

## Moving Ahead in Your Research

*E. E. Eischen*

Doing research can be exhilarating, but finding problems and figuring out what to do when you get stuck can feel daunting. To develop a research program and overcome associated challenges, it is important to identify approaches to research that work for you. Here are some of my favorites.

1. **Journal.** Keeping a math journal has been my most helpful professional habit, from shortly before I began working on my dissertation through being awarded tenure.<sup>1</sup> You can use a journal to log goals and your progress toward them, record details of important mathematical conversations, track hours spent on different research tasks, or determine how new approaches—such as those suggested below—impact your research.
2. **Keep a problem list.** During the past twelve years, I have generated a list of over 150 potential research problems. Even if ninety percent are flawed, that leaves fifteen good ones. Keeping such a list can insulate you from the anxiety of having nothing to work on. It also provides a low-stakes exercise in finding problems. The skills we developed as students can be useful for finding new problems. For example, we were all trained to ask what happens when we change hypotheses in a theorem, investigate how much further a new technique allows us to extend a result, and make conjectures based on examples we have computed. If

you do not self-edit, you will likely find new problems along the way. Keep several of your problems in mind, and continually refine them, also tying them to more central problems and techniques. You might need to reformulate a problem several times to make it feasible and interesting. As ideas strike, jot details on your list. For help identifying ones worth pursuing, discuss them with more experienced members of the field. Like anything, finding problems gets easier with practice.

3. **Embrace “mistakes” and “failure.”** Many items on my problem list landed there as a byproduct of my attempt to overcome an obstacle in my research. In his seminal talk “You and Your Research,” Richard Hamming observed, “[O]ften the great scientists, by turning the problem around a bit, changed a defect to an asset. For example, many scientists when they found they couldn’t do a problem finally began to study why not. They then turned it around the other way and said, ‘But of course, this is what it is’ and got an important result.” If your goal is simply to explore what is true and why, unexpected outcomes become guideposts rather than stop signs.
4. **Continually learn and relearn.** To develop mathematical intuition, it helps to learn not just the newest results but also the history of a field. I have found papers from several decades ago particularly helpful for developing intuition in my field, which has, in turn, helped me learn newer material. Often, you can find important older papers by tracing references in newer papers back repeatedly. Terry Tao’s article “Learn and re-learn your field” (part of the wealth of helpful career advice on his blog) offers specific advice for engaging with material while learning it, while Ravi Vakil’s “Three Things” exercise (among other useful advice on his webpage) can help you engage with research talks.

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<sup>1</sup>*Thanks to Julianna Tymoczko for encouraging me to start journaling about my research twelve years ago (on August 2, 2006, my journal shows).*

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DOI: <http://dx.doi.org/10.1090/noti1791>

5. **Commit specific times to research.** As with any skill, you get better at research through practice. In “How to get a PhD in Mathematics in a Timely Fashion,” Sara Billey recommends twenty highly focused hours per week for research. Balancing this with other responsibilities that also require peak focus can be challenging, so find a target that is achievable for you. You can maximize your chances of finding time for research by scheduling it on your calendar and adhering to the schedule.
6. **Protect the time required for tasks needing different kinds of energy.** To determine how much time you need for different aspects of research, track your time. To the extent possible, schedule research tasks for times you can focus sufficiently. (You can look up references in the fifteen minutes before class, but carefully patching a hole in a proof is likely to require a bigger chunk of uninterrupted focus.) If you are frequently interrupted, consider joining a weekly writing circle to help protect some of your time.
7. **Communicate in different ways to see both the forest and the trees.** Communicating about your research in a variety of ways with different audiences can help deepen your own understanding. Writing a paper often forces you to see the trees, while a good talk typically emphasizes the forest. Either, done carefully, is likely to lead you to new insights and questions.
8. **Work supportively with others, as well as alone.** Working alone can help you develop individual strengths valuable not only in independent research but also for collaborations. Collaborating gives you the opportunity to learn from others and pool different areas of expertise for more powerful results. Different members may support a collaboration in different ways, for example via technical knowledge, novel ideas, or clear writing. While most collaborations begin informally, by one researcher mentioning a problem to another (for example, from your problem list), there are also structured programs to promote collaborations, such as Math Research Communities, Research Collaboration Conferences for Women, and the NSF/NIH Innovation Lab.
9. **Bite off one piece at a time.** If developing a new skill or project feels overwhelming, break it into manageable pieces. For example, an individual who finds it difficult to ask experts in their field questions could make a list of all the experts with whom they might want to communicate and then ask one of them a question each week.
10. **Eat, sleep, exercise, breathe.** Theorem-proving devices don’t actually run solely on coffee, at least not indefinitely. It is important to take care of yourself. Otherwise, all the tips here soon become irrelevant.



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