of reasoning. That second comparison needs its own justification; it is not automatically controlled.

The example shows why an evidence matrix is more than a vote count. Counting positive and negative papers hides the circumstances that produced their results. Comparing systems, conditions, definitions, and limitations can turn an apparent disagreement into a testable question.

It also shows why a missing field matters. A blank uncertainty column is not permission to assume the values are precise. A missing failure definition is not permission to assume all laboratories used the same endpoint. Keep those omissions visible. They tell you both how far the current evidence reaches and what a more informative experiment would need to report. The aim is a defensible synthesis, rather than a simple majority decision among papers.

11. IMRaD gives each section a job

Slide 11 · Starts 21:29

IMRaD gives each part of the paper a job. The Introduction establishes a worthwhile question that is not yet resolved. Methods makes the answer checkable. Results reports the observations. Discussion explains their meaning and defines how far the claim can reach.

Think of these sections as making promises to one another. An aim stated in the Introduction needs a corresponding answer in the Results. A number in the Results needs a procedure or calculation in Methods that can produce it. An interpretation in the Discussion needs a traceable connection to the reported evidence.

For example, suppose the aim is to determine whether an additive increases cell lifetime. Methods must describe the preparations, operating conditions, measurement, and definition of failure. Results must present the relevant comparison. Discussion can then consider what the difference means and the conditions under which it was observed. A lifetime increase alone does not automatically establish a molecular mechanism.

The section heading is not enough to determine what a sentence does. A sentence printed under Results can still make an interpretation. A paragraph in Discussion can merely repeat observations without explaining their significance. Read the function of the text, not only the label above it.

A useful check follows the chain from aim, to method, to result, to interpretation. At each connection, ask whether the next part actually fulfills the previous part's promise. If the connection is missing, the problem may concern evidence or reasoning rather than English style.

This is why polishing sentences cannot repair every manuscript. A fluent sentence can still make an unsupported claim. First make the argument complete and aligned. Then improve the language that carries it. Structure allows a stranger to follow how the answer was obtained and what the answer supports.

12. Reverse-outline paragraph functions

Slide 12 · Starts 23:42

A reverse outline records the function of each paragraph after a text has been written. It asks what the paragraph does for the argument, rather than only what topic it mentions.

For example, saying that a paragraph is about zinc dendrites identifies its content. Saying that it narrows the problem to zinc operation at high current identifies its function. The second description shows where the paragraph moves the reader. Useful starting verbs include establishes, narrows, reports, contrasts, explains, bounds, and states.

To make the outline, number the paragraphs. Write one short function statement for each, ideally ten words or fewer, beginning with a verb. Tag the job the paragraph serves, even if that job differs from the section in which it appears. Then summarize each section in one line and read the outline without the original text.

The short limit is a diagnostic tool. If one paragraph needs several unrelated verbs, it may be doing several jobs and may need dividing. If you cannot identify a useful function, ask what would be lost if the paragraph disappeared. The answer may reveal an important contribution, or it may show that the paragraph is unnecessary.

Repeated functions can reveal a stalled argument. Two paragraphs may narrow from a broad energy problem to the same zinc system without adding a new step. The prose can sound smooth while the argument circles back.

Reading the functions separately makes that movement visible. You can see whether the Introduction progresses toward a gap, whether the Discussion develops an interpretation, and whether an essential step is missing. Use this method before spending time on sentence editing. It is easier to repair a paragraph's job when you can name the job clearly.

13. Name the break and the repair

Slide 13 · Starts 25:44

A reverse outline helps identify five recurring breaks in an argument. Naming the break matters because different breaks require different repairs.

The first is an orphan aim: an aim without a corresponding result. Imagine that the Introduction promises to assess full cell viability, but the Results contains only half cell measurements. The repair is to provide the missing evidence or narrow the stated aim and conclusions to the work actually completed. A change

in wording should make the boundary accurate, rather than hide the missing experiment.

The second is an unsupported claim. Suppose the Discussion attributes a lifetime improvement to a particular interphase, while the Results contains only cycling curves and surface images. If the relevant interphase property was not measured, the causal explanation goes beyond those observations. Additional evidence may be needed. Alternatively, the explanation must remain a possibility with its limitations made clear.

The third is an invisible method. A paper reports a number without describing the procedure or calculation that produces it. An average efficiency is not fully checkable if readers do not know the formula, the averaging period, or how failed cycles were handled. Naming the instrument does not supply those missing decisions.

The fourth is a doubled move. Several paragraphs perform the same job without advancing the argument. The fifth is a buried gap. The reader reaches the aim before understanding which unresolved problem makes the study necessary.

Several breaks can occur together. An overly broad aim may encourage an unsupported interpretation, and an undefined measurement can make that interpretation difficult to check. Start by tracing the claim backward before deciding which repair is needed.

When reporting a problem, identify its location, its function, and what is missing. Compare two comments. The Introduction is poorly connected is broad and difficult to act on. The final Introduction paragraph promises a full cell assessment, but no Result addresses that aim is specific. It points directly to the broken connection.

The repair might involve adding evidence, narrowing a claim, moving a paragraph, or removing repetition. Those actions are different from replacing a few words with more academic vocabulary. A manuscript improves when the repair matches the actual problem. The outline is useful because it makes those choices visible before the details of the prose distract us.

14. An Introduction moves toward one question

Slide 14 · Starts 28:40

An Introduction often performs five connected moves. It establishes a relevant context, narrows to a specific system, synthesizes what is known and where it stops, states a consequential gap, and states an aim that a result can answer.

Begin with a context that matters to the intended reader. It should be specific enough to support this paper, rather than a sentence so general that it could open almost any article. Then narrow the scope. Each narrowing should exclude something and bring the reader closer to the question you will address.

The literature section needs to explain what the evidence establishes. A list of author names is not enough. Connect the studies so readers can see the current answer, its conditions, and its limits. From that synthesis, identify the unresolved point that matters for your question.

Next explain the consequence of the gap. What can we not predict, explain, or decide because the required evidence is missing? The aim should then state what this paper will settle. It should follow naturally from the gap, rather than introduce an unrelated project at the end.

These are five functions, not a requirement for exactly five paragraphs. One function may need more than one paragraph. A paragraph may sometimes perform closely connected functions. What matters is whether the argument advances in a clear direction.

Use a reverse outline to check that direction. If the Introduction reaches a specific system, then returns to a broad context and narrows to the same system again, the reader has to travel the same path twice. Repair the sequence so each move contributes a necessary step toward the question. A focused Introduction gives the reader a reason to care and a clear expectation for what the paper will answer.

15. Turn an absence into a consequential gap

Slide 15 · Starts 30:41

An absence in the literature is not yet a complete reason for another study. The statement that few papers have examined a topic tells us about coverage. It does not tell us what the missing knowledge prevents us from doing.

Consider the solvent example as a teaching case. The absence statement says that few studies report blended solvent degradation under realistic flue gas conditions. The gap statement adds the consequence: without degradation rates under those conditions, solvent replacement costs cannot be estimated reliably. The second statement connects missing evidence to a decision.

This example illustrates the form of the argument. It is not a claim that every current solvent literature still has that exact gap. In your own work, the known and unknown parts must be supported by the sources you actually searched and evaluated.

Build the reasoning in three steps: what is known, what is not known, and what the uncertainty costs us. Keep the consequence proportional to the missing evidence. One unavailable measurement rarely justifies saying that all process design is impossible. A more precise consequence might be that a particular cost estimate remains uncertain over a defined operating range.

Your evidence matrix helps check the first two steps. It can reveal differences in conditions, an unreported metric, or a regime that all selected studies exclude. Then ask what prediction, explanation, or decision would improve if that information became available.

Also keep the search boundary visible. Not finding a measurement in your selected papers does not prove that nobody has ever measured it. Describe the coverage you can defend. A useful gap is both consequential and traceable: readers can see why the missing evidence matters and how you established that it is missing from the relevant body of work.

16. Write an aim that a measurement can settle

Slide 16 · Starts 32:51

A useful aim is one that a result can answer. To understand solvent degradation expresses an interest, but it does not yet identify the measurement or comparison that would make the aim complete. We need to turn the broad intention into an operational question.

The synthetic example does this by proposing to measure the degradation rate of two solvent blends at two oxygen levels, with temperature and the rest of the gas composition held fixed. We can now identify the factors being compared and the quantity that will answer the question.

That aim creates commitments for Methods. The blends must be defined. The oxygen levels must be specified. The procedure must explain how degradation is measured and how the rate is calculated. Fixed temperature needs an actual value, a unit, and a description of how it is controlled. The aim does not need every procedural detail, but the methods must eventually provide them.

The Results also has commitments. It should report the stated comparisons, rather than show only the blend that gives the most favorable outcome. If a planned comparison could not be completed, the paper should make that limitation visible and adjust the scope of its conclusions.

The wording also sets a boundary on interpretation. Measuring a degradation rate does not by itself identify every reaction step or prove a unique mechanism. Different pathways can sometimes produce similar overall rates. If a mechanistic aim is intended, the evidence plan must include measurements capable of distinguishing the relevant explanations.

An operational aim can also identify an inconvenient result as informative. If neither blend improves the rate under the specified conditions, that still answers the comparison. A useful aim does not require the preferred outcome.

Check your own aim using three questions. What will be measured? What will be compared? What kind of result could settle the question? If the only answer is that we will understand more, the aim probably needs another level of specificity.

A clear aim helps before the writing begins. It guides the experiment, identifies the measurements that are necessary, and provides a structure for the Results. Later, it also helps remove interesting but unrelated material. The paper does not have to answer every question about the system. It does need to answer the particular question it promises to address.

17. Methods must produce every reported quantity

Slide 17 · Starts 35:40

Methods must explain how every important reported quantity was produced. Readers need to know what was used, what was done, under which conditions, and how measurements became the final values. An instrument name alone cannot provide that information.

Relevant details may include materials, composition, preparation, equipment settings, the measurement sequence, and the calculation. For a treatment comparison, describe both the treatment and the control. State what differs between them and which conditions are matched. Otherwise the reader cannot identify what the comparison actually tests.

Explain the level of replication. Repeating a measurement on one sample is different from preparing several independent samples. Report exclusions and the basis for uncertainty in a way that respects how the observations were collected. We will examine that distinction in the next example.

Operational definitions are equally important. Failure might mean capacity falling below a threshold, a short circuit, or a voltage limit. Efficiency might mean an average over a stated interval or a value measured at the end. Stable needs a duration and an acceptable range of change. Familiar words do not guarantee that different laboratories used the same definition.

To audit a draft, start with a major number in Results and trace it backward. Find the measurement, equation, conditions, and decisions that produced it. If an essential link is missing, an invisible method remains in the manuscript.

The goal is not to write the longest possible Methods section. Include the information that affects reproducibility and interpretation, and organize it so readers can find the procedure they need. A checkable method connects the numerical answer to the question it is supposed to resolve. It lets another researcher understand both what to repeat and what a meaningful comparison would require.

18. Identify independent experimental units

Slide 18 · Starts 37:52

Consider a synthetic polymer film experiment. For each formulation, three batches are prepared independently. Four coupons are cut from every batch and tested, producing twelve coupon measurements per formulation.

The treatment formulation contains additive X. The control uses the same formulation without X.

For a comparison of formulations, what is the independent sample size per group? Which preparation and testing conditions should be matched? Discuss both questions with a partner. Explain where independent preparation occurs, rather than only counting the number of measurements. Also consider whether coupons from the same batch share anything that could affect their results. Prepare a short answer with your reason. Take two minutes before moving to the worked answer.

> Practice pause after this narration: 02:00. Pause the recording for longer whenever you need.

19. Worked answer: batches are the independent units

Slide 19 · Starts 40:46

For this formulation comparison, the independent sample size is three batches per formulation. The independent preparation occurs three times. The four coupons from one batch are subsamples that share a preparation history. Twelve coupon measurements therefore do not represent twelve independent preparations.

The coupons are still useful. They can reveal variation within a batch and improve our description of that batch. The problem appears when we treat every coupon as if it came from a completely separate preparation. That would make the amount of independent evidence look larger than the experimental design provides.

One analysis approach is to summarize the observations at the batch level before comparing formulations. Another is to use a method that accounts for coupons being nested within batches. We do not need a statistical formula here. The important principle is to preserve the structure of the experiment

when summarizing the data.

For the control comparison, match relevant factors such as polymer lot, casting procedure, thickness, conditioning, and test settings when appropriate to the question. Then the intended difference is the presence of additive X. Unplanned differences can complicate interpretation. If coupons are damaged or measurements are excluded, report the criteria and the numbers involved.

The experimental unit is not always a batch. It depends on where treatment is assigned and where independent experimental variation is created. A different preparation and assignment design could require a different answer. That is why Methods must describe the actual design and define what the reported sample size means.

Reporting this distinction also helps readers compare your experiment with other studies. Three independent batches with four subsamples each is a different design from twelve independent batches, even when both designs produce twelve numerical values.

This completes the chain we have been building. The gap identifies the unresolved problem. The aim defines the comparison. The method produces a checkable answer. Accurate controls, definitions, and independent units make it possible to report that answer clearly and interpret it within the evidence.

20. Results report the trade-off

Slide 20 · Starts 43:21

We now turn from the structure of a paper to the evidence inside its Results, figures, Discussion, and Conclusion. We will use one reaction case throughout so that you can follow each claim back to the same measurements. All the values are synthetic teaching data. They do not describe an actual reactor or catalyst.

The question is how temperature affects conversion of A and selectivity to the desired product B. We tested four temperatures, from three hundred to three hundred seventy-five degrees Celsius, while keeping residence time at two point zero seconds. Conversion tells us how much of the feed A was consumed. Selectivity tells us how much desired B was formed relative to the A consumed, using the definition for this case.

Look at both responses. Mean conversion rises from forty to eighty percent, while mean selectivity falls from ninety to sixty-five percent. If we report only conversion, the reader receives an incomplete account of the result. The second response changes the interpretation: increased consumption of A comes with reduced selectivity to B.

A useful Results statement gives the direction, magnitude, and tested conditions. At a residence time of two seconds, raising temperature from three hundred to three hundred seventy-five degrees increased mean conversion by forty percentage points and reduced mean selectivity by twenty-five percentage points.

These measurements show a trade-off within the tested range. They do not yet tell us its mechanism or establish a preferred operating temperature. Notice how the sentence answers what changed before trying to explain why it changed. That separation makes the later reasoning easier to examine.

21. Identify independent experimental units

Slide 21 · Starts 45:18

Before interpreting an error bar, ask what counts as one independent unit. Suppose we prepare and carry out the reaction independently three times at a given temperature. Each run has its own preparation and execution. In this teaching case, those three runs give us a sample size of three.

Now consider a different design. We carry out the reaction once and read the same sample with an instrument three times. We obtain three numbers, but we still have only one independent reaction run. The repeated readings help assess measurement repeatability. They do not reveal how much independently prepared reaction runs would vary.

This distinction matters because the uncertainty we can estimate depends on what actually varies independently. If readings from one run are treated as separate experiments, the evidence appears more extensive than it is. The analysis may then suggest a level of precision that the experimental design does not support.

Some studies have several levels, such as samples within batches or readings within samples. You need not force every design into one simple pattern. You do need to name the unit and use an analysis that respects those levels. In our case, one row in the original reaction table represents one independent simulated run.

So write more than n equals three. Write three independent runs per temperature, or describe the actual unit in your own study. Think about your project now. What must be prepared or started again to create one independent unit? Which measurements are repeated observations of the same unit? Take a moment to make that distinction concrete.

> Practice pause after this narration: 00:10. Pause the recording for longer whenever you need.

22. SD, SE and CI answer different questions

Slide 22 · Starts 47:21

This separate synthetic illustration shows why we need to keep readings and runs separate. There are three independent runs, with several technical readings within each run. The first run has readings of thirty-seven, thirty-eight, and thirty-nine percent, giving a run mean of thirty-eight. The next run has a mean of forty, and the third has a mean of forty-two.

For the between-run summary, our three values are therefore thirty-eight, forty, and forty-two percent. Their mean is forty percent. Their sample standard deviation, or SD, is two percentage points. SD describes spread among the independent run values. It answers how variable those runs are around their mean. The extra instrument readings do not turn three runs into nine independent experiments.

Standard error, or SE, answers a different question: how precisely have we estimated the population mean from these independent units? Under suitable assumptions, the SE of the mean is the sample SD divided by the square root of n. Here, two divided by the square root of three is approximately one point one five percentage points. The same observations give different numerical summaries because the summaries answer different questions.

A confidence interval is different again. A ninety-five percent confidence interval for the population mean uses a procedure designed to cover that fixed population mean in about ninety-five percent of repeated studies, under the method's assumptions. It is not a range containing ninety-five percent of individual runs. It is also not another name for mean plus or minus one SD.

With only three runs, our estimate of variability is itself uncertain. An interval calculation needs an appropriate method and assumptions, rather than simply placing a familiar label on a bar. For example, a conventional small-sample interval for a normal population mean uses a t distribution, not just an automatic multiplier of two.

Whenever you see bars, ask what quantity they represent, what independent units produced them, and what assumptions support their interpretation. Overlap or nonoverlap of SD bars alone does not establish statistical significance. If you use the word significant, provide the statistical basis. Before moving on, explain to yourself the difference between spread among runs and precision of an estimated mean. Those are the central questions behind SD and SE.

> Practice pause after this narration: 00:15. Pause the recording for longer whenever you need.

23. Practice: name the change precisely

Slide 23 · Starts 50:27

Try the calculations before looking at the worked answer. Conversion changes from forty to eighty percent. Selectivity changes from ninety to sixty-five percent. For each response, express the change in two ways. First, calculate the change in percentage points. Then calculate the relative percentage change using the initial value as the denominator.

Include the positive or negative sign and write a short sentence, not just a number. Make the reference value clear enough that another reader could recover your calculation. Work independently first, then compare with a partner if one is available. If you are studying alone, check whether your two answers describe the same change on different bases. You have ninety seconds before the answer on the next slide.

> Practice pause after this narration: 01:30. Pause the recording for longer whenever you need.

24. Worked answer: points and relative change

Slide 24 · Starts 52:51

Start with conversion. Eighty minus forty equals forty, so conversion increased by forty percentage points. That is the direct difference between the two percentages. To calculate relative change, divide that difference by the initial value. Forty divided by forty, multiplied by one hundred, gives an increase of one hundred percent.

Saying that conversion doubled is therefore correct for this comparison. It does not mean that the final conversion became one hundred percent. The final value remains eighty percent. One hundred percent is the size of the increase relative to the starting value of forty percent.

Now consider selectivity. Sixty-five minus ninety equals negative twenty-five, so selectivity decreased by twenty-five percentage points. For relative change, negative twenty-five divided by ninety, multiplied by one hundred, is approximately negative twenty-seven point eight percent. We can say that selectivity decreased by twenty-seven point eight percent relative to its initial value of ninety percent.

The two calculations are useful, but they are not interchangeable. The sentence selectivity fell by twenty-five percent could be read as a relative decrease of twenty-five percent. That would describe a different endpoint. Using percentage points removes that ambiguity when you mean the direct difference.

A reliable check is to identify your denominator. A percentage-point difference subtracts one percentage from the other. A relative percentage change divides the difference by a stated reference value. If you reverse the comparison and choose a different reference, the relative percentage will change. Clear wording lets the reader see that choice. Compare your two sentences with these answers and correct the units before you use the numbers in Results.

25. Choose the display for the question

Slide 25 · Starts 54:57

Choose a display by asking what the reader needs to find out. If the question is how response varies with temperature, points positioned on a temperature axis are useful. Connecting lines may help the eye follow the sequence. Unless we explicitly fit a model, those lines do not show a measured response at every temperature between the points.

If the question concerns variation, show information about the individual observations. The distribution example on this slide is separate from our reaction case. Each of its two groups has six observations, a mean of fifty percent, and a sample SD of about five point one four percentage points. Yet the values are arranged differently. One group has one observation at or above fifty-four percent; the other has two.

A mean and SD can therefore match while other features of the data differ. Individual points help reveal features that a short summary hides. They also make the available sample size visible. With only three runs in our reaction case, drawing a smooth density could imply much more detail about a population distribution than those three observations support.

If the question is about exact values, a table may be the clearest choice. It can show units, sample sizes, and defined uncertainty without requiring a reader to estimate values from positions. A table and a figure can serve different purposes, although unnecessary duplication uses space.

Before drawing anything, finish this sentence: the reader should use this display to see what? Then choose marks and summaries that make that answer visible. The display is part of the argument because it determines which features of the evidence are easy to inspect.

26. Honest axes preserve the comparison

Slide 26 · Starts 56:56

This separate illustration shows the same response values, sixty and sixty-six percent, in both panels. The vertical-axis limits change, so the visual impression changes even though the measurements do not. A narrow range makes differences occupy more of the plotting area. A broad range makes those same

differences occupy less. Read the numerical limits before judging the size of an effect from its appearance.

For bars, length represents magnitude. A zero baseline allows the displayed lengths to preserve that relationship. Truncating the baseline can make a modest numerical difference look like a large ratio of bar lengths. This is why a zero baseline is the usual requirement for a bar chart.

For points and lines, a nonzero start can be appropriate. A restricted range may help a reader inspect small differences that matter scientifically. Keep the limits visible and ensure that the reader can recover the actual magnitude. The choice should help answer the question, with enough context to interpret the answer.

Also consider how readers compare panels. When two panels sit side by side, people naturally compare heights, slopes, and distances. Comparable scales support direct comparison. If different scales are necessary, make that choice explicit so that similar-looking movements are not mistaken for similar numerical changes.

For predicted versus observed values, for example, equal scales and an identity line help the reader assess agreement. That is a different purpose from showing a small response change over time, so the appropriate design may differ. There is no useful rule that every point plot must start at zero. There is a useful responsibility to make the scale honest, visible, and suited to the comparison. Good axis choices help readers assess your evidence rather than relying on a first visual impression.

Extend this into a six-part figure audit. Are truncated axes clearly justified? Do dual axes invite a misleading comparison? Is uncertainty shown or its absence explained? Has a selected range hidden relevant observations? Does apparent resolution exceed the evidence, as with a smooth surface from sparse measurements? Are reused images or image regions disclosed and traceable? These questions connect visual choices to the evidence. A polished appearance cannot answer them; you need the underlying information and an honest account of what was done.

27. A caption defines every mark

Slide 27 · Starts 59:48

A caption gives the reader the information needed to interpret the figure. Read the example on this slide as a sequence of answers. What is plotted? Conversion of A and selectivity to B against temperature. Under what condition? A residence time of two point zero seconds. What do the points mean? Means of three independent runs at each temperature.

Then ask what the bars represent. The caption says plus or minus one sample SD. The phrase error bars by itself would leave the reader uncertain. Bars could represent SD, SE, a confidence interval, or another quantity. Their meaning changes the interpretation, so the author must define it. The caption also explains that lines guide the eye. This avoids suggesting that the connecting lines are a fitted model.

Finally, it states that the values are synthetic teaching data. The status and origin of the evidence matter. A reader should not mistake a hypothetical illustration for a measured finding from a real system.

Use a simple matching check. For every kind of mark, find the words that explain it. A point, line, shaded band, box, or special symbol should have a meaning that the reader can identify. Then reverse the check. For every statement in the caption, confirm that the saved figure actually shows what the statement describes.

This is especially important after revision. If you replace SD bars with confidence intervals, revise the caption. If you rearrange panels, check any references to left and right. If you remove individual observations, do not leave a sentence saying that dots represent all runs. Small mismatches can survive because the caption and figure are edited at different times.

A caption does not need to repeat the entire Results paragraph. Its main purpose is to provide the keys for reading the evidence. The Results paragraph can then explain the central finding and magnitude. Together, they let the reader understand both the visual encoding and the scientific comparison.

Look back at the trade-off figure now. Check the variables, units, fixed condition, sample size, independent unit, and meaning of each mark. Could someone understand the figure without opening your analysis file or asking you a question? Take a short moment to identify any information that would still be missing.

> Practice pause after this narration: 00:10. Pause the recording for longer whenever you need.

28. Start with one row per independent run

Slide 28 · Starts 1:02:39

We will now follow the figure workflow without assuming any Python knowledge. The same reasoning applies whether you use a spreadsheet, a notebook, or another analysis tool. Start with the original observations, preserve their structure, create a checked summary, build the display, and inspect the exported result.

In our reaction table, one row represents one independent simulated run. The columns record temperature, run number, conversion, and selectivity. At three hundred degrees, the first row pairs conversion of thirty-eight percent with selectivity of ninety-one percent. The next row pairs forty with ninety, and the third pairs forty-two with eighty-nine. These are the same runs expressed through two responses.

That pairing must survive the workflow. If you sort one response column by itself, you can attach the conversion from one run to the selectivity from another. The numbers may still look reasonable, but the relationship between them has been changed. This matters whenever a later calculation uses both values, as a per-run yield calculation does.

Before making a summary, check what each row means. Confirm the units, column names, number of observations, and any missing values. The full reaction table has twelve rows: four temperatures with three independent runs each. Twelve total rows does not mean twelve independent runs at every temperature. Counting within groups is part of checking the experimental structure.

Keep the original run table and make the grouped summary as a separate, traceable step. Do not replace all the observations with four means and discard the path back to them. You may later need the individual values to assess variation, investigate an unusual run, or calculate a quantity that depends on paired responses.

This principle also helps with mistakes. If the final plot looks unexpected, you can ask whether the issue began in the original data, grouping, calculation, or display. A documented sequence gives you places to inspect. A figure edited manually until it looks right does not provide the same record.

Choose one row on the slide and explain what it represents. Then ask whether every value in that row would remain linked to the same run throughout your own analysis. That is the connection we want to preserve from observations to claims.

> Practice pause after this narration: 00:10. Pause the recording for longer whenever you need.

29. Check the grouped summary before plotting

Slide 29 · Starts 1:05:33

Once the original table is checked, group the runs by temperature and calculate the mean and sample SD for each response. The table on this slide is the summary used for the reaction figure. At three hundred degrees, conversion is forty plus or minus two percent, and selectivity is ninety plus or minus one percent. Here, the plus or minus quantity is explicitly one sample SD.

You do not have to calculate every cell manually. It is sensible to check at least one group against the observations. Thirty-eight, forty, and forty-two must give a mean of forty and a sample SD of two percentage points. This small check connects the numerical output to values you understand. It can reveal a wrong column, an incorrect group, or a different definition of the summary.

Next, keep the ordering consistent. The mean at three hundred degrees must be paired with the SD for three hundred degrees. If one list is sorted differently from another, the bars can be attached to the wrong means. A plot may still render successfully while making an incorrect statement about the data. Successful display is not the same as scientific correctness.

Check labels and units before export. Then open the saved file itself. A label that was visible in the working window might be cut off in the export, or the intended two-panel figure might not be the one that was saved. Inspect the artifact your reader will receive. The sequence is original observations, checked summary, labeled figure, export, and inspection. Each step has a question that can be answered before moving to the next.

30. Keep a package that recreates the figure

Slide 30 · Starts 1:07:24

Imagine returning to this figure six months from now. You need to change a unit label, or a collaborator asks how a mean was calculated. If you have kept only the exported image, the route from observations to marks may be lost. Keep a small package that can recreate the figure.

It should contain the original run table with its units, the analysis and figure instructions, the tools and required dependencies, the palette, the caption, and the exported files. The instructions might be in a notebook, recorded spreadsheet formulas, or another procedure that someone can follow. What matters is that the transformations are visible and repeatable.

Avoid undocumented manual changes to selected values or marks. If a correction is necessary, record what changed and why, while preserving the original information. If the figure depends on a separate palette file or a particular software feature, include enough information to recover that dependency.

The practical test is a fresh start. Use the saved inputs and follow the instructions without relying on values left in a program's memory or steps remembered only by the author. Confirm that the summary and exported figure appear again with the intended values and labels.

This is a useful form of reproducibility even for a small assignment. It also makes revision faster because the figure is a result of a documented process. Ask yourself what a classmate would still need to ask you after receiving the package. Any essential step that exists only in your memory is a candidate for clearer documentation. Take a moment to identify one such dependency in work you have done.

> Practice pause after this narration: 00:10. Pause the recording for longer whenever you need.

31. Inspect the exported figure at its final size

Slide 31 · Starts 1:09:32

Judge a figure at the size in which it will be read. A label that looks clear on a full screen may become unreadable at one-column width. Export quality therefore includes both the file format and the size of the marks and text.

For lines and text, vector output such as a suitable PDF or SVG is often useful. It preserves their shapes when the figure is resized. For raster output, our lab standard is at least six hundred dots per inch at the intended physical size. A high resolution does not rescue labels that were designed too small. It simply records that small design with more pixels.

Open the exported file and check axes, units, markers, and uncertainty bars. Confirm that nothing has been clipped. Embedded fonts help preserve the intended text across machines. The final file deserves inspection rather than an assumption that it matches the working window.

Now consider grayscale. If color is the only way to distinguish groups, meaning may disappear when printed or when a reader has difficulty separating the colors. Use suitable shapes, direct labels, or panel structure to maintain the distinction. You do not need to apply every possible visual difference at once; choose enough to make the comparison clear.

Color also carries a consistent role in our palette. Teal represents a control, baseline, or reference, and amber represents the effect of interest. Conversion and selectivity are both responses in this case. One is not the control for the other. We can distinguish them with separate panels and clear labels while using amber consistently. The purpose of these choices is a readable scientific comparison in the actual output.

32. Conversion, selectivity and estimated yield

Slide 32 · Starts 1:11:31

All four temperatures in this comparison use a residence time of two point zero seconds. We can now move from reporting the trade-off to considering its meaning. Begin with the definitions. Conversion is A consumed divided by A fed. Selectivity to B is B formed divided by A consumed. For this case, we assume a one-to-one molar relationship between A and B and no B in the feed. Under that basis, yield in percent is conversion multiplied by selectivity and divided by one hundred.

The table uses mean conversion multiplied by mean selectivity, so we call the result a yield estimate. At three hundred fifty degrees, seventy times seventy-eight divided by one hundred gives fifty-four point six percent. At three hundred seventy-five degrees, eighty times sixty-five divided by one hundred gives fifty-two percent. The higher conversion at the higher temperature does not give the higher yield estimate, because selectivity has decreased.

There is an important detail about averaging. The product of two means is not generally the same as the mean of the paired products. If we want the mean yield across runs, first calculate yield from conversion and selectivity within each run, then average those yields. This preserves the pairing and allows us to examine the variability of the quantity we actually want.

In this synthetic dataset, at three hundred fifty degrees the product of means is fifty-four point six percent. The mean of the three paired-run yields is approximately fifty-four point five eight seven percent. Both round to fifty-four point six at one decimal place. Equal rounded results do not make the definitions interchangeable.

What can we conclude? Three hundred fifty degrees has the highest estimate among the four tested temperatures. We have not established a global optimum, and we have not shown that the difference of two point six percentage points is statistically significant. Intermediate temperatures could give another result, and uncertainty requires analysis.

An industrial decision would also depend on energy, separation, stability, cost, and constraints. The useful implication is that the objective matters: maximizing conversion and maximizing desired-product yield need not select the same condition. Look at the two rows again and identify exactly how the second response changes the decision you might otherwise make from conversion alone.

> Practice pause after this narration: 00:15. Pause the recording for longer whenever you need.

33. Explanations need a control and a prediction

Slide 33 · Starts 1:14:38

We observe that selectivity falls with temperature. We do not yet know why. A Discussion should distinguish that observation from explanations proposed for it. One possibility is that product B reacts further to form byproducts. Another is that a temperature-dependent sampling or analysis bias reduces the apparent selectivity. The existing trend does not separate these possibilities.

A useful explanation leads to a test and a predicted outcome. To investigate further reaction of B, we could vary residence time at a fixed temperature, controlling other relevant factors. If that process contributes, longer residence might accompany lower selectivity and increased byproduct formation. Measuring the byproducts matters because a decrease in B alone does not tell us where the material went. However, more byproducts at longer residence time would only be consistent with further reaction of B. They might form directly from A. To distinguish the precursor, we need more specific evidence, such as a controlled reaction starting with known B or suitable tracing of B into the byproducts. Those tests also need appropriate controls.

This comparison also requires care. Changing residence time can affect conversion and other aspects of the reaction. We should plan the conditions and measurements so that the pattern is informative, rather than treating any time dependence as proof of one mechanism.

To investigate analysis bias, we could pass mixtures of known composition through the sampling and analysis procedure. If measured recovery depends on the procedure or condition, that pattern suggests a contribution from the measurement process. The known mixture provides a reference against which an apparent change can be assessed.

One test rarely excludes every alternative. A result matching a prediction can support an explanation without uniquely proving it. Equally, a result that does not match should change how confidently we use that explanation. This is why adding may or could to a mechanism sentence is insufficient by itself. Cautious wording needs a reason and an account of what evidence is missing.

Choose one row in the table. State the proposed comparison, what should be controlled, and the expected pattern if the explanation contributes. Then name an outcome that would make you question it. For example, consider what unchanged selectivity and no increase in byproducts would mean in a well-controlled residence-time test. The point is to connect a hypothesis to evidence that could change our interpretation, rather than protecting the hypothesis from every possible result.

> Practice pause after this narration: 00:20. Pause the recording for longer whenever you need.

34. Compare literature on the same basis

Slide 34 · Starts 1:18:01

A literature comparison should help the reader interpret the result on a comparable basis. Suppose another paper reports a yield of fifty-five percent. We cannot conclude that its system outperforms our estimate of fifty-four point six percent simply by placing the numbers next to each other.

Start with the systems. Check the feed, catalyst, reactor, operating range, and residence time. A difference in these conditions may be central to the interpretation. Next, examine definitions. Conversion, selectivity, and yield can use different denominators or reporting bases. A molar yield and a mass-based yield are not automatically interchangeable just because both are reported as percentages.

Then check measurement methods, independent units, and uncertainty. A small numerical difference may not support the ranking you want to make. Ask whether the evidence permits a direct comparison, a limited comparison with stated differences, or only a discussion of related behavior.

A good comparison explains why the source is relevant and what might account for agreement or disagreement. It does more than list several papers and their highest reported values. Keep our own observations distinct from the findings attributed to another study.

Use a verified source. If the necessary paper has not yet been checked, describe the search and extraction you need to complete. Do not invent a citation or a literature result to make a paragraph seem finished. Imagine that you are about to compare the hypothetical fifty-five percent value with ours. Identify one item you would inspect in that paper before writing the comparison. The definition and denominator are often a useful starting point.

> Practice pause after this narration: 00:10. Pause the recording for longer whenever you need.

35. A limitation must change the claim

Slide 35 · Starts 1:20:11

A useful limitation changes how the result should be interpreted. It is more than a list of weaknesses. We tested four temperatures, so we can identify the highest value among those tested. We cannot locate the true maximum of a continuous response from those four points alone. That limitation changes the wording from optimal temperature to highest among the tested temperatures.

We used only a residence time of two point zero seconds. That limits generalization to other residence times. Keep the condition in the claim rather than allowing the reader to assume the temperature trend applies everywhere.

We have three independent runs per temperature. They provide information about between-run variation, but a variability estimate from a small sample is uncertain. If the decision concerns yield, evaluate the paired-run yields and their uncertainty rather than silently transferring the SD of conversion to a different quantity.

Finally, we have no energy-use or long-term stability measurements. The data therefore do not establish industrial suitability. A condition that looks promising for one response may be less attractive when separation demands, durability, or operating costs are included.

Notice the pattern: evidence boundary, consequence for the claim, and perhaps a next test. This turns a limitation into part of the scientific reasoning. It helps readers see what the study supports and what further evidence could change the decision. Choose one row now and revise a claim in your mind. Which exact words must change because of that limitation? If you can name the change, you are using the limitation rather than merely acknowledging that one exists.

> Practice pause after this narration: 00:10. Pause the recording for longer whenever you need.

36. A conclusion answers within the tested scope

Slide 36 · Starts 1:22:19

The Conclusion gives the answer to the original research question that the reader should retain. The Discussion has developed the interpretation, considered explanations, and identified boundaries. The Conclusion draws those elements into a supported answer without repeating every value in the table.

Use three moves as a checking tool. First, answer: state the central finding and a meaningful magnitude. In this case, conversion increased while selectivity decreased. Second, bound: name the tested conditions and the uncertainty that matters to the claim. The residence time and the tested range help keep the answer within the evidence. Third, give an implication: state the decision supported or the next useful test.

These are functions, not a requirement that every Conclusion contain exactly three sentences. Different journals and projects have different structures. The useful question is whether a reader can identify the answer, its limits, and its significance for the next decision.

Every result in the Conclusion should already be available in Results. If you calculate something new while writing the final paragraph, return to the appropriate section and report it properly. An interpretation should likewise have support in the argument you have developed.

Avoid an untested promise such as a guaranteed increase in industrial efficiency when the study contains no industrial evaluation. You can state a defensible direction for further evaluation without promising its outcome. Look at the last sentence of a conclusion you might write. Does it answer the original question or extend a supported implication, or has it started a new claim that would require another study? Take a short moment to check that boundary.

> Practice pause after this narration: 00:10. Pause the recording for longer whenever you need.

37. Practice: turn a claim into a conclusion

Slide 37 · Starts 1:24:27

Revise this claim in two sentences: three hundred seventy-five degrees is the best condition because conversion is highest, and the selectivity trend proves that B decomposes. Check both best and proves against the available evidence.

Include one numerical comparison, the tested condition, and a defensible implication or next test. You can use the yield estimates: fifty-four point six percent at three hundred fifty degrees, compared with fifty-two percent at three hundred seventy-five degrees. There is no mechanism test in the current dataset.

Write in your own words. Then identify what is an observation, what remains a hypothesis, and where the scope is stated. If a partner is available, ask them to circle any wording stronger than its evidence. If you are alone, perform the same check yourself. Take two minutes before the worked answer appears on the next slide.

> Practice pause after this narration: 02:00. Pause the recording for longer whenever you need.

38. Worked answer: evidence sets the boundary

Slide 38 · Starts 1:27:30

Here is one possible answer. At a residence time of two seconds, the yield estimate calculated from mean conversion and selectivity was highest among the four temperatures at three hundred fifty degrees: fifty-four point six percent, compared with fifty-two percent at three hundred seventy-five degrees. This comparison identifies a condition for further testing; a controlled residence-time study with byproduct measurements could test further reaction of B as one possible explanation.

Your sentences do not have to match these words. Check what the revision accomplishes. Highest among the four temperatures replaces best. It describes the tested comparison without claiming a global optimum. Yield estimate calculated from the means identifies the quantity being compared. It does not silently become the mean yield of the paired runs. The residence time remains visible, so the scope is clear.

The mechanism claim also changes. Instead of saying that decomposition has been proved, the revision proposes a controlled test of further reaction as one possible explanation. These are different levels of claim. Byproduct formation alone would not identify B as its precursor; a B-specific control or suitable tracing would strengthen that discrimination. A proposed experiment is useful because it specifies evidence that might change the interpretation.

Suppose a well-controlled test increases residence time at fixed temperature, but selectivity does not fall and byproducts do not increase. That outcome would make us reconsider how much further reaction explains the original trend. We would examine the test's sensitivity and conditions and consider alternative explanations. We should not simply preserve the original mechanism sentence regardless of the result.

Also notice the difference of two point six percentage points between the displayed yield estimates. We have not called that difference statistically significant. Doing so would require an appropriate analysis of the relevant uncertainty. A clear numerical difference in a table and a supported statistical conclusion are distinct things.

Read your revised sentences once more. Can the reader recover the comparison and its conditions? Can the reader distinguish the measured finding from the proposed explanation? Is the next test specific enough to have an informative predicted outcome? Those checks connect Results, figures, Discussion, and Conclusion into one traceable argument. The strength of the conclusion comes from that connection: the wording tells the reader what the evidence supports and where further work is needed.

39. Apply the review to one paper

Slide 39 · Starts 1:30:32

To finish, apply these ideas to a paper that you are reading or a manuscript that you are writing. Choose one central claim and trace it back through the paper. Find the result that supports it, the method that produced that result and the aim that made the measurement relevant. If a link is missing, write the missing connection as a specific revision. For example, a claim about longer lifetime needs an operational definition of failure and observations made under conditions that address the intended use.

Next, inspect one figure. Identify the independent experimental unit, the number of those units and the meaning of every point, line and uncertainty bar. Check the denominator of every percentage. Ask whether the axis limits and the displayed data range preserve the comparison that the caption invites. If you needed to update that figure next month, could you locate the original measurements and repeat the saved processing steps?

Then examine one comparison with the literature. Put the outcomes, conditions and definitions beside one another before deciding how directly the reported numbers can be compared. A difference can be informative even when it does not isolate a cause. State which comparison the available evidence settles and which comparison requires additional measurements.

Now read the conclusion. It should answer the original question with a finding that already appears in the Results. Its scope should name the conditions that matter. A proposed explanation should lead to a test with a predicted outcome that could change your interpretation. In our reactor example, the largest conversion did not identify the largest yield estimate. The decision depended on the stated objective and on information about both conversion and selectivity.

When you return to the review, use the transcript to revisit the reasoning behind any uncertain step. A useful revision preserves the evidence, makes its meaning easier to inspect and brings the claim into line with what was actually tested.

Write two sentences for your own work. In the first, state a finding with its magnitude and scope. In the second, propose a next measurement and say what outcome would favor one explanation. Take thirty seconds now to make those sentences concrete.

> Practice pause after this narration: 00:30. Pause the recording for longer whenever you need.

Teaching sources

Course syllabus 2105620, Semester 1, 2026, and the teaching decks for Weeks 1, 3, 4, 5, 6, 8, 9 and 10. All numerical teaching examples are identified as synthetic. The review uses the original Week 8 reaction case at a residence time of 2.0 seconds, plus separately constructed examples for experimental units, distributions and axes.

The recording uses the synthetic male English voice Michael, generated locally with Kokoro-82M. The transcript and narrated figures were checked against the teaching sources.