How to Become a Successful Researcher? – Guidelines for Graduate Students and Budding Scientists

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How to become a good researcher is a question often asked by budding scientists or fresh graduate students. While I answer this question based on the method I follow and experiences that I have acquired from 15 years of my research career, (disclaimer!) some mentors may have a different way of training their pupils. It is also important to highlight that the quantification of "successful" here is not based on how many papers you can publish in a given period or the journal citation index of your papers. Here, from success, I mean how well you can solve a complex problem, which the rest of the world considers exceptionally challenging.

First, let's analyze whether you meet the prerequisites for Research (and if you don't, this section will tell you what you need to develop as the intrinsic characteristics).

Curiosity: Fundamental Research is unthinkable without you being curious enough. Imagine if Newton were not curious about things falling and had accepted it as some usual stuff, he would not have discovered gravitation. Similarly, if Einstein were not curious about light and relative motion, we wouldn't have seen the advancements that we see today. More than being curious, they were also critical of old or established doctrines. You can name any legendry scientist, from Galileo to Feynman; they all were curious as well as critical. If you are not curious enough and critical about what you already know, you may not become a good researcher. Now you may be thinking of one or more of the following questions:

1. Am I curious enough? To judge this, recall how many times you have tried to observe things more closely, have asked questions, and tried to find an answer to those questions? Here I am talking about anything and everything that you see around.

2. Am I critical enough? To judge this, recall how many times you have been critical about your observation. Observations can be seen as following "it's obvious and it's around us, and I don't care why it is like this" or "it may be around us, but I would like to know why it is like the way I see it. I am not happy with the obvious explanation". For example, Galileo was not satisfied with the Church's doctrine that our Earth is at the universe's centre. He instead preferred to observe things from scratch and re-conclude everything. Similarly, Newton was not satisfied with what Galileo concluded and felt that his findings are not complete. This is how their ability to think critically, their curiosity, and observational capability led them to great discoveries. I should mention – just for completeness – that Einstein was also not convinced with Newton's discoveries and beliefs before the 20th century that we have understood this universe well. Rest is history.

What Else You Should Have: While curiosity and critical/analytical thinking are essential prerequisites before you can indulge yourself in Research, there are a few other traits that are important to become a successful scientist. These are:

Urgency in Research (without losing patience): Before I elaborate on urgency in Research, I should highlight that you must not lose your patience. This could be while conducting an experiment, while working on a problem, and of course, throughout your Research. In other words, never give up on

what you are working on. You must keep trying. If your idea is reasonable, it will work. Possibly you may need to change your approach or thought process. Now regarding urgency, Maxwell did not sleep well until he proved that electricity, magnetism, and light are manifestations of the same phenomenon. Similarly, Faraday had sleepless nights till he established the basis for the concept of the electromagnetic field. Feynman did not sleep for several nights when he was at the verge of discovering the explanation for beta decay, which lead to the development of the Nobel Prize-winning theory of quantum electrodynamics.

Discipline: Ph.D. or research training requires discipline and consistency in work. This does not need to be elaborated more.

24×7 Engagement and Sense of Detachment: The profession of Research requires 24 hours of involvement. Whether it's performing experiments, discussing results, reading papers, or thinking about new ideas, a researcher is always involved in at least one of these four processes. However, not all days are the same for a researcher. This is the exciting thing about being a researcher, but also the depressive part sometimes. Sometimes we fail, but it gives us a great feeling when we are successful in our findings. The bottom line is that you explore new things every day. To survive this marathon, you also need to detach yourself from success and failures and focus on enjoying the journey.

Learn to Become an Independent Researcher First: Research means exploring new ideas and pursuing new knowledge while addressing fundamental/big open questions. Often, a Ph.D. is the first step in the process of becoming a successful researcher. Before successful, you need to become an independent researcher. Ph.D. is, therefore, in all sense a training program, not a degree program, which helps you to evolve as an independent researcher. I believe in following three stages of Ph.D. training:

Stage 1: When you work under your PhD supervisor, your advisor defines ideas and problems. This is the stage when you learn how to address a problem from your advisor.

Stage 2: When you work with your advisor, you and your advisor evolve jointly with ideas and problem definitions. This is the stage when you and your advisor learn from each other.

Stage 3: When you are independently able to define/identify a problem statement, drive the work and lead to a conclusion with your advisor's very little help. In other words, this is the final stage when you are working on a problem identified by you (means you have become curious and critical enough) and can solve the problem on your own with least guidance (means you can work systematically and independently). This is also the stage when your advisor learns from you (means you created new knowledge).

Once you pass stage 3, you can be called a Ph.D. or an independent researcher. With this definition, it should be clear that the time required for completing a Ph.D. (a question often asked) depends on how fast (slow) you learn to become an independent researcher. This depends on your learning/exploration ability, everyday progress, commitment, and time investment. You must also not listen to those who say PhD is a frustrating job and requires enough patience and enormous time. You certainly need patience, but when (i) you are in the lab and performing experiments, (ii) you are analysing results, and (iii) you are documenting your work, writing reports and scientific articles, etc. Otherwise, Research is fun, and you get into it only if you see the fun in it.

How to Deal with a Complex (Research) Problem: Now that you know what is involved in becoming a researcher, what the prerequisites are, and what life commitment you have to make, it's

time for me to tell you how to handle a complex problem. After all, as a researcher, this is what you do. And if you do it well repeatedly, it makes you a successful scientist. To solve a complex problem, you need to find the root cause responsible for the problem. Once you have understood the problem well, solving it becomes easier. The following step-by-step approach may come in handy.

1. First, you must break the problem. Break it to as many as possible smaller threads, which may be the (root) cause of the problem. Try to give your problem enough thought. Try to argue and counter-argue every possibility. Shortlist possibilities that cannot be counter-argued based on available observations or earlier findings.
2. Also, critically review earlier findings. Sometimes you may also find a flaw in an earlier finding, which led to misleading conclusions in many other subsequent works. Do not feel shy of critically analyzing earlier works if earlier conclusions can be factually counter argued.
3. Now, keeping in mind the thoughts you populated from exercises listed above (in points 1 & 2), come up with a few hypotheses – one of these could be the possible cause for the problem.
4. Define a set of experiments to prove (or disprove) the hypothesis you have built. From defining experiments, what I mean is design experiments through which you should be able to prove your hypothesis. If the results are the opposite, you must trash that hypothesis and move to the next one. However, do not trash the results and keep them for analysis at a later stage. Sometimes the results would be opposite because you started with a hypothesis that was just the opposite of what it should have been.
5. Sometimes, you will not be able to develop conclusive arguments even if your experimental results are aligned to the hypothesis you started with. You must not stop here and move to the next hypothesis or next set of experiments.
6. Once you are done with all set of experiments to prove and disprove all ideas you started with, now put all the findings in front of you and analyse together. You must keep all your results together and jot down every possible observation you can make.
7. Now start arguing and counter-arguing your observations. Do not conclude at this stage. Try to narrow down your split (set of hypotheses you started with) until you cannot counter-argue the ideas/hypothesis you started with. After narrowing down the original set, you may still have several open questions. Or, you may have come up with a new set of questions based on your new set of observations. In this case, you will have to repeat steps 4 – 6.
8. This process continues till you are not able to develop conclusive evidence to validate your hypothesis.
9. Once you have developed enough evidence to prove one or more hypotheses (and disprove others), you must also try to counter-argue it to validate it further. This may require a new set of experiments.
10. Now, given that you have very well understood the problem or the root cause responsible for it, you should be able to solve it quickly. You need to be open-minded and imaginative about possible ways to mitigate the root cause.

Last but not the Least: These are the things which I usually tell fresh graduate students or budding scientists during their initial phase of research training:

1. Take the risk, and do not be afraid to fail. Do not listen to people who say, "this is not possible." Everything is possible; things appear to be impossible only till it's not done.
2. Work hardest and count only when you find it difficult to proceed, not before. Someone somewhere is always working harder than you. Remember, you cannot go on hiking or mountain climbing with your hands in your pocket.

3. Your strategy to get better should be to compete with yourself.
4. Life is about making mistakes. Accept them, learn from them, and try not to repeat. Failures are bound to come in Research (and life too). It is imperative to move on and learn the lessons from those failures. But keep moving – it is a marathon that you are running.
5. Do not work and expect results randomly; give it a detailed thought before setting up your experiments. Do your homework well.
6. Do not get disappointed/frustrated when your work is rejected/criticized by your peers or experts in your area. Constructive criticism helps you improve your work. You can reasonably assume that in the beginning the world will criticize your work. That is always there. However, you should take this positively. Initially, criticism keeps you on your toe, which will push you to give your best. You must not get de-motivated and lose hope. Remember, significant findings/discoveries take time.
7. Accept who you are, know your strengths and weaknesses, and work (i) to exploit your potential and (ii) fix your weaknesses.
8. Do not keep a hard requirement that the answer has to be correct. Keep your brain malleable. Be interested in knowing the answer. That is what makes the difference.
9. Things get interesting when you fail. Hold on; the solution is nearby.
10. Maintain your inner peace. Nothing is more important than your mental health.
11. Be patient with your work, do not rush things. It takes time and a lot of focus to get the required results.
12. Learn to work with what is available and exploit the available resources to the maximum. The novelty comes when you use a tool in a way no one has ever used it.
13. Try to give it back by helping others. Acknowledge and thank people for all that you have achieved and target to bring at least two people to a level better than you.
14. **Stay (mentally and physically) fit, refreshed, and motivated.** (My group plays cricket)
15. **Find excitement in everything you learn. Remember that you are in it because you enjoy doing it.**

This is my research/cricket team (Pic taken in 2017).