I. Philosophy for an Effective Research Team

X. Preamble

As a Professor running our research enterprise, there are three major drivers that influence how I try to manage our group:

- 1. Desire to educate scientists who will be highly competent once they leave, which means learning how to tackle difficult unstructured problems effectively, efficiently, and creatively.
- 2. The practical need to use resources effectively to do excellent science important for our society and that will be judged externally as high impact so our team can continue our research with sufficient funding to make real progress.
- 3. The desire to help lab members be healthy and happy while part of our team, and also have successful careers in the long term.

-Shannon Boettcher

Below is an outline of a philosophy that was developed by the entire Boettcher group in 2020, as well as with input from a large number of alumni, to help us to balance these three, sometimes conflicting, drivers and other priorities of the students. Every group member since 2020 has contributed to this document.

A. Fostering individual and inter-personal balance (set healthy expectations)

- 1. Schedule and prioritize self-care and work-life balance. Grad school is hard. Burnouts are real and the wider culture of self-care and work-life balance is lacking. You are no good to anyone else if you aren't good to yourself first. One can often be more productive with a well-scheduled 8-9 h work day than a 12 h work day, if you cultivate good time-management practices. Don't compare yourself to others. Everyone has different life demands and work different hours. Have a hobby, put it in your calendar, and stick to it. Sometimes you will have to put in long hours, work over the weekend, or schedule instrument time in the evenings, but don't make these everyday events. Don't feel guilty for taking a vacation and disconnecting. Respect and support grad students who are caregivers and parents of young children. Take advantage of counseling services available on campus. Talk with your peers about self-care, mental health, and time management strategies.
- 2. Strive for honest communication. Be honest with your advisor and make it clear what you and/or your team want and why. Do not avoid your PI. Try to understand other perspectives and realities. Completing a PhD program is demanding and formative. Being a PI is also extremely demanding. PIs are under constant pressure to procure funding, publish extensively, and manage university politics, with no-one to take over their duties when needed. This reality, however, is not an excuse to not hold a PI to a high standard for mentorship, nor is it an excuse for PIs not to recognize the real challenges students face in their studies.
- **3. Practice empathy and actively address issues before they become serious.** Fellow students are often the best suited and most aware of the issues their peers face. Create a culture where those who are proactive in caring and supporting those who are

struggling are celebrated, thanked, etc. Almost everyone has large "ups and downs" in graduate school. Sometimes the downs can be really low and everyone needs a strong peer group to get through this. If you see someone struggling check in with them and offer to help! Be intentional to check in on all group members, especially if some are working in lab spaces with less day-to-day interactions with others.

- 4. Learn how to say "no", even to your PI. You do not have to do everything all the time. Avoid burnout by practicing saying "no" and coming up with creative solutions that reduce busy work. Think about whether a request is better suited to someone else's expertise, career goals, schedule etc. Your PI's first choice for a job may not be the best choice necessarily. Show genuine gratitude when others help you. Learn to set healthy expectations both of yourself and with others.
- 5. Create a culture of inclusivity, empowerment, and change. Group leadership means making the changes that need to be made to improve the team function. Every student must feel supported in driving positive change in the group culture/dynamic as well as practical aspects. Regularly bring your suggestions to improve the group function to group meeting. View change as an experiment. Be willing to experiment in the social and organization dynamic in your group to find the best structure, which will evolve with the personnel and their needs. Don't be complacent. Recognize that every person has 20+ years of personal history that they bring to the table. They may also have a completely different cultural background than you and their previous and current experiences may be dramatically different from yours. Actively provide a seat at the table for and promote members of underrepresented groups. Practice active listening and empathy.
- 6. **Try to participate in activities organized by the lab** (outings, hikes, zoom happy hours). Such activities help you to get to know your colleagues better and form strong bonds. Also try to attend presentations and practice talks given by your colleagues to support them and give your feedback. It's important to show interest and caring towards your lab mates. Encourage others to do the same.

B. Research Culture

- 1. Collaborate. "Credit is not a conserved quantity" Steve Chu (Nobel Prize Winner in Physics). Shannon prefers including liberally as co-authors all who contributed time, expertise, intellectual input, and/or collected data on manuscripts. This incentivizes a culture of collaboration and generates self-reinforcing positive energy. For example, include newer students in projects near publication and in the paper writing process. As new students develop in their 2nd and 3rd year and start to publish their own work, include former mentors who contributed perhaps only intellectually as co-authors. However, there are many philosophies regarding authorship. Critically, communicate with your collaborators at the outset and throughout the research process regarding their contributed to every aspect of your project and decide for each paper in consult with your PI the authorship and credit assignment.
- 2. **Avoid territorialism.** There are, literally, an infinite number of interesting and important research questions. If you feel there is effort duplication that is unproductive in the group, bring up the issue in sub-group or to your PI so that the responsibilities can be clearly delineated and new areas developed as needed. You can't and shouldn't plan your entire PhD. Welcome new additions to your group. They are new resources to help you solve problems. Integrate them into your team and work to publish with them collaboratively as fast as possible while doing good science. If the team's goal is to drive

the science forward as effectively as possible, then everyone wins in the end. If someone else has a good idea that you want to try, just ask them first and offer to collaborate. Simultaneously, respect the boundaries between projects and specific requests from your coworkers about working on individual ideas. Be deliberate and specific in conversations about project boundaries.

- 3. Work to have the group interests in mind. Consider offering to do routine things for others if you are already doing it for yourself. For example, making electrode substrates is a time-consuming activity, but you can make a lot in one shot. Ask your lab mates if they need those electrodes as well, make extra, and leave them in the shared drawer. Or if you make aqua regia solution to clean your Pt electrode, offer to clean other Pt electrodes that your lab mates use. Share papers relevant to others. It will minimize waste and save everyone's time. Everybody will appreciate you contributing to shared lab efforts.
- 4. Embrace challenge. Learn how to distinguish between being reasonably conservative with your time and energy, and being complacent or "lazy". Research will be hard, but lean into it. Doing hard things will make you a better scientist. Remember, from afar, things look more difficult than they often are. Just think how many techniques and skills you already mastered. This next one you need to acquire will likely be no different. Do not pay too much attention to people that try to convince you that things will not work, especially if they don't specifically explain why that would be the case. Make a careful plan, get advice from open-minded experts and move ahead.
- 5. Curate knowledge. Create documents and, especially, videos of all the common laboratory actions. How to make an electrode, set up a PEC cell (with the items you actually have in lab), make an XPS measurement, print a poster, register for classes, etc. Curate all COMSOL programs, excel spreadsheets, Mathematica files. Organize data repositories, instrument guides, instruments setups, tutorials, data processing scripts, etc. Recognize and appreciate those who spend time doing this and offer to include them in your research.
- 6. Make it enjoyable and meaningful. Despite being hard, graduate school has the potential to be a very positive experience. You have huge amounts of freedom and relatively little responsibility relative to later stages in your life (e.g. procuring project funding, managing employees, etc.). You have a wonderful peer group that largely shares and empathizes with your challenges. You have the freedom to (and should) choose activities that best prepare you for your career aspirations. Drive change in your local environment to make it as enjoyable as possible. If you don't see a path forward to make it rewarding, consider doing something else. You are not a failure or not worth less because you don't have a PhD. In fact, in all stages in life you need to be willing to change course and try something new if a given course is not making you happy.
- 7. Foster a supportive and inclusive community for ethnic, cultural, and gender minority groups. Diversity brings different backgrounds, perspectives, and experiences to the table that can lead to more innovative and creative solutions. Embrace diversity in lab and at UO, and take intentional steps to create an environment that welcomes all groups of people. Refrain from using derogatory terms or statements that are harmful or disrespectful to others, avoid stereotyping or generalizations, educate yourself about common microaggressions or discriminatory acts in the workforce, and be aware of personal implicit biases that may contribute to an exclusionary environment. Speak up if you see behavior inconsistent with the above.

- 8. Celebrate success. Each paper published is a real milestone, regardless of where it is published and what the impact factor of the journal is. Getting a job offer is a big deal. Passing each stage of your PhD process is important. Cultivate a group culture of celebration. Getting accepted to give talks at conferences, getting internships, getting honorable mention for awards, etc. there are many small "wins" in graduate school. Celebrate your and other's wins.
- 9. Fail fast. Most ideas your advisor will provide will not be well thought out. Even most well thought out ideas will "fail" as originally envisioned. But, you should make sure to learn something about why experiments didn't go as anticipated. No experiment is a true failure unless you don't learn anything! Be aware of what nature is telling you; and work with nature not against it. Doing experiments right and collecting high quality data is important (especially at the publication stage), but don't let perfection inhibit progress.
- 10. Innovate to improve efficiency. Group members should keep abreast of new technologies that could expedite processes for the group. A process that wastes a few minutes of everyone's day for years is worth spending time to redesign/improve. Group members should consider what routine processing steps can be expedited (for example with a script). Are you spending 30 minutes a day walking between two labs to access instruments X and Y? Maybe someone knows how to configure one of those instruments for remote access. Sometimes it is worth considering each individual step of a data workup and asking yourself, "is there a hot key for this operation..." If you get good at time saving shortcuts/hotkeys in a heavily used program, then present your findings as a tutorial or write a "how to" guide.
- **11. Generate quality science hypotheses to test.** Generate research plans that focus on answering a question as opposed to making a "widget" or simply increasing performance (like a more active or stable OER catalyst). If you answer a reasonable question both the "yes" and "no" answer is interesting and publishable. If you can't make a widget the result is not publishable. Widgets are good outcomes as well, but usually it is better if they are derived from a science advance and don't drive the science. (i.e. if you figure out how a catalyst works, it is usually much easier to make it better!)
- **12. Maintain high standards for your research.** Try to understand the equipment you use, how it works, and how the data is manipulated. Of course, do not fabricate or manipulate data without reporting how the data has been manipulated. Show all data to your advisor and discuss data to be discarded and the reasoning for this.
- **13. Demand high safety standards from yourself and others.** Accidents happen too often in academic laboratories and can be very dangerous. Learn from near-misses, even small ones, and discuss these as a group and curate the learning about common mistakes and issues. There is no shame in making a mistake. Trust your instinct; if you see something that looks odd, ask somebody. Be kind but firm when correcting or advising on the practices of others. When receiving such feedback, don't take it personally. Realize that mistakes are bound to occur occasionally. They usually are pointing it out to make sure things are done safely and responsibly, not to belittle you or your ability. Keep the lab clean and clean up after yourself. However, don't be paralyzed. Learn how to do stuff safely, efficiently, and with confidence.
- 14. **Read literature outside your field.** Broaden your research horizon. You will not be doing what you were doing during your PhD for the rest of your life. Start with related fields. If you work on photoelectrochemistry, read some reviews from the solar cell

community. If you work on electrocatalysis, read papers in the thermal heterogeneous catalysis field. Do not worry if you cannot understand all the specifics. Often, these are not well described in research articles in a language that is understandable for outsiders. Make sure you also cover relevant fields from an industrial perspective. With a PhD, you can be expected to understand how a field-effect-transistor works, even though you have never touched a semiconductor. A good place to start reading literature that is related (but not identical) to areas of interest of our team is the Boettcher group RSS literature feed: https://zapier.com/engine/rss/5184145/Boettcherlab/

15. **Conduct yourself professionally when representing the lab.** Speak and email with respect when communicating with industrial and academic representatives. Cultivating good first impressions can lead to interesting and productive collaborations and relationships down the road. You never know who or when your network will be critical to your professional goals. Do your research ahead of time to be prepared for meetings and discussions with collaborators. Be an example of this behavior for your mentees and new graduate students. Avoid negative or "trash" talking others in conversations with people you only have a professional relationship with. Consider the consequences of speaking too casually or "honestly" in a professional setting. It's hard to rebuild a bridge that you casually burnt.

C. Leadership & Vision

- 1. Cultivate leaders. Leaders are defined by their actions not by their titles. Self-organize into smaller sub-units. Each sub-unit needs leadership from senior students or those with more leadership drive. Each sub-unit should meet on a weekly or biweekly basis to present progress and plan new experiments, (even without the PI). Each sub-unit could consider curating a journal feed with interesting new articles that are discussed and dissected and serve to help originate ideas. Senior graduate students should see the value in mentoring younger students (see collaboration point above). Consider exploring options for leadership training outside of the research group.
- 2. Practice ideation. Try to generate new research ideas on a regular basis. Discuss these with your sub-group. Think about basic science impact (i.e. new foundational knowledge) versus meeting an applied technology goal. Both are important, but be deliberate. Practice "practical" and "big picture" ideation. Implement good ideas and/or discuss with colleagues. Practice "what if" thought experiments in your head or with others. Attend talks/seminars. Ask yourself during seminars "how does this connect to my work" "how could I leverage this to gain insight in my system" "how does this connect to my colleagues work".... etc. (always formulate a good question to ask at the end of the talk!). Don't be afraid to develop your own research projects ("dark projects") that you implement without your PI's knowledge (assuming it is not too expensive and can be done safely). Dark projects help you understand what it takes to independently ideate and execute. They are an exercise in evaluating your own creative limits and help you empathize with challenges faced by PIs. Your creative instincts are unique and will lead you to variable spaces that your PI may not have considered. Sometimes "failing" in the right direction is better than your advisor telling you not to do the experiment in the first place. However, realize that you must balance trying your own ideas with executing and developing on advice provided by your advisor.
- **3. Give tutorial talks and idea pitches.** Replace some literature talks with either tutorials (that are useful to group members) or new project pitches/proposals.

- 4. Create a culture of self-improvement. You have access to incredible physical and intellectual resources. Use them. Make it normal for students to reach out to other groups to ask how to do things, for advice on experiments, etc. Reach out to alumni for advice. Leverage staff. Come to your advisor with a list of specific questions and be assertive and proactive in getting what you need to be successful. Create a support structure in the group so that folks who are naturally better equipped to find collaborators and seek outside advice, advocate and support those who struggle more with this. Be a "connector" if you enjoy that. Remember, science is rarely done by individuals; it is done by teams. Leadership, mentorship and management of groups and individuals is critical to the success of scientific endeavors. Don't be afraid to ask questions of anybody in science!
- 5. Seek deep constructive criticism. Practice giving and receiving constructive criticism. Deliver constructive criticism from a place of kindness, and work to get your ego out of it. Receive constructive criticism with grace and sincerity, avoid a defensive stance. Constructive criticism and deep questioning often come off as aggressive and negative, but ultimately are extremely helpful in driving your project. *But*, also don't be afraid to communicate if you need a different "style" to receive that criticism. And be mindful of how your criticism is being received by others it takes time to adapt to a mindset that accepts and appreciates such feedback and sometimes you should wait to deliver suggestions until the situation is appropriate. This openness and honesty applies everywhere, including safety, research, community, inclusivity, etc.
- 6. Find a mentor who is not your research advisor. Even if you only email with this person or have the occasional phone call to pick their brain, having an outside perspective can be invaluable. Look for another PI in the department, or elsewhere, who you respect and admire; reach out to former group members who have interesting careers; talk to the postdocs in your group and other groups. *More data is always better.* Reach out to group alumni, especially if seeking advice on work after graduate school. If you arestruggling to find someone in your department who you feel would be a good mentor given your background and aspirations,, reach out to someone at another university or institution or to your advisor/peers who could help find others in the community with whom you can develop a mentee relationship Social media (Twitter, LinkedIn, etc.) can be useful to augment direct interactions.