

Growing Through Discussion

EGCL Research Manual

“Research can be performed alone, but growth as a researcher takes place through discussion and correction.”

1. Growth Is Determined by the Slope, Not the Starting Point

Students enter the laboratory with different starting abilities. Some have extensive experimental experience, some read papers quickly, and others have strong chemical intuition or presentation skills. If this is represented as a growth curve, a student's ability at the time of entry corresponds to the y-intercept. A high starting point can make someone appear ahead at first, while a lower starting point can make the first few months look slower.

But the position reached at the end of a master's or PhD program is determined less by the y-intercept than by the slope of growth. A student who is initially inexperienced but corrects their judgment and behavior every week can grow rapidly. By contrast, a student who starts with strong abilities but keeps repeating familiar habits and cannot turn feedback into action may eventually stop growing. Over several years, even a small difference in slope creates a very large gap.

The most important factor determining that slope is not simply diligence or experimental speed. It is the ability to accept that your present judgment may be wrong, absorb an external standard, and actually change what you do next. Receptiveness matters in research not because it makes someone polite or obedient, but because it determines the rate of growth.

Initial ability determines the starting point. The ability to receive feedback and correct behavior determines the slope.

2. Polite Answers Do Not Mean an Open Mind

Many students believe that they are not overly proud and that they listen well to others. In individual meetings, they may indeed respond very politely. They nod while hearing feedback and say, “Yes, I understand.” In that moment, they can appear highly receptive. But if the way they conduct research, interpret data, structure presentations, and choose experiments is almost unchanged at the next meeting, then the feedback was not actually accepted.

Hearing words with your ears and allowing those words to enter your judgment system are very different things. Receptiveness cannot be judged by whether you avoid arguing during a meeting. It should be visible in what you stopped doing because of the feedback, what you studied newly, and how you redesigned an experiment. If the words are polite but the behavior never changes, a person can appear open while remaining very firmly closed inside.

I sometimes compare such a student to a seedling kept inside a small plastic pot. EGCL is fertile soil containing many generations of research experience, trial and error, literature knowledge, and scientific standards. If a new seedling leaves its pot and roots itself in this soil, it can rapidly absorb nutrients that would be difficult to obtain alone. But if the seedling never leaves the plastic pot, then even in the middle of fertile ground, its roots continue to circle within the same narrow boundary.

The small pot is comfortable. You can preserve familiar habits and judgments and avoid the discomfort of having your own way of thinking broken. But once the roots fill the pot, there is no more room to grow.

Genuine receptiveness is not simply receiving more water. It is accepting the discomfort of breaking the pot around you and allowing your roots to extend into a wider soil.

Receptiveness is not demonstrated by saying, "I understand." It is demonstrated by what actually changes afterward.

3. Why We Have Individual Meetings

The ultimate purpose of an individual meeting is not to inspect homework or attendance. I do not meet with students every week simply to check whether they took time off, how many hours they spent in the laboratory, or how many promised experiments they completed. Basic diligence is certainly necessary for a researcher. But if that were the only goal, an experimental notebook or schedule sheet would be enough.

Meetings are necessary because the direction of research can shift easily even over a short period. Research is not a task in which you make a plan at the beginning and automatically arrive at the answer by following it to the end. New data can change a hypothesis, reading the literature can raise the level of the question, and unexpected results can force the order of experiments to be redesigned. In that process, the local view seen by a student working closely with one dataset and the broader outline seen by a PI with experience across many projects may differ. The individual meeting connects these two views so that the research map can be redrawn continuously.

Therefore, what I most want to see in a meeting is not simply "what was done this week." I want to see how last week's discussion changed this week's thinking and behavior, how new results strengthened or weakened the existing hypothesis, and how the current judgment leads to next week's choices. A good meeting is not a place to report a week of activity in the past tense. It is a place to decide the next direction of the research together in the present tense.

An individual meeting is not a time to inspect the student. It is a time to recalibrate the direction of the research every week.

4. Bring Something We Can Discuss

Bringing data to an individual meeting is obviously important. But simply placing data on the screen and reading out values and trends does not complete the meeting. Results are the starting point of discussion, not the discussion itself. Before the meeting, the student should already have thought about why the result may have occurred, which explanation is most plausible, what conflicts with the existing hypothesis, and what needs to be checked next.

I do not expect a completed correct answer in the meeting. The interpretation may be wrong, and a proposed hypothesis may collapse in later experiments. What matters is whether the student looked at the result and generated questions independently. Do not stop at, "This result is different from what I expected." Separate several possible reasons for the difference and think about what evidence could distinguish among them. Only then can different lines of thought collide during the meeting and create a new direction.

Students who grow well consistently bring material that allows the discussion to continue. Even a single figure can contain several questions and choices. I listen to the student's thinking and offer alternative possibilities, and the student revises the logic again. In such meetings, brainstorming occurs rather than one-way instruction. Sometimes a question that emerges during discussion becomes more central to the research than the result originally prepared for the meeting.

By contrast, if a student shows the data, finishes explaining them, and then simply waits for my answer, the meeting quickly becomes one-directional. If the student brings no thinking, the PI has to create all the hypotheses and next experiments. A direction obtained in that way is difficult for the student to truly own, and at the next meeting the student may again wait for the answer. Research independence does not begin by making every decision alone. It begins by entering the discussion with your own interpretation.

Bring not only results to an individual meeting, but also the interpretations, questions, and points that can be discussed around those results.

5. Hiding Is a Form of Self-Isolation

Everyone has weeks when experiments do not go according to plan. There are also weeks when illness or unexpected events interfere. Such situations are understandable. The problem is not the absence of strong results itself. The problem begins when the student also cuts off contact with the research. Some students say only, "It is still in progress," and sometimes do not even show incomplete results. They may think unfinished data are not worth showing, or they may not want to expose slow progress.

But research does not become thinkable only after a polished result exists. If an experiment failed, the reasons for failure, the stage at which the problem occurred, and what should be changed next are all subjects for discussion. If the dataset is still incomplete, you can organize the relevant literature, reconsider the current experimental design, or prepare decision paths for several possible outcomes. Even when there is little new data, there is always something that can be thought about.

If a student brings out nothing, the week's meeting naturally passes without much discussion. I also lose the opportunity to think deeply about that student's project. New ideas continue to emerge while discussing other students' work, but there is no question that can follow the statement, "I am still working on it." One such week may not matter much. But if this pattern repeats, the student's research gradually moves outside the laboratory's sphere of discussion.

This is not because the PI intentionally excludes the student. The student isolates the project by failing to put it into the shared space of discussion. A person can come to the laboratory every day and still be intellectually alone if they do not share their questions and data. Hiding can feel like avoiding evaluation in the moment, but in reality it also sacrifices the attention and thinking time the research could have received.

Even in a week with limited results, do not hide from the research. The moment you stop showing and talking about it, you begin pushing your own project outside the space of discussion and growth.

6. A Research Group Is Larger Than Your Own Project

EGCL is not organized as one large team in which every student performs nearly the same project. Smaller teams are formed, membership can change by semester, and the research topics may not be directly similar. From the outside, it may appear more efficient to group only people working on the same subject. But there is a clear reason why the laboratory is not organized that way.

Researchers do not grow only from knowledge produced within their narrow field. Different fields define problems differently, use different analytical methods as routine tools, and describe the same phenomena using different languages and strategies. The concept of a control experiment used in catalysis can reshape experimental design in adsorption. A failed synthesis experience in materials research can provide a clue for solving a problem in a completely different reaction system. Even when the research subjects are not directly related, ways of framing and solving problems can move across fields.

Therefore, the purpose of listening to a presentation from someone in another topic during group meeting is not to memorize every detail of that person's research. Observe what question they started from, what evidence they use to distinguish claims, how they interpret unexpected results, and how discussion changes the direction of the project. In trying to understand another field, you may begin to question assumptions that had seemed obvious within your own.

Diversity in a research group does not simply mean that unrelated projects occupy the same room. It means that different knowledge and problem-solving approaches can move among people. If you do not create those connections yourself, diverse research topics remain only unfamiliar activities happening nearby. If you participate actively, however, you can turn experience accumulated outside your own project into an asset for your own research.

Trying to understand research in another field does not take you away from your own work. It expands the range of thinking that your own work can use.

7. Your Presentation Is Not the End of the Meeting

Some students behave as if the meeting ends the moment their own presentation is over. Afterward, they watch the clock, look at their phone, or simply wait for other discussions to finish. They feel that their responsibility is complete because they successfully presented the part they prepared. But in a group meeting, your presentation time is only one part of the learning.

You should continue making questions and participating in discussion while listening to other students' research. If the topic is far from your expertise, you may not understand every technical detail. Even so, you can still ask what the research question is, whether the presented data are sufficient to support the claim, and whether alternative explanations are possible. Asking about something you do not understand is also meaningful participation. Good questions do not have to come only from experts in the field. A person with a different background can sometimes expose an assumption that specialists have accepted without noticing.

The habit of participating in discussion is not merely a service to help other people. While thinking together about someone else's problem, you train your own problem-solving ability. A student who notices that another study lacks an adequate control may begin to see the same weakness more quickly in their own experiments. A student who understands a new analytical method from another field may discover a measurement possibility that was previously invisible in their own research.

Watching the clock after your presentation is over is like staring only at the ground under your feet. You may be able to manage the task directly in front of you, but your scientific horizon does not expand. A researcher should grow beyond someone who simply manages a small assigned area diligently and become someone who can connect surrounding scientific problems to their own thinking.

A group meeting does not end when your presentation ends. It ends only after you have also used other people's problems to expand your own thinking.

8. A List of Experiments Is Not a Research Story

When students interpret meetings as homework checks, they often try to prove that they were not idle. They show every sample synthesized, every characterization measurement collected, and every reaction experiment performed during the week. They assume that the larger the number of results, the more their effort will be recognized. But performing ten or even one hundred experiments does not by itself mean that the research has moved forward.

If each result is disconnected from the previous one, if you cannot explain why the experiment was necessary, and if the next question remains unchanged regardless of the result, then what you have is not one research story but a list of separate activities. The value of research is created less by the number of data points than by the logical connections among them. Even many figures cannot become the backbone of a paper if they do not converge on one question.

Good meeting materials do not list every experiment in chronological order. They first present the central question the research is trying to answer, then show what was understood up to last week and how this week's evidence changed that map. Unimportant data should be moved to the back or omitted entirely when necessary. Knowing what not to show is also evidence that you understand the research.

Core question -> Existing understanding -> New evidence -> Revised interpretation -> Next decision

9. Brownian Motion Is Not Research Progress

Research that continues generating experiments without direction resembles Brownian motion. A particle is constantly moving, and its short-term displacement may not be small, but because there is no consistent direction, it can remain close to its starting point even after a long time. A student can also stay extremely busy and continuously produce experimental results. But if each week's decisions are disconnected from previous judgments, the central research question may remain almost unchanged even after a year.

Students who struggle in research are not always people who perform too few experiments. In many cases, they are extremely busy experimentally but cannot see the overall structure. Every time a new result appears, they move in a new direction, and the next week their attention shifts to another phenomenon. Each individual observation may look interesting, but none is developed deeply enough to converge into a conclusion.

Research is closer to finding a way out of a maze. What matters is not how many paths you walked during the week, but whether you updated the map after identifying a dead end, understood your current position, and moved in a direction that brings you closer to the exit. A failed experiment is meaningful if it erases part of the map or marks a dead end. A positive result can still fail to advance the research if it cannot be placed on the overall map.

Activity shows movement. Research progress is movement with direction.

10. “You Are Not Working Hard” Rarely Means “Do More Experiments”

When I tell a student, “You are not working hard enough,” many students interpret the statement as meaning that they have not performed enough experiments. The next week, they make more samples, collect more analyses, and increase the number of results, assuming that greater visible activity will reverse the previous evaluation. But in EGCL, there are not many students who literally do no experiments. The problem is usually somewhere else.

What I mean by insufficient effort is often that the student did not look deeply enough at the data, did not try to build logic among the results, did not study the necessary literature in sufficient depth, avoided evidence that contradicted their interpretation, or did not think carefully about why the next experiment was necessary. These activities are less visible than staying busy at the bench, but this invisible time often determines the level of the research.

If feedback has truly been accepted, the next week should show not merely a larger number of experiments but a different structure of thought. The order of figures may change, a result that once

seemed important may move to the background, and the control experiment needed to support a hypothesis may become clear. Sometimes research can advance far more during a week with almost no new experiments if the literature is studied again and existing data are reinterpreted.

The correct response to feedback is not always more experiments. Often, the first thing that needs to change is the depth and structure of thinking.

11. How to Prepare for an Individual Meeting

Preparing for a meeting does not begin with making the slides look attractive. First, organize how your research map has changed since the previous meeting. Before preparing the presentation, you should be able to answer the following questions for yourself.

1. What was the most important feedback from the previous meeting?
2. What did I actually change because of that feedback?
3. What is the core result from this week, and how does it connect to the previous results?
4. Does this result support the current hypothesis, require it to be revised, or force it to be abandoned?
5. What is the largest uncertainty at this moment?
6. What experiment or study is needed next week in order to make the next decision?

At the beginning of the meeting, briefly restate the big question and the current position of the research. If you assume that the PI already knows the project and immediately begin with detailed data, you may also lose sight of the overall context yourself. This does not mean repeating the same long Introduction every week. The central hypothesis, the conclusion up to the previous week, and the question being addressed this week should be connected clearly within one or two slides.

For each figure, show not only “what was done,” but also “why it was done” and “what changed because of the result.” Data quality, reproducibility, and the appropriateness of controls must be checked, but those alone are not enough. After explaining a figure, always state what the result means within the current research map. If the interpretation is uncertain, distinguish among several possibilities and identify what evidence would be needed to discriminate among them.

At the end, do not simply list next week's experiments. Present their priority and decision structure. For example: “We will first test A. If the result is X, we will proceed to B; if it is Y, we will examine C.” The next action should be derived from the current logic. A good plan is not one with many tasks. It is one in which it is clear what you will be able to decide when the next week is over.

12. The Meeting Is Complete Only When Behavior Changes

Receiving good questions and having a long discussion during a meeting does not mean the feedback process is complete. Immediately after the meeting, reorganize the discussion in your own language. Distinguish what was merely a suggestion from what was a core problem that must be corrected, and decide which parts of the existing plan should be maintained and which should be abandoned. If any part remains unclear, do not simply move on; clarify it.

The first thing that should be visible at the next meeting is not new data, but evidence that the previous feedback was incorporated. If the structure of the presentation was the problem, the structure should be different. If literature understanding was insufficient, the result of studying the relevant papers should be visible. If the logic was weak, the relationship between hypothesis and evidence should be reorganized before more experiments are added. If the same criticism repeats every week, then regardless of how well the student answered during the meeting, the feedback loop is not functioning.

Trust between PI and student is also built through this repetition. When the PI becomes confident that the student understands feedback accurately and can correct the research independently, the student can be given greater autonomy and more difficult research problems. If the same problems repeat every week, the PI has little choice but to check increasingly detailed steps, and the student may begin to feel controlled. Autonomy is not a right granted automatically at the beginning. It is the result of trust accumulated through the ability to self-correct.

Feedback -> Interpretation -> Correction of behavior -> New evidence -> Better judgment

13. The Goal Is Independence, Not Permanent Dependence

Correcting direction together in individual meetings does not mean that students should wait for the PI's answer every time. Early in training, the difference in experience means the PI may provide more questions and directions. But as the same categories of feedback accumulate, the student must make those judgment standards their own. A problem that the PI identified previously should be something the student notices first the next time. A question for which the student once needed an answer should later become a question the student raises independently.

Good feedback does not simply provide the correct answer for one experiment. It transfers a standard that can be used to judge similar problems in the future. For example, if you are told that your control experiment is insufficient, you should not stop after adding one control for that particular week. In all later studies, you should begin by asking what comparisons are needed to distinguish your claim from alternative explanations. Feedback should remain not as an isolated event, but as a generalized standard of judgment.

As the student grows, the character of the meeting should also change. At first, the PI and student may decide together what should be done. Later, the student should bring several options and explain the advantages, disadvantages, and priorities of each. With further growth, the student should propose the major research question and strategy first, while the PI takes the role of criticizing and expanding them. This is the direction that individual meetings should ultimately move toward.

A good meeting does not make the student more dependent on the PI. It enables the student to travel farther independently before the next meeting.

Closing Note

An individual meeting is not a time to evaluate how hard a student lived during the previous week. It is a time to determine whether the research is accumulating without losing direction, whether new results are connected to existing questions, and whether the student's judgment has grown since the previous week. To make that possible, the student needs to bring not only results but also interpretations and questions, and should prepare material that allows discussion to continue.

Students clearly enter the laboratory with different abilities. But the difference after several years is determined more by the slope of growth than by the starting point. That slope comes not from politely listening to feedback, but from being willing to break the familiar pot around yourself and change your behavior. If the same criticism repeats while only the number of experiments increases, there may be more motion, but the direction has not changed.

A good researcher is not the person who brings the largest number of results. It is the person who sees the overall map, judges the position of each result, turns away quickly from dead ends, and incorporates each week's learning into the next decision. A good researcher also does not remain confined to their own project, but participates in the problems of others. When the questions, failures, analytical methods, and

solution strategies circulating in the laboratory are absorbed, one person's experience becomes connected to the experience of the entire research group.

The success of an individual meeting is not decided in the meeting itself. Its value is demonstrated by what is different the following week.