Spinning plates and juggling balls

Project managing your PhD

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A project is a “temporary endeavour undertaken to create a unique product, service or result” [1]. Although this is a generic definition, it pretty much describes any PhD research project. There are many ways to manage a project effectively and efficiently. Unfortunately, most of us are so busy with our science that we forget about the importance of planning and management to our own success, sanity and health. Instead, we approach our first three years of genuine scientific endeavour wide-eyed and unprepared to juggle the hundreds of tiny balls that make up a PhD. Several techniques from the realm of ‘project management’ might therefore be helpful for PhD students who need to plan and manage the many competing demands that doctoral research can place on them.

A PhD comprises both the research itself and the acquisition of skills and knowledge that will facilitate your future career. As such, it is of paramount importance to establish your own objectives early on. For example, alongside dividing your project into work packages—smaller projects that might be discrete or might build on each other—it is also essential to define which so-called transferable skills—additional knowledge and experience that might improve your job prospects—you feel will be of greatest use to you, depending on what you want to do after your PhD. The importance of these skills is becoming more widely recognized and taken far more seriously, and you should find that your supervisor is willing to give you the time to pursue them—your institute or university usually requires that he or she does so. More importantly, you should give yourself the time to invest in these skills, as they are going to be vital to everything you do once your PhD project is over.

Doctoral research requires a multitude of skills, most of which you will inevitably lack when you commence your PhD programme. The first step is to identify the gaps in your knowledge to plan what skills on which to focus. This will allow you to acquire them in good time, either through professional activities—shadowing a post-doc, teaching undergraduates, joining journal clubs and blogging—or through both internal and external courses and workshops to improve communication, presentation, writing, networking and other skills. In addition to your planned skills acquisitions, you will also have situations arise, in which you need to acquire new skills quickly. The more you plan training activities and skills acquisition in advance, however, the smoother this aspect will be of your PhD. By way of example, part of my own PhD project relates to statistical analysis of data. An early analysis highlighted several areas in which I had to improve my skills, including hierarchical cluster analysis, principal component analysis and χ^2 testing against standard distributions. Having identified these gaps in knowledge early on in my doctoral programme, I could plan ahead accordingly when and how to acquire these skills.

The full scope of your PhD project is usually unknown at the outset, and even the direction of your research might well change before you are finished. ‘Rolling wave planning’ is a technique that allows you to take these facts into account and plan the short-term future in detail, with a high-level provision for medium- to long-term activities. For those new to developing project schedules, I advocate a simple five-step approach. First, make an

ordered list of high-level activities needed to achieve your goal. Second, expand this list by adding lower-level activities for which you have a detailed understanding of the scope, for example work to be performed in the next six months. You now have a work breakdown structure. Third, turn this work breakdown structure into a dependency-driven list by adding associations between the activities, for example by adding links to precursor activities that need to be completed before another activity can be started. Fourth, estimate the duration of each activity and extrapolate the start and end dates beginning with the first scheduled activity. Finally, as you progress through your research, and the scope of future activities becomes clearer, update the project schedule with these low-level activities as they become known. This approach of generating a hybrid-level project schedule, and updating with detailed activities as the scope becomes clearer, is known as ‘rolling wave planning’.

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There is a range of professional software to help develop project schedules, but there are also various freeware tools available. Alternatively, you can use one of the many word processing or spreadsheet applications to make a simple Gantt chart. Along with the technical scope of your doctoral research, it would also be useful to include milestones that your institution

Fig 1 | The project management triangle as applied to a PhD. Three competing constraints influence project management: time, scope and cost. The time constraint reinforces that projects are temporary endeavours, and that in most cases have defined timescales (absolute deadlines). The cost constraint refers to the budgeted amount allocated to the project that, from the perspective of doctoral research students, will predominantly be focused on the amount and duration of the stipend awarded, but might also incorporate various expenses such as bench fees, conference fees and consumables. For those changing career, the cost might also comprise an element of salary sacrifice. The scope constraint refers to what must be done, produced or developed to meet the objective of the project, which in the case of a PhD generally comprises the actual doctoral research to be performed, development (and submission) of the thesis, publication of one or more journal articles, presentation at conferences and potentially teaching. The triple constraint principle highlights that any change to one of the constraints will have an impact on one or both of the other constraints. For example, increased scope typically leads to increased time and cost; tight time constraints usually mean that an overrun in activities (such as experimentation) might have a knock-on effect of requiring the scope to be reduced to submit your thesis on time, or increasing the overall amount of time required to complete your PhD. Similarly, a tight budget could mean you cannot gain access to various resources, resulting in either increased time or a reduction in scope. Recently, a fourth component of the project management triangle has been introduced highlighting that along with the three constraints competing with each other, they also interact to form a fourth dimension of quality.

enforces; for example literature review submission, formal progress reports and thesis chapter outlines. Including these in your rolling wave planning will allow you to keep in mind the bigger picture and the formal aspects that must be completed for your PhD, in parallel with the progress you are making towards your specific research subject.

It is of course a cliché, but it is true that ‘failing to plan is planning to fail’. Of course the fluid nature of research makes

it difficult to estimate accurately the time that it will take to complete various experiments, especially as a novice researcher. I therefore believe that although experiments do overrun and PhD projects can change, developing a project schedule is not a futile activity. By having a plan, even if it is made up of ‘guesstimates’, you can forecast roughly how much time you have left for your research and roughly what you can realistically hope to achieve. After all, without a plan, how can you predict when

you will complete your research, submit your thesis and ultimately gain your PhD?

The serious consideration of scope is necessary in any project, but even more when you are simultaneously project manager, research scientist and key stakeholder. This raises various crucial questions regarding scope management: what is my doctoral research all about (the goal), and what work do I need to do to meet this goal? Once this has been agreed between you and your supervisor(s), it is essential to manage the scope of your project—the breadth and number of experiments you will perform—and how this will achieve your goal(s). Furthermore, be specific—knowing exactly what you want to achieve will keep you motivated until you get there.

Project managers often use the concept of the triple constraint to manage work: scope, time and cost are intricately linked in a project and the different level of focus that each is given affects the perceived quality (by others) of project deliverables (Fig 1). Project managers understand that any deviation in one of the triple constraints changes one or both of the others. This is where the project schedule really comes into its own by allowing you to forecast when you will complete the agreed goals of your PhD project. For example, is your doctoral programme for a fixed-term period? If so, then once a project schedule has been agreed that uses all of the time available, any project overruns will cause an overrun to the overall PhD. The two main possibilities for a PhD student to manage this situation and bring the projected completion back into acceptable timescales are either to work longer or to reduce the scope or goals of the project, either by conducting fewer experiments to answer the same question or by modifying the depth of the question being asked. This leads to the issue of whether there is a minimum set of goals that need to be achieved, or whether several agreed activities are ‘nice to haves’, but are not crucial for the overall PhD. I believe that your supervisor(s)

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are best suited to answer questions about the minimum goals and the scope needed to achieve them.

If you need to complete your doctoral programme within a specified time frame, then you need to manage your goals and scope mercilessly—do not allow additional research questions or extra experiments to take away precious time. This does not mean that you cannot deviate, but any deviations need to be managed. Remember, whether you wish to remain in scientific research or not, the PhD is a stepping-stone to your future career and not the end goal in itself. Once you have achieved the goals agreed with your supervisor, it is more

beneficial for you to write-up your doctoral thesis and move on [2].

Good communication is essential in every area of work, but even more so for a PhD as you are simultaneously learning how to research along with doing the research. Often, access to your supervisor is limited by constraints on his/her or your time, which means that clear communication is vital. Do not assume that your supervisor knows every intricate detail of what you are doing; he or she might have a large group in which each member is looking at complementary aspects of a more general topic. It is, therefore, your responsibility to ensure that

all your stakeholders—supervisors, postdoc leads and any others involved—know what you are doing and, more importantly, why you are doing it.

This is another area in which the apt use of technology can maximize efficiency. Subject to institutional licensing, collaboration tools such as SkillsForge or Evernote can improve communication between stakeholders. For example, meeting minutes, action points to be followed and research results can be uploaded for sharing. Supervisors can then review the material at a convenient time to ensure that they stay up to date with the progress of each student within their research group.

As PhD students usually aspire to become research scientists, it is of paramount importance that you learn the correct application of the scientific method and the context in which your work is being done. Before jumping into practical work—wet-lab experiments or computational modelling—it is important to understand the meaning and relevance of your project in relation to existing knowledge and the underlying science. For example, the hypothesis-driven research life cycle in systems biology [3,4]—my own field—advises that computational models should be developed on the basis of wet-lab data relating to the underlying biological system. Almeida-Souza and Baets state that a PhD in science is an opportunity to learn how to tackle problems scientifically and, as such, requires the development of skills in critical thinking, hypothesis formulation and experimental design [5]. I believe that the requirement for these skills is universal across the sciences, and that molecular biosciences and computational systems biology are no different.

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Therefore, before the first wet-lab experiment is performed, or the first line of code is written, it is essential that we understand why the experiment is important and what results we might expect to support our initial hypotheses. Furthermore, regarding computational systems biology, I believe that it is also essential for wet-lab and computational researchers to collaborate to ensure both have a consistent understanding of the data and the purpose of the computational model. After all, for the most part, computational models are developed for their predictive capacities and to allow hypothesis generation for subsequent wet-lab experimentation. Baxter *et al* have extensively covered this area and advocate not only designing the project up-front, but also the need for quality control [6].

You need to manage the scope and goals of your PhD mercilessly and, at the same time, be flexible enough to grasp

new opportunities. Conversations at conferences, for instance, can open up opportunities for collaboration and take your research in a direction that you had not considered previously. In my case, I was invited to turn a conference paper relating to my masters degree into a full paper for a special issue of a well-known bioinformatics journal. Although it was not related to my doctoral research, the prospect was too good to turn down. I therefore discussed the idea with my PhD supervisor, and once we were in agreement, I updated the project schedule to incorporate this new activity, trying to mitigate as much as possible the resulting slippages to my doctoral research. In essence, I had performed an impromptu risk–reward analysis and decided that the reward that would be gained from publishing this work outweighed the risk of a slight overrun of my PhD thesis. It must be noted that I was lucky in this instance, as my PhD supervisor also supervised the research project during my master's degree, so a full paper would be beneficial for both of us.

A project risk is “an uncertain event or condition, that if it occurs, has an effect on at least one project objective” [1]. The positive side to risks is that the likelihood of their future occurrence can be mitigated by planning in the present. Once a risk is realized, however, and its effects begin to be felt, it has turned into a project issue. The first step in trying to manage risks is their identification. Risk identification in this context is the process of determining which events, if they occurred, would affect your research. In the context of a molecular biosciences PhD, I believe that general risks relate to access to resources, such as people—postdocs and collaborators, for example—reagents, cell lines and shared equipment. For example, if your work uses fluorescent proteins within single cell analysis, how would you be affected if the fluorescence microscope was booked out by another research lab? Similarly, in computational systems biology, if the design process for your computational model requires access to wet-lab data, what would the effect(s) be if this was not available?

Once risks are identified, it is important to develop risk response plans. By using the above example of access to a microscope, what should your response be if you cannot gain access? The initial risk response

would be to liaise with the other research lab to understand their requirements and ascertain whether you could gain access at a mutually convenient time. Alternatively, another approach might be to work outside normal office hours, either throughout the evenings or on the weekend, subject to health and safety procedures at your institution and your own health and well-being. I believe that a degree of creativity is often required when developing effective risk response plans.

A PhD thesis is a hefty document that might run to many hundreds of pages. They are generally not written as a single large document from start to finish, but as chapters. In the molecular biosciences, a thesis consists of an initial literature review early in the doctoral programme, work-in-progress documents for materials and methods, experimental results throughout the middle section, which is followed by analysis and critical evaluation towards the end of your experimental work. Whether through software tools or through your own manual methods, such as keeping a configuration log and keeping a copy of each version of your working documents, it is essential that you maintain an up-to-date repository of all your notes. I have found through experience that it is beneficial to save not only the final versions, but also each of the working drafts of documents generated throughout your PhD. Ideas previously discounted, and thus removed from more recent versions of documents, might once again take centre stage at a later date.

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This can be aided through the development and use of a project library with a logical folder structure to facilitate easy access to documentation. Noble [7] provides an in-depth discussion of organizing your computational biology project—in particular the value of version control—but the concepts are transferable across disciplines. Furthermore, do not forget to back-up your work, and without seeming too pessimistic, back-up your back-up!

Finally, look after the most important resource: you. Exercise, diet, alcohol, caffeine and holidays all affect your well-being. Holidays and time away from the lab or office allow you to take a step back from the detail and reflect on your experiences and progress. Sometimes, time off allows you to process issues subconsciously and develop new approaches to overcome problems that you have been tackling for extended periods of time without success. Finally, holidays also help you recharge your batteries and enthusiasm to return to your project with fresh vigour. If you have sensibly and reasonably planned time off alongside your work, you will be able to enjoy it.

Although a PhD requires consistent commitment, you simply cannot—and should not—work at full capacity all of the time. Issues arise periodically throughout any project, and if you have no reserves of energy—either mental or physical—you will be unable to tackle them head on with the step change of performance that is

required. Furthermore, doctoral research is a marathon and not a sprint; we all experience the symptoms of burnout from time to time, and sometimes it is better to walk away for a short period to recharge than to carry on, become stale, and ultimately slow down.

To conclude, I wish you good luck with your doctoral research, and I hope these techniques help you to manage your PhD project through to successful completion.

CONFLICT OF INTEREST

The author declares that he has no conflict of interest.

REFERENCES

1. Project Management Institute (2008) *A Guide to the Project Management Body of Knowledge* 4th Edn. Newton Square, Pennsylvania, USA: Project Management Institute
2. Gu J, Bourne PE (2007) Ten simple rules for graduate students. *PLoS Comput Biol* **3**: e229
3. Kitano H (2002) Systems biology: a brief overview. *Science* **295**: 1662–1664
4. Kitano H (2002) Computational systems biology. *Nature* **420**: 206–210
5. Almeida-Souza L, Baets J (2012) PhD survival guide. Some brief advice for PhD students. *EMBO Rep* **13**: 189–192
6. Baxter SM, Day SW, Fetrow JS, Reisinger SJ (2006) Scientific software development is not an oxymoron. *PLoS Comput Biol* **2**: e87
7. Noble WS (2009) A quick guide to organizing computational biology projects. *PLoS Comput Biol* **5**: e1000424

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