Seven Habits of a Highly Successful Engineering PhD Student

A Learning Perspective

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Seven Habits of a Highly Successful Engineering PhD Student - A Learning Perspective

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Abstract:

This paper discusses the PhD education in a learning context with a specific focus on the science and engineering discipline. In this context, a brief theoretical reflection over the learning processes of forthcoming researchers is provided, followed by an analysis of the competencies expected from the PhD study as a training process. Having this theoretical framework as a reference, various concepts and perspectives, that are important in the development of a promising researcher, are examined and explicated in the form of seven suggested best practices. These include fundamental competencies like diligence and critical thinking, along with newer concepts like seeing the PhD education as a process instead of being a goal, and the need for collaborative learning and peer network support.

Keywords: PhD studies, Learning theory

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Introduction

The Doctorate of Philosophy (PhD) degree is the highest earned academic degree in most countries. It is a research training where the student learns what research implies and how they themselves can become an independent researcher [1]. The Framework for Qualifications of the European Higher Education Area (FQ-EHEA) divides higher education into three cycles, respectively corresponding to the bachelor's, master's and doctoral degree. At the bachelor's or master's level, the student has little autonomy over the course structure and curriculum. In comparison, the PhD study is more flexible in terms of the structure and the duration. For example, FQ-EHEA specifies the ECTS credits of the first two cycles, but not so at the doctoral level [2].

We live in a globalized world with ease of movement across borders. Globalization influences the higher education sector as well, and have created wider and borderless opportunities in higher education [3], [4]. Universities in the Western world now host a large number of PhD students from different regions of the world, with many of them having completed their bachelor's/master's education from their home country [5]. Accordingly, the students' backgrounds are not homogenous. The different cultural and educational backgrounds result in the students having different perception of the PhD studies, and expectations thereof [6].

The market driven approach of today's globalized economy has also affected the higher education sector. The gradual shift in focus towards efficiency, economies of scale and the quantitative drive to produce research is having its impact on the higher education sector [7]. PhD graduates were historically expected to lend a tenure-track academic career. This is changing with a large number of the graduates having positions in the non-academic labor market in recent times [8], [9], [10], and is an important contributing factor to the building of the knowledge economy [9]. Alongside these changes in outlook, the nature of the doctoral training phase is under considerable scrutiny [11]. There is also a growing level of criticism towards the PhD process, for example, in terms of the length, success rate, and competitiveness [9], [12].

Consequently, the doctoral education and training is undergoing a stage of reformation [13]. One of the main objectives is for the doctoral education to better meet the aims of the society and the needs of the evolving economy, as instantiated in FQ-EHEA [2] and the framework of Chinese higher education reforms [14], [15]. The recent introduction of the two-plus-two PhD program at Aalborg University, Denmark - which is a `master's leading to PhD' program with two additional years for the PhD following the master's degree – can be seen as a specific example of such reform. With the ongoing developments within the doctoral process, the expectations of, and from, the students are also evolving. As an example, the `PhD student as a classical lone scholar' model is being increasingly replaced with a collaborative learner model where the students learn by working in a project group instead of being solely responsible for their work [16].

Besides these changes to the context of PhD education, a further motivation for considering the PhD learning framework is rooted in some recent empirical studies. A survey involving 1390 PhD students revealed that 64% of them were, either `struggling to engage', or `disengaged' with their PhD study despite an overwhelming majority of them identifying themselves as an elite group of students [17]. The authors have suggested underlying epistemic weakness as a key factor behind their finding. The doctoral study is more complex and more abstract compared to formal education at lower levels; and requires effectively managing a complex array of intellectual, personal, institutional and social demands. The student`s success depends on how well the student conceptualize the nature of learning, both in general and in relation to his specific task, his engagement with the learning context, and his effective management of the accompanying proactive and reactive decision-making processes [18].

This paper presents the PhD study within a learning framework. The main objective is to provide students with the bigger picture of what PhD study within the science and engineering field means and forward some suggestions on how

they can traverse through the complex and difficult PhD landscape. The contribution is divided into two main parts. The first – and seemingly more theoretical – part is based on an analysis of the PhD study with a learning perspective and investigates the requirements and expectations of an ideal PhD graduate. The expected level of competence a student should develop upon graduating with a PhD is analyzed from a learning perspective in this part. In addition, we also consider the `examination goal', i.e., what are the formal requirements for graduation? The second part is aimed at bridging the theoretical aspect with practice. With the first part as a background in the theoretical framework, the latter part provides effective best-practice tips that can help in achieving the identified requirements. This is inspired by the authors' personal reflections and experiences. Though the analysis and the corresponding guidelines are shaped by a background within a specific field of study, we believe it will be equally valid for other disciplines within the broad field of science and technology studies.

What is Learning and Teaching?

Some years ago, Säljö [19] carried out a simple, but very useful piece of research. He asked a number of adult students what they understood by learning. Their responses fell into five main categories:

- *Learning as a quantitative increase in knowledge. Learning is acquiring information or `knowing a lot'.*
- *Learning as memorizing. Learning is storing information that can be reproduced.*
- *Learning as acquiring facts, skills, and methods that can be retained and used as necessary.*
- *Learning as making sense or abstracting meaning. Learning involves relating parts of the subject matter to each other and to the real world.*
- *Learning as interpreting and understanding reality in a different way. Learning involves comprehending the world by reinterpreting knowledge.* (quoted in [20] and [21]).

These categories reflect a progressively complex theoretical view of learning, without indicating any particular association between the five categories. Concepts 1 to 3 present learning as something starting from a point external to the learner, something that are 'fed' to, or acquired by, the learner. In contrast, the last two concepts point to learning as an internalization of a concept, i.e., something done to understand a particular aspect (or aspects) of the real world.

Ideally, teaching is an integral part of learning. In the formal setting of institutional learning, as in universities, the teacher mostly leads the students through their learning, thus helping students to implement the "something done" in the aim of achieving the concepts 4 and 5 listed earlier. Smith has defined teaching as [22]:

Teaching is the process of attending to people's needs, experiences and feelings, and making specific interventions to help them learn particular things. Interventions commonly take the form of questioning, listening, giving information, explaining some phenomenon, demonstrating a skill or process, testing understanding and capacity, and facilitating learning activities (such as note taking, discussion, assignment writing, simulations and practice).

The Process of Learning and Teaching

Teaching is the process of presenting a subject matter to the students. It can be both, direct as well as indirect. Direct teaching is the transfer of knowledge from a teacher to a student as in the setting of a classroom lecture, whereas indirect is the individual student's acquisition of knowledge under the guidance and supervision of the teacher. The goal of teaching is to reliably transfer knowledge of a given subject matter to the student so that he can apply it in his interaction with the real world, i.e., acquiring the concepts 1 - 5 listed above. This involves ensuring the student comprehends the subject matter as best as possible with all its implications and moving well beyond rote memorization.

Different Factors Impacting Effective Learning: Teaching effectiveness depends on a number of factors. The different factors that influences the learning process and schematically presented in Figure 1. Let us consider a subject matter S that is to be taught. The subject matter S is first distorted by factors such as the teacher's abilities, efforts, experience etc., resulting in his subject knowledge (represented by *S'*). It should be noted that the teacher's subject knowledge is an important factor in learning effectiveness, and the students' learning is seriously affected if the teacher's subject knowledge is below a certain threshold [23].

The teacher's efficiency in delivering the lesson is the next impediment to learning. Competent presentation and communication skills and discerning use of various pedagogical techniques can aid in improving the teaching efficiency. On the student's part, the amount of learning is constrained by his attention, abilities and efforts. Finally, the resultant image of the subject matter *S* at the student end is the subject knowledge *S''*. It should also be noted that, external factors also contribute to learning effectiveness; for example, there are times of special sensitivity more conducive to learning [22].

Traditionally the process of teaching takes place by serving a group of students in the classroom setting. However, effective learning should not be confined to the classroom setting alone. A teacher can extend the students' learning by extending the learning process. This can happen when a teacher strives to not only transfer knowledge to a student, but also teaches and motivates him to explore and seek knowledge himself. Hence, the teacher can help to connect the student directly to the subject matter as a secondary *learning link* in addition to the existing primary link through himself as illustrated in Figure 1. However, this secondary link cannot generally replace the primary learning link through the teacher, as the student cannot always learn effectively just by exploring the subject matter without the aid of a teacher. The teacher needs to teach the fundamentals and the basics of the subject matter to the student. The student can then build further expertise based on these fundamentals through explorations of the subject matter, either under the guidance of the teacher, or on his own.

Let us illustrate the leaning process with an example, say that of learning how to drive. It is almost impossible for one to learn how to drive safely and responsibly, for instance by just reading a set of instruction manuals, without the help of an instructor. The driving instructor has to be a sufficiently experienced and learned driver himself in order to have effective learning (subject knowledge above a certain threshold). The teaching process itself is a combination of some theory followed by practice. Once a student learns how to drive, he can then further improve his driving skills through exploration during driving, by reading various guides, and through the experiences of other drivers (the addition of a secondary direct learning link).

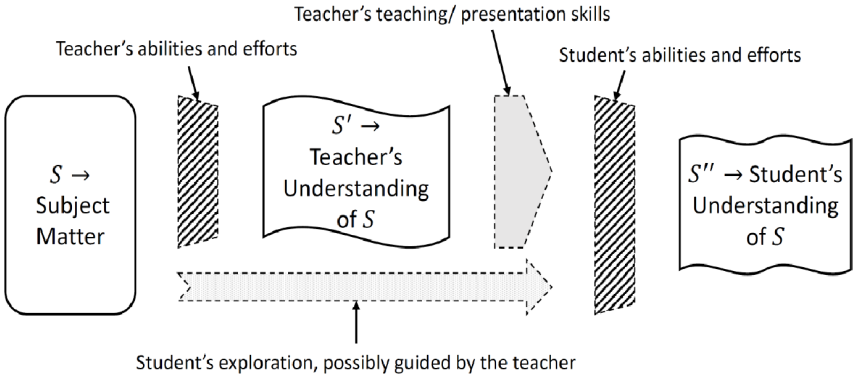

Figure 1: A schematic diagram of the learning process illustrating the various factors impacting

Different Stages of Learning

The outcome of Säljö's experiment cited earlier in this section can be formalized in various ways by formally categorizing different stages of learning. The students at each of these different stages primarily learn through different means, such as instruction, practice and apprenticeship, to become a subject matter expert. The stages, presented in [24, pp. 27-44] are summarized in the following.

Stage 1 – Novice: The first stage of learning is the novice stage where the students are taught a set of rules that can be applied to a set of conditions. For example, a driving student learns some general rules about shifting gears based on the speed. The main learning goal at this stage is to recognize the condition and apply the rules accordingly. However, such limited knowledge without contextualization does not produce performance in the real world.

Stage 2 – Advanced Beginner: The salient feature of the second stage of learning is the shift from rules to maxims. A maxim is an expression of a general truth or principle, and has a wider meaning. With experience, the novice student begins to develop an understanding of the context, and begins to realize them. Teaching in this stage introduces different situational settings and teaches the student how to relate to different maxims accordingly.

Stage 3 – Competence: Just memorizing sets of maxims and then determining the actions to follow can be overwhelming due to the wide range of situations that one can encounter in real life. The competence stage is differentiated from the earlier stage through the ability to recognize what is important in a particular situation and focus on one (or few) important aspects. Students at this stage base

their decisions by deciding on a plan or perspective to adopt according to the situation, which generally involves a number of maxims. Being enthusiastically involved in the outcome helps the student to develop his skills further, whereas the lack thereof leads to stagnation. An engaging teacher is more likely to better engage the students, and motivate and excite them in the learning process.

Stage 4 – Proficiency: A competent student is able to analyze a situation, determine the important aspects and then deliberate on the action that needs to be taken. On the other hand, a proficient student can recognize the problems instantly, while needing time to decide on the consequent action required. Internalization of the situational discriminations and its assimilation into intuitive analysis of the situation results in proficiency.

Stage 5 – Expertise: An expert is able to subconsciously determine the type of action required in most of the commonly arising situations. However, an expert is tested when a new situation that is recognized as sufficiently novel presents itself; or when there are more than one compelling perspectives to a given situation. A student at this stage learns by applying the skills he has obtained to new (and possibly) controlled situations presented by the teacher, and through observation and imitation of an expert as in an apprenticeship.

Stage 6 – Mastery: What distinguishes a master from an expert is the ability to create new theories and to see the domain of subject matter from a holistic perspective. He is able to see how different ideas interconnect with each other, and is able to generalize the existing knowledge into an overarching framework that can be applied to new situations. It may be noted that mastery is a lifelong process, and usually involves oneself as his own teacher.

The PhD Study

Having laid out a brief introduction to learning and its different stages, we now present the PhD study from a learning perspective in this section. The doctorate degree first came into existence in the Islamic guild school of law in the ninth century [25]. The first doctorate in the West was awarded in medieval Paris around the year 1150 [26]. The term *doctorate* is derived from the Latin word *docere*, meaning to teach. The PhD degree in Medieval Latin was called *licantia docendi*, "the license to teach" – a translation of the original Arabic term, *ijazat at tadris* [25]. In the formative setting, the doctorate was obtained following an oral examination determining the originality of a candidate's theses and a disputation set up to test his ability to defend them – a practice still being followed around the globe.

Required competences of PhD

In the early times, the doctorate degree implied two key qualifications, namely: i) competence in the subject matter, and ii) authority to teach and issue opinions. Accordingly, upon successful completion of the doctorate degree, a graduate was expected to simultaneously be a master (in Latin *magister*), one eligible to give opinion (*professor*), and eligible to teach (*doctor*). With the passage of time, the roles of professor and doctor came to be used synonymously, while the master role evolved into what is today known as the master's degree.

In modern times, a PhD involves advanced academic work and research. The framework of qualifications for the European Higher Education Area have specified the following qualification as outcomes of the doctoral degree [2]:

- *'a systematic understanding of a field of study and mastery of the skills and methods of research associated with that field;*
- *ability to conceive, design, implement and adapt a substantial process of research with scholarly integrity;*
- *contribution through original research that extends the frontier of knowledge by developing a substantial body of work, some of which merits national or international refereed publication;*
- *capable of critical analysis, evaluation and synthesis of new and complex ideas;*
- *can communicate with their peers, the larger scholarly community and with society in general about their areas of expertise;*
- *can promote, within academic and professional contexts, technological, social or cultural advancement in a knowledge based society'.*

The modern PhD studies typically involves carrying out original research on the selected topic, and writing and defending a dissertation. A fundamental goal of the candidature is to contribute new knowledge that is important to the field of study. As an example, the official guidelines given to external PhD thesis opponents at Aalborg University states: *'…based on the thesis in its preliminary form, evaluate whether the candidate has demonstrated a capacity to carry out a scientific project involving independent use of scientific methodology and hereby furthering research at the level equivalent to the international standard of PhD degrees within the subject area.*' Some of the key terms in the above guideline include *independence, use of established/accepted scientific methodologies, and furthering research.* Since the PhD is a research degree without a predefined curriculum, the student is expected to have the ability to work independently on his own. While the supervisor is there to help him in the process, the student bears the sole responsibility for most of the learning goals and milestones.

The first step in research involves identification and formulation of the research problem. Generally, the problem formulation stage involves identifying the objective of the research and the relevant constraints that forms the plausible solution space. Furthermore, any practical considerations, such as complexity, implement-ability etc. should also be considered at this stage. In addition, a PhD student is expected to have a solid understanding of the existing knowledge base in order to be able to further research and contribute with new knowledge. This should be done by identifying established/accepted scientific methodologies and relevant theories, and applying them to the considered research problem. Moreover, the student has to be aware of the broader generalizations of the applicable theories, and relevant practical considerations.

Finally, and perhaps one of the most significant differences of a modern PhD in relation to the founding concept is in the emphasis placed on collaboration. Today's problems are much more complex and multi-dimensional than those of earlier times. According to the World Economic Forum, Critical-thinking, Creativity, Communication and Collaboration are among the core competencies required for solving such complex problems [27]. Hence, alongside personal qualifications, the ability to work in a team and communicate and collaborate

with other experts is increasingly becoming an essential skill in today's PhD graduates. Moreover, diverging from the age-old image of being an academic, the doctorate holder is increasingly being regarded as a resource in emerging knowledge societies [28].

Learning at the PhD level

We present a general characterization of the PhD study in this subsection. Doctoral education aims at providing the students with a systematic understanding of their field of study, resulting in them gaining expertise, not only on the subject matter, but also in research methods associated with the field. The focus in on the ability to conceptualize, execute and apply research in the respective field. The transition from the undergraduate to the post-graduate thinking calls for a fundamental transformation in the way knowledge is acquired, analyzed and presented [17]. Comparing the expected qualifications of the PhD study to the different stages of learning outlined earlier in Section II-2, the PhD level of education broadly matches stages 4 and 5, namely *Proficiency and Expertise*. The complex and abstract level of understanding required from a doctoral candidate in order to contribute new knowledge [29] also falls within these two stages of learning.

The doctoral education has traditionally been viewed in the light of a master-apprenticeship model, where the student learns from one master, namely the supervisor [1]. However, modern PhD education have broadened in scope, requiring a PhD holder to have wide professional, personal and cultural competencies beyond their field of expertise in order to become independent researchers in the twenty-first century. Such a paradigm shift renders the master-apprenticeship model too narrow to appropriately capture the doctoral study [30].

Independence and learning from various sources is also a key attribute of doctoral learning. The PhD process may typically begin with a mentor-apprenticeship relationship between the supervisor and the student. Within this mentor-apprenticeship relationship, two different styles of research supervision has been identified, the *research practice-oriented* and the *research relation-oriented* supervision. The former describes a relation where the supervisor's and the doctoral student's research is closely related, whereas the latter refers to a scenario where the doctoral student's research lack a clear connection with that of the supervisor's [31]. However, as the student becomes skilled through the course of the study, the student-supervisor relationship evolves from a close master-apprenticeship model towards independence from the supervisor and learning from multiple sources [5]. For example, Nerad suggests that the PhD study has evolved from the traditional apprenticeship model towards institutionalizing communities of practice, recognizing peers as sources of, and partners in, learning [16]. Learning within a community of practice is especially important in the science and engineering fields where the PhD studies are usually part of a larger research project. Important aspects of the PhD process are learned informally from peers, and from the collaboration context/frame/setup itself – i.e. making use of a research network, realizing that criticism can be advantageous, the "multiplication" gain from joining forces and the filtering of massive information through collaboration [32]. In light of the above description of the PhD study, Figure 2 presents a modified version of the teacher-focused model of the learning

process illustrated in Figure 1, adapting the more complex teaching and learning process in the doctoral education.

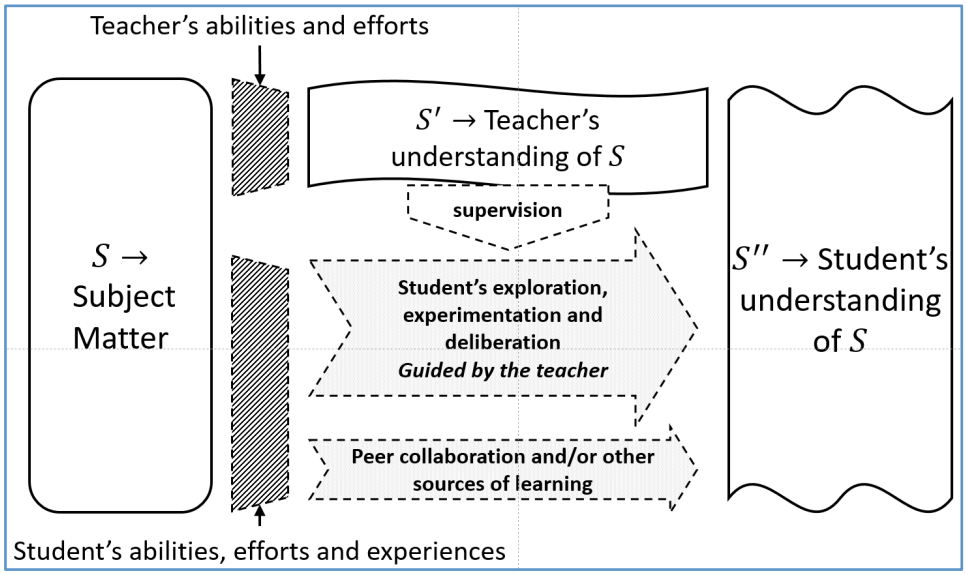

Figure 2: A modified schematic diagram of the learning process reflecting the more complex learning process in the doctoral education where the student's exploration, experimentation and deliberation is at the center stage.

Seven Habits of a Successful PhD Student

The objective of this contribution is to suggest some of the qualities or habits (i.e., best practices) of a PhD student that can enable a student to obtain the required competencies outlined in the preceding section. Such practices are aimed at ensuring a fruitful and successful learning experience. Seven such best practices are listed in this section. The proposed suggestions are a culmination of our experience of going through the PhD process, our involvement in the supervision of and interactions with PhD students.

1. PhD is a process, not a goal

PhD is a training in research, which opens the door to a career in academia or research. Hence, the goal is not the degree in and of itself, rather the objective is to obtain a systematic understanding of the field of study and in research skills within that field. The doctoral study is a skills development phase, where one need to emphasize on the process of doctoral education and training. In other words, exploration, experimentation and deliberation on the subject matter by the student is encouraged, as illustrated in Figure 2.

The personal motivation behind doing a PhD is an important factor in this aspect. There are many different reasons for enrolling in PhD studies, for example: pursuing a PhD in the absence of other job offers, as a necessary intermediate steps leading to a research career, for the passion of learning etc. [33]. Undoubtedly, those with a stronger motivation for pursuing a PhD are more aware of it being a process. Consequently, they are also in a better position to

whither the arduous and long study period. One should be driven by the curiosity and drive to learn, and discover something new in order to make the best out of their PhD study.

2. Know your fundamentals well

Just as a strong building requires a solid foundation, one should have a very good understanding of the basics in order to go further into the research. Inquiry-based studies and problem-based studies are approaches to learning that tie these two aspects together through exemplary cases [34], [35]. As we have elucidated earlier in Section III-1, the creation of new knowledge and insights are among the key objectives of the doctoral education. A clear picture of the existing knowledge base is an important pre-requisite for creating new knowledge. Furthermore, learning is enhanced if the students develop a clear conceptual understanding of the topic, which can be achieved through self-conscious reflections on the student's part.

This aspect can sometimes be overlooked, especially when the PhD is part of larger project where there is a strong push to produce results early on. Moreover, one may be able to get through the PhD without such a solid foundation. However, one is likely to be left with an underlying epistemic weakness as a consequence of such a lacking.

Being at a higher level of education, learning in the doctoral setting focuses on the individual self. The doctorate is a key milestone in the student's journey to become an independent researcher [5], i.e. moving towards learning stages 5 and 6 outlined in Section II-2. As such, gaining fundamental knowledge of the topic, to the level of proficiency, is the prerogative of the student himself. The supervisor should not be relied upon for such knowledge acquisition, though he may act as the mentor who guides the student to relevant sources of information [1].

3. Critical and Creative Thinking

Critical thinking is understood in terms of general rational thinking and discipline-specific skills. In general, there are multiple perspectives or aspects to any given scenario. A critical thinker is able to analyze a given scenario (or a piece of information) from a number of different perspectives instead of limiting himself to a fixed logical orientation. In the context of scientific research, critical thinking is crucial for problem formulation and analysis. In particular, it opens the possibility to consider a particular problem using different approaches in order to envision new possibilities, innovative procedures, and fresh prospects. Examples of critical thinking acts with respect to the PhD studies include understanding and applying theory, questioning existing knowledge, and motivating one's methodological choices [36].

Creativity implies producing something novel and adaptive as assessed by the community of peers [37]. Curiosity, independence, assertiveness and intrinsic motivation are among the traits found in a creative person. Creativity requires willingness to take risk, thinking outside the box and believing in oneself – i.e., standing by one's ideas if they really believe in it. In the academic setting, originality or novelty, and relevance or value to the community of practice are important essence of creativity. Examples of creative thinking acts include understanding the relationship between theory and practice, trying out new

(possibly different) ideas and methods, and presenting the research finding in a lucid and accessible way [36].

The role of critical and creative thinking, especially the latter, in successful doctoral training and accomplishing meaningful learning outcomes cannot be over-emphasized. However, and rather surprisingly, a recent study [36] showed that doctoral students understand critical and creative thinking in a number of ways. Moreover, critical thinking often overshadows creative thinking in practice, resulting in a defensive research approach instead of an open and independent mind. Developing a sense of agency - the awareness that one is in charge of, and responsible - for his PhD studies is a crucial factor for improving the student's critical and creative thinking.

4. Collaborative Learning and Support Network

A collaborative model where doctoral students learn in groups is increasingly replacing the traditional view of the doctoral student as a `lone scholar' characterized by individual endeavor. The role of collaboration with peers in the doctoral learning process is schematically illustrated in Figure 2. Research training is more efficient when there is a critical mass of experts, allowing doctoral students to learn through interaction with them [5]. PhD studies, especially in the science and engineering fields, are increasingly becoming parts of a larger research project. Collaboration with other members of the research project can greatly enhance learning and allow new students to quickly gain foothold within the project.

Alongside background knowledge within the specific topic, the doctoral study also requires a set of methodological and similar relevant skills (e.g. computer programming). Collaboration with other students provide a community of practice to learn such skills rather conveniently. In addition, every research group has some unwritten rules of practice, both academic and social, developed over the years. Such knowledge is passed down from a group of student to another through their community of practice. Furthermore, collaboration allows students to form a support network among themselves. Beside the academic aspect, the long doctoral study requires a student to manage a complex array of personal, social and interpersonal demands [17]. Forming a collaborative network with other students can provide a strong support network in these aspects too.

5. You are in Charge

The doctoral study typically begins with a `mentor-apprentice' relationship where the supervisor guides the student through the process. In particular, two different styles of research supervision has been identified, the research practice-oriented and the research relation-oriented supervision, where they differ in relation to whether the supervisor's research is closely related to that of the student's (*research practice-oriented*) or not (*research relation-oriented*) [31]. The end goal however, is for the student to pursue independence relatively quickly and take charge of his study. As earlier discussed in Section III, doctoral training is a student-driven learning activity, and the student himself is in charge of and responsible for his PhD studies. In particular, it is the student's responsibility to explore potentially interesting research questions, experiment different potential solutions and deliberate on the findings to take initiative for pursuing a certain research direction. The role of the supervisor is to provide

expert feedback, assist the student if he strays significantly from the project goals and timelines and help to develop the student's writing [38].

6. Read, Read and Read!

With the plethora of new publications updating every day, it may be a colossal task to keep updated of all the developments within the specific field of study, let alone the broader fields that might be more or less relevant. However, the PhD student should still attempt to regularly update himself with the general development trends within the field of study. If the PhD is part of a larger project, one can easily update oneself from peers within the project, and through attending potentially relevant meetings and other similar fora. Tutorial style articles and listening through various presentations, especially at conferences, are also good sources for keeping abreast with latest developments. This point is further related to the collaborative working mentioned earlier; the amount of information one can be exposed to these days is enormous, and no single person can cope with it all. Hence, some filtering though collaborative peers can be important.

7. There is More to the PhD Than Meets the Eye

The emphasis of doctoral education is no longer wholly upon the production of new knowledge, but also on the acquisition of transferable skills [39] that are in-line with the ambitions and goals of the knowledge society. The modern doctoral study is intended to prepare the student with a wide range of skills giving him a competitive advantage in the academic and non-academic job market. In general, a doctoral student should look beyond the thesis and prepare himself for the post-PhD period by acquiring a wide range of soft skills. Skills like teamwork, collaboration, critical and creative thinking are acquired naturally through the doctoral training. Moreover, the student is also informally (and at times formally) trained in project management while managing their individual PhD study, and in communication and presentation skills through academic writing and conference presentations. Such skills can be further formalized by attending relevant courses, and through practice. In addition, acquiring skills that are of specific relevance to PhDs outside academia, such as intellectual property and patent creation, are also becoming important these days, especially in certain fields of studies.

Conclusion

Doctoral study is a long and arduous process with the students embracing both independent self-directed study and collaborative shared learning. It is an elite level of study, where the graduates are expected to acquire skills and knowledge corresponding to an expert within the field of study. Though originally set out as a qualification towards an academic career, policy makers are increasingly considering doctorate holders as competitive resources in the emerging knowledge society. This study analyzes the doctoral study within a learning framework. First, we have formally defined learning and teaching, accompanied by a presentation of the different stages of learning. This is then

juxtaposed with an overview of the PhD study, culminating in identification of the expected requirements from a doctoral graduate. Finally, we recommend a set of seven best practices reflecting the presented theoretical background, that can help a candidate meet these requirements. We believe these recommendations can aid the doctoral student to have a broad perspective to his long and strenuous study and better appreciate his efforts, resulting in a successful completion of the doctorate degree, and a satisfactory research career.

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