HOW TO GET A PH.D.: Methods and Practical Hints I-II (2009-2010)

Aarne Mämmelä 15.9.2009

VTT TECHNICAL RESEARCH CENTRE OF FINLAND

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I Postgraduate Studies in the Faculty of Technology
Aarne Määmmälä

We will present a brief summary of the requirements for doctoral studies and a doctoral thesis, and its various phases. We will show that the roles of the supervisor, advisor, and student are different. The terms intelligence, creativity, and independence will be briefly explained. The inductive and deductive approaches will be briefly introduced and used extensively in later sessions. The inductive approach is essential for learning, but the deductive approach will strengthen our understanding. Research is a challenging learning process where the solution is not initially known, opposite to learning at school. A bibliography, vocabulary, and chronology of science and engineering will be available on the course page to support learning.
Doctoral Studies – Craft of Using the Hammer

- Introduction
- Contents of the course
- Doctoral studies
- Supervisor, advisor, and student
- Learning process
- Conclusions

Introduction
Introduction

• The course is to cover a postgraduate student’s scientific general studies whose aim is “good familiarity with historical development and basic problems, as well as research and design methods of engineering sciences”
• Research is a demanding learning process where the solution is not initially known by anybody, thus we need a hypothesis for the solution to guide our research
• Research is not at all straightforward (there is not really any “method”), but quite much creativity is needed: where to find existing knowledge, how to discover new knowledge, how to publish new knowledge

Contents of the Course
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- Lectures on Tuesdays at 13-16 (no lecture on 20.10.)
- Exam **11.12.** (Part I, 3 credits), additional exams if needed
  - compulsory lectures, small coursework **12.11.**
  - Part I must be accepted before Part II is accepted
- Send questions by **24.11.** for the discussion session (course feedback also requested later)
- Course work (Part II, 5 credits, voluntary addition)
  - proposal for requirements **12.11.**
  - feedback 11.12.
  - final report **28.4.2010**
- Grades: 1-5

Coursework, Part I

- Extended abstract and a list of references classified into books, review papers and original papers
- Define a research problem, suitable keywords, and a starting point (a recent original paper) for your search
- Corresponds to one question in the exam
- If you decide to submit the coursework proposal for Part II, it will replace the coursework of Part I
- More detailed instructions on the course page
Coursework, Part II

- Literature search, and analysis, and reporting of the findings
- Define a research problem, suitable keywords, and a starting point (a recent original paper) for your search
- Use at least three databases:
  - electronic library (IEEE Xplore, ACM Digital Library, SPIE Digital Library, etc.)
  - abstracts database (INSPEC, COMPENDEX, etc.)
  - citation index (Google Scholar, SCI-Expanded, SCOPUS, etc.)
- Final report about 10-20 pages
- More detailed instructions on the course page

PROGRAM (1) - changes possible

I Session 15.9.2008 at 13.15-16
1. Aarne Mämmelä, Postgraduate Studies in the Faculty of Technology.
2. Aarne Mämmelä, Literature Reviews: Existing Knowledge from Data Bases.

II Session 22.9.2008 at 13.15-16

III Session 29.9.2008 at 13.15-16

IV Session 6.10.2008 at 13.15-16
6. Harri Haapasalo, Designing Qualitative Approach in Research.

V Session 13.10.2008 at 13.15-16
7. Erkki Oja, Experiences of a Senior Researcher.
8. Lauri Pirttiaho, Specialist in Industry.

20.10. No session

VI Session 27.10.2008 at 13.15-16
PROGRAM (2) - changes possible

VII Session 3.11.2008 at 13.15-16
11. Aarne Mämmelä, History of Research Methods

VIII Session 10.11.2008 at 13.15-16
12. Riitta Keiski, Good Practices in Researcher Education.

IX Session 17.11.2008 at 13.15-16
14. Timo Koivumäki, Quantitative Questionnaire Study.

X Session 24.11.2008 at 13.15-16

XI Session 1.12.2008 at 13.15-16
17. Aarne Mämmelä and Olli Silven, Discussion Session.
18. Aarne Mämmelä, Summary of the Course.

XII Session 8.12.2008 at 13.15-16
19. A session reserved for one additional lecture.

Doctoral Studies
Simplified Research Process

- Problem
- Initial data collection (literature review)
- Tentative solution (hypothesis)
- Analysis/simulations/experiments
- System model (prototype)
- Theory/paper (new knowledge)

Note. In practice the process is highly iterative.

Methodological Approaches and Research Methods

<table>
<thead>
<tr>
<th>Methodological approaches</th>
<th>Research methods</th>
</tr>
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<tbody>
<tr>
<td>Actors approach</td>
<td>Idiographic research</td>
</tr>
<tr>
<td>Systems approach</td>
<td>Constructive research</td>
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<tr>
<td>Analytical approach</td>
<td>Nomothetic research</td>
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</tbody>
</table>
Criteria for Scientific Work

- **Criteria for scientific theories**
  - Agreement with data (reality)
  - Coherence (unity)
  - Generality
  - Fertility

- **Criteria for papers**
  - Originality (novelty)
  - Significance (impact)
  - Correctness
  - Readability

- **Structure of a paper**
  - Introduction
  - Materials and methods
  - Results
  - Discussion

Note. The research must be done in a proper way to produce new knowledge and papers.

Time Frame for a Doctoral Thesis
(4 years of full time work)

1. Proposal
2. Courses
3. Literature
4. Experiments
5. Reports
6. Papers
7. Thesis
8. Defence
Progress of Doctoral Studies

- Pre-examiners selected (department council)
- Manuscript ready, pre-examination starts
- Manuscript accepted for publication, opponents selected
- Public defence
- Publication of the manuscript
- Acceptance (faculty council)
- Supervisor selected

4 years - 3 months - 10 days - 4 weeks

Instructions of the Faculty of Technology

(www.ttk.oulu.fi/opinnot)

- Decrees (asetus teknistieteellisistä tutkinnoista, asetus yliopistojen tutkinnoista, in Finnish only)
  - Degree regulations (Tutkintosääntö, in Finnish only)
- Guidelines for postgraduate studies
- Writing instructions of the ACTA series (in Finnish only)
- Progression of public defences of doctoral thesis
  - Instructions for the pre-examiner
  - Instructions for the opponent
- See also instructions of faculties and departments
  - www.oulu.fi/english/faculties_and_departments.html
Official Requirements for a Doctor

- **major subject**: deep familiarity with own research area and its societal significance, ability to independently discover new scientific knowledge, 35-45 credits (opintopiste, op), and preparation of a doctoral thesis and its successful public defence
- **minor subject**: good familiarity with other related research areas, 10-20 credits (op)
- **general scientific studies**: good familiarity with historical development and basic problems, as well as research and design methods of engineering sciences, 5-8 credits (op)
- The total requirement is 60 credits (op), which correspond to 1600 hours (one academic year) of full time work

Requirements for the Doctoral Thesis

- The requirements are defined in the [degree regulations](http://www.ee.oulu.fi/En/Admissions/Doctors)
- Alternatives:
  - **monograph**: a single integral publication (50-200 pages)
  - **article-based dissertation**: a summary of 30-80 pages and a collection of separate conference and journal papers
- Papers must deal with an integral set of problems. An objective account of the student’s contribution to each publication is presented in the summary.
- The exact number of papers has not been defined, but there must be several ("useita") of them (normally 5-8 papers from which some are usually journal papers and most of the papers include your name as the first author).
- [www.ee.oulu.fi/En/Admissions/Doctors](http://www.ee.oulu.fi/En/Admissions/Doctors)
Supervisor, Advisor, and Student

Roles of Supervisor, Advisor, and Student (1)

• **Thesis supervisor (valvoja, ohjaaja)** is a representative of the university. The supervisor must be a professor or doctor (usually at least a docent) at the university. A template is available for the application concerning supervision.

• **Thesis advisor (ohjaaja)** is usually a representative of the workplace, recommended but not mandatory in Oulu. The advisor gives day-to-day guidance and reads the thesis before the pre-examination. The advisor does not give ready-made solutions but rather ways of thinking and encourages to use the available infrastructure on the student’s own initiative. The development of research culture depends heavily on advisors.
Roles of Supervisor, Advisor, and Student (2)

- **Student** does the detailed planning (for example detailed time schedule with intermediate steps; do not lose your window of opportunity), carry out the actual research, write the manuscript and follow the given recommendations, the student must be able to *discover new scientific knowledge independently*.

Other Persons Related to the Thesis

- **Pre-examiner (esitarkastaja)** is the reviewer or referee of the thesis before it is published. There are at least two pre-examiners. Often the manuscript must be examined twice before it can be accepted to be published.
- **Opponent (vastaväättäjä)** is the person who examines the thesis in the public defence. There are usually one or two opponents. If there are two opponents, one of them may be one of the pre-examiners.
- **Custos (kustos)** is the chairman of the public defence, usually the same as the supervisor. The custos represents the university.
Intelligence, Creativity, and Independence

- **Intelligence** refers to the ability to keep everything well organized. Intelligent people are usually active, interested in their environment and other people, and they tend to think critically and show high initiative.

- **Creativity** refers to originality of thought: the ability to define new problems and suggest novel solutions to them. Creative people tend to think of ambiguous problems as a challenge: they like to work on the edge of chaos. Creativity requires certain amount of intelligence, but highly intelligent people are not always very creative.

- **Intuition** refers to an ability to make decisions with fragmentary information, often based on earlier experience although unconsciously. It may lead to a better solution than detailed analysis when the problem is very complicated. Dreams may reflect intuition.

- **Independence**: Independent work is expected but that does not mean that you should not use the infrastructure around you, you must show initiative since nobody else will write your thesis.

Advisor is Your Best Friend

- The local advisor is any **doctor** familiar with the topic and usually working for the same employer
- Look for a good advisor [Sternberg81]
  - Be there for the length of your project
  - Experience on research in the same area (must be a doctor, but peer students may be very useful)
  - Pedagogical skills, know the large picture, know literature
  - Respected by colleagues, critical, tough methodologist
  - Interested in your topic, gives comments, you respect him or her
How to Keep Your Advisor?

- **Orient** your advisor (system model, block diagrams, table of contents).
- **Follow instructions** (make notes and read them), but also discuss and argue.
- Write concise **progress reports** (organize the material, limit the scope).
- **Show initiative**, get into the driver’s seat from the back seat [Sternberg81], do not just wait that everything is made ready for you, the advisor gives you ways of thinking.
- If you show that you do not appreciate the work of the advisor, this is one certain way to loose the advisor.
- Collaboration in research implies **writing papers together**.

Success as a Researcher

**How does a researcher work?**

- make always notes in a **notebook**
- make **summaries** on what has been learned
- make **plans** for the future all the time (outlines, roadmaps, visions)
- **discuss**, ask questions and argue (criticism)
Learning Process

Bottom-Up Learning Process [Felder88]

Methods of reasoning:

**Induction (bottom up):** the conclusion, though supported by the premises, does not follow from them necessarily (often proceeds from particular to general)

**Deduction (top down):** if the premises are true the conclusion must be true, i.e., deduction preserves the truth (often proceeds from general to particular)
What about Stress

- Our society emphasizes **efficiency**, which may lead to stress
- We live on a society of **interruptions**, which in fact implies inefficiency: we should respect each other’s time; you are most efficient with two parallel projects
- **Methods** to prevent stress: enough sleep and rest (reserve some free time in time schedules), healthy food, physical exercise, social relations, detailed plans (budgets, time schedules, checklists)

Preparations for Exams

- **Self-discipline**: Start early enough (several weeks before the exam), collect the required material, make a time schedule, repeat what you learned the day before, repeat everything in the end
- **Thoroughness**: Find relations and simple principles, compare to what you have learned earlier, clarify possible conflicts, remember criticalness (mistakes are possible), learn new concepts and terms and their definitions (use also dictionaries), learn also the pronunciation of English terms
- **Activeness**: Discuss with other students and do something actively, take part in teaching, ask questions, read textbooks, compare sources, go through the algebra including all intermediate steps, take exercises
- **Summaries**: Write your own summaries (outlines) and read them in the end, underline the textbook, concentrate on the essential points, make notes in your summaries or in the textbook
How to Get a D.Sc. (Tech.)

- The decree of the council of state defined the translation of tekniikan tohtori as “Doctor of Science (Technology)”
- The degree is abbreviated by TKK as “D.Sc. (Tech.)”
  - Tekniikan lisensiaatti is Licentiate of Science (Technology), Lic.Sc. (Tech.)
  - Diplomi-insinööri is Master of Science (Technology), M.Sc. (tech.)
  - Tekniikan kandidaatti is Bachelor of Science (Technology), B.Sc. (Tech.)

www.tkk.fi/fi/opintot/opintohallinto/kieliversiot/index/

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Some Etymology

- **Science**, Latin *scientia* “knowledge”, main modern (restricted) sense of “body of regular or methodical observations or propositions ... concerning any subject or speculation” from 1725
- **Research**, Old French *rechercher* “seek out, search closely”, meaning “scientific inquiry” from 1639.
- **Doctor**, Greek *didaktōr* “teacher”, Latin *doctor* “teacher”, “holder of highest degree in university” from 1375.
- **Ph.D.**, Latin *Philosophiae Doctor*, doctor of philosophy.
- **Professor**, Latin *professus* “having declared publicly”, *professor* “person who professes to be an expert in some art or science, teacher of highest rank” (1380).
- **Docent**, from Latin *docentem*, from *docere* “to show, teach” (1639)
- **Custos**, from Latin *custos* “guardian, keeper, protection”
- **Karonkka** (a banquet after the public defence, in Finnish), a diminutive form *koronka* of the Russian word *korona* “crown”, related to the word *koronovanije* “coronation”.

Conclusions

• The basic aim in doctoral studies is to show the ability to **discover new scientific knowledge**

• This course will teach the research methods, but there is no straightforward deductive approach from the definition of the problem to the solution (hypothesis), which needs **creativity**

• **Communications** in various forms (advisors, other students, papers) is essential for the success in research
Additional Material: Vocabulary (extract)

- **accuracy** (tarkkuus) accuracy of measurement, the closeness of agreement between a measurement result and the accepted reference value [amc03], --- the most appropriate means of expressing the accuracy is uncertainty [amc03], see mean-square error, instrument

- **precision** (täsmällisyys) measurement precision, the closeness of agreement between independent measurement results obtained under stipulated conditions [amc03], ---, see granularity, resolution, trueness, accuracy, uncertainty, coverage interval, coverage probability, tolerance, instrument, significant digit, most significant bit, least significant bit

Additional Material: Bibliography (extract)

1.1 LIBRARIES

Foreign libraries

- Library of Congress, www.loc.gov (The largest library in the world, founded in 1789. Note that the library database is freely available.)

4.1 ENCYCLOPEDIAS

- Encyclopedia Britannica (32 volume set), Encyclopedia Britannica, 2003 (ISBN 0852299613). (The largest encyclopedia in the world including 65000 entries, published since 1768, -- available also as a one-volume version with the title Britannica Concise Encyclopedia, including 28000 entries, free of charge at concise.britannica.com..)
Additional Material: Chronology (extract)

1990 World Wide Web (WWW), concept (T. Berners-Lee)
1992 Internet browser (Mosaic)
1993 Open access journals
1994 WWW commercial
1994 Netscape browser (Netscape)
1995 Explorer browser (Microsoft)
1995 Altavista search engine
1995 Journal Storage (JSTOR)
1995 Amazon bookstore online
1996 IEEE/IEE Electronic Library (IEL)
1996 Abebooks second-hand bookstore online (R. and V. Pura, K. and C. Waters)
1996 Acronym Finder (M. Molloy)
1997 CiteSeer electronic library (S. Lawrence, K. Bollacker, L. Giles)
1998 Google search engine
2000 IEEE Xplore online
2002 ISI Web of Knowledge online
2003 CiteSeerX (L. Giles and I. Councill)
2004 Google Scholar
2004 Scopus citation index
2004 Google Book Search

Recommended Reading (1)

Encyclopedias

- Wikipedia, en.wikipedia.org. (Largest online encyclopedia. No peer review.)
- Eric Weisstein’s world of science, scienceworld.wolfram.com

Other books

- Abebooks, www.abebooks.com (Used books from various second-hand bookshops.)
- Amazon, www.amazon.com (A bookstore, can be used as a digital library of books.)
- Booknet, www.booknet.fi (New and used books in Finland.)
- Google Book Search, books.google.com. (Digital library of books.)
- Open Library, openlibrary.org (Digital library of books.)
Recommended Reading (2)

Papers
- *Google Scholar*, scholar.google.com. (Digital library of papers.)
- *IEEE Xplore*, ieeexplore.ieee.org. (Digital library of papers.)
- *JSTOR*, Journal Storage, www.jstor.org. (The scholarly journal archive. Some very old papers are there from 1665.)
- *Web of Science*, portal.isiknowledge.com/portal.cgi. (Includes SCI-Expanded, an abstract database and citation index.)

Search engines

Recommended Reading (3)

Writing instructions
- “On the use of italic and roman fonts for symbols in scientific text,” www.iupac.org/standing/idscls/fonts_for_symbols.html. (Additional examples.)
Oxford dictionaries (International Phonetic Alphabet (IPA) used.)


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Dictionaries of American English (IPA not used.)


Recommended Reading (6)

**Finnish-English-Finnish dictionaries**

- *Suuri englanti-suomi-sanakirja*. Gummerus, 2005, 1382 pp., ISBN 951-20-6721-8. (New dictionary that is also available as a MOT dictionary *MOT Englanti* from Kielikone, see www.kielikone.fi for other MOT dictionaries. Over 70000 entries and over 50000 examples.)

Recommended Reading (7)

**Finnish-English-Finnish vocabularies**

- TEPA term bank, www.tsk.fi. (This term bank is maintained by the Finnish Terminology Centre, Sanastokeskus TSK. Includes many SFS vocabularies.)

**Metrology and statistics**

- ISO 31 Quantities and units. (The general principles of SI quantities and units and mathematical signs and symbols are defined. Part of the terms are translated in SFS-ISO 31-0 and 31-11, available in SFS-käsikirja 19.)
- International vocabulary of metrology – Basic and general concepts and associated terms (VIM). (The most important terms of metrology are defined, including accuracy, trueness, precision, and uncertainty. Part of the terms are translated in SFS 3700 , available in SFS-käsikirja 19.)
- ISO 3534 Statistics – Vocabulary and symbols. (The most important statistical terms are defined. Part of the terms are translated in SFS-käsikirja 178.)
Recommended Reading (10)

Research methods, philosophy of science, and systems thinking


Recommended Reading (11)

History of science and technology

Abbreviations

- ACM, Association for Computing Machinery
- COMPENDEX, Computerized Engineering Index
- IEE, Institution of Electrical Engineers
- IEEE, Institute of Electrical and Electronics Engineers
- IMRAD, introduction, materials and methods, results, and discussion
- INSPEC, Information Services in Physics, Electrotechnology, Computers, and Control
- IPA, International Phonetic Alphabet
- ISI, Institute for Scientific Information
- ISO, International Standards Organization
- op., opintopiste, credit
- Ph.D., Philosophiae Doctor, Doctor of Philosophy
- R&D, research and development
- SCI-Expanded, Science Citation Index Expanded
- SPIE, International Society for Optical Engineering
- TEPA, termipankki, term bank
- TKK, Teknillinen korkeakoulu, Helsinki University of Technology
- VTT, Valtion teknillinen tutkimuskeskus, Technical Research Centre of Finland

Some Guides

References