HOW TO WRITE AND DEFEND A GRADUATE THESIS

The purpose of this guide is a synthetic presentation of practical recommendations and known risks associated with developing a graduate thesis, with particular emphasis on the text of the thesis. The motivation for preparing the guide was the recurrence of problems and errors observed in the supervised and reviewed theses and the reiteration of questions and doubts raised by students of the Institute of Computer Science, Warsaw University of Technology.

Purpose and beneficiaries

The hierarchy of goals of the thesis may be complex, but usually, the most important are:

- obtaining by the author the title of engineer or master of science,
- solving a problem or developing a product.

In the reality of the Institute of Computer Science, the problem is usually technical, and the practical result of the student's work is usually computer software or an electronic device.

In addition to the author, the beneficiaries of the graduate thesis may be other people and institutions interested in using the theoretical or practical outcomes of the thesis.
Due to the first goal, the reviewer appears as the most important thesis reader, and such a perspective is used throughout this document.

Engineer's thesis vs. master's thesis

The similarities and differences between the engineer's and master's thesis are reflected by the evaluation criteria indicated in the review forms.

The common criteria are:

- *whether the scope and results of the thesis correspond to the requirements set,*
- *whether the thesis's form (content layout, linguistic correctness, editing, illustrations, terminology, list of sources) meets the requirements for scientific and technical publications.*

In the case of an engineer's thesis, the reviewer should also evaluate:

- *whether the source analysis is suitable for the graduate task,*
- *whether the student has chosen the right engineering tools to perform the task and whether they have demonstrated the ability to use them,*
- *what the practical result of the thesis is.*

In the case of the master's thesis, the specific criteria are as follows:

- *whether the analysis of sources is comprehensive, critical, adequately correlated with the subject of the thesis,*
- *whether the suitable methods for solving the problem have been selected and whether they have been skillfully used,*
- *whether correct conclusions have been made,*
- *what the independent contribution of the student is.*

In other words, each thesis should be written on the subject thoroughly and comprehensibly, while the assessment is focused on the technological aspects of an engineer's thesis and on the methodological and research aspects (if any) of a master's thesis.

Subject and scope

The subject of the thesis may correlate with the research activity of the division in which the work is carried out or may result from the supervisor's interests – not necessarily within the nominal area of activities of the parent organizational unit. It is also possible to propose a subject by a student or any combination of these variants.

The final subject does not have to be formulated at the very beginning, and the original subject can be changed if the circumstances justify this. Making the initial subject narrower or more precise is the simplest case. Choosing another subject within the same area appears riskier, but using some outcomes of previous work or the literature review results is usually possible. The most challenging option is to choose a new subject from outside the original area of interest, invalidating the results of the previous student's efforts. Such a scenario may result from a change of supervisor, suspension of financing of a project or other equally drastic circumstances.

From the teaching perspective, the subject of the assessment is primarily the technological or methodological correctness of the author's concepts and activities. The thesis is essentially a pretext to present the intellectual potential and skills of the author, with particular emphasis on the ability to solve problems and use sources. In this sense, the subject of the thesis is of secondary importance, and the adverse outcomes (rejection of a hypothesis, mediocre results of a researched method, etc.) do not prejudge its negative assessment.

When determining the scope of the thesis, it is necessary to indicate the expected theoretical and practical results and realistically assess the possibility of achieving them in the available timeframe. In the case of technical products, the related requirements should be identified or defined, and the genesis of the thesis subject usually determines the origin of these requirements.

Size and content

The text of the thesis is a mandatory outcome, and one of its basic characteristics is volume. A too-extensive thesis is tedious to read and, consequently, difficult to follow. On the contrary, a too-short thesis may be incomprehensible due to excessive simplifications or mental shortcuts. Besides, a small volume alone may raise the reviewer's doubts. In practice, 60-100 pages (including appendices) seem like a safe volume range.

The volume of the thesis may be controlled to some extent by changing margins, line spacing, etc., but undue thinning or condensing of the text negatively affects perception. On the other hand, the volume primarily depends on the thesis scope and content.

The scope results from the subject and goal of the thesis, and the selected way of describing how to achieve this goal determines the content. The appropriate definition of the scope remains at the discretion of the supervisor. Like the subject, the scope can be changed during implementation if there is an important reason for this. Controlling the size of the thesis by changing the content may consist in including extensive descriptions of the tools, components, protocols, etc. (when trying to increase the volume) or limiting this type of information to literature references with short comments (when trying to reduce the volume).

The plan

Due to the nature of a graduate thesis development, this undertaking has the features of a project. Therefore, from the organizational point of view, it can be supported using techniques used in project management, with particular emphasis on managing scope, schedule and risk during the planning and monitoring work progress. In the case of co-authorship, integration management should also be considered (e.g. by agreeing on the terminology, narrative style and formatting).

Planning activities into stages and defining deadlines will help to avoid significant slippage, while defining the outcomes associated with each stage will facilitate the achievement of the intended goal. Analyzing compliance with the plan will enable an early decision to intensify activities, change tools or methods, and in exceptional cases – change the scope or subject of the thesis.

The table of contents is a helpful instrument supporting the planning, progress monitoring and communication between the student and the supervisor. Section titles, jointly determining the scope of the thesis, also define its logical structure through their order and hierarchy. After including descriptions of the content of individual sections, the table of contents becomes an outline. Additional annotations may indicate the planned volume of sections, the dates of completion and the expected results of subsequent chapters. Such an approach makes it possible to agree relatively precisely about the structure, contents and schedule of activities and define control points.

The structure

A typical thesis includes:

- introduction,
- an overview of the relevant domain of knowledge/technology,
- assumptions and requirements for the solution,
- solution design,
- description of architecture or selected implementation components,
- description of the method and results of verification of the developed solution,
- a summary,
- appendices (optional),
- bibliography.

The introduction should specify at least the purpose and scope of the thesis. An essential element is a justification for taking up a given subject (why it is worth dealing with a particular problem). Usually, this section also includes information about the structure of the thesis and formatting rules (using abbreviations and proper names, highlighting user interface elements in the text, etc.). In the case of co-authorship, it is advisable to indicate the contributions of the authors explicitly. The primary function of the introduction is to properly prepare the readers for the main part of the thesis and convince them of its subject's topicality and attractiveness.

The domain review should comply with the thesis's subject, purpose and scope. Describing the properties of well-known solutions, theoretical works or research results seems pointless if they are irrelevant to the further sections of the thesis.

The assumptions and requirements should be related (or at least not contradictory) to the results of the domain review. Additional requirements or postulates are sometimes formulated by the author or supervisor or result from the subject or scope of the thesis (such as using a specific method, interface, technology, platform, language, etc.).

The description of the design – regardless of the notation used – should allow the reader to understand the compliance of the proposed solution with the assumptions and requirements formulated in the previous section.

The description of the implementation requires special attention because presenting all system components is usually counterproductive. It makes more sense to focus on the critical parts of the solution from the perspective of the intended functionality, performance, etc. – with particular emphasis on the author's original ideas and the items necessary to achieve the declared goal.

The description of the verification of the solution should include the characteristics of the method and the reasons for selecting it, the activities carried out (tests, simulation, etc.), and the results obtained. It should demonstrate that the verification method is appropriate for the specific case and that its application (scenarios, probability distributions, value ranges, number of iterations, etc.) justifies considering the results complete and reliable. Linking individual tests or experiments to specific requirements and demonstrating full coverage appears to be the safest formula. It is also essential to provide a clear interpretation of the results obtained – especially when they are counterintuitive or deviate from the results published in other works in the field.

The summary should synthetically and objectively confront the results with the purpose of the thesis and confirm its complete (or incomplete) implementation. It is also worth describing additional, unplanned outcomes and the possibilities of exploring them, as well as the theoretical and practical significance of the conclusions formulated. This section may also include directions for further work and a list of the author's original achievements.

The appendices contain supplementary materials separated from the main part of the thesis due to their nature or level of detail. The appendices may cover schematic diagrams, detailed experiment reports, user manuals for the developed software, etc. These materials are usually not necessary to understand the concept of the solution but can be helpful for readers interested in technical details. On top of this, a list of used terms and abbreviations may also be provided as an appendix.

The bibliography contains a list of sources of knowledge referred to in the thesis. The primary function of this section is to enable readers to benefit from the literature indicated by the author, and therefore they should be described appropriately. The title, authors, publisher, place and year of publication, and, if necessary, volume designation and page numbers should be specified for printed publications. Some of these parameters do not apply to electronic publications; nevertheless, the author should indicate such sources reliably. In addition, many websites change their structure or location, and the published materials are deleted or archived over time. Therefore, besides indicating original locations and access dates, it is worth including copies of such materials on the media attached to the thesis.

Regardless of the specificity of a thesis, certain sections have strategic significance for perception and therefore deserve special attention. The **abstract** builds the first impression about the thesis, so it should provide crucial information about its purpose, context and results in an exciting form. The **keywords** should adequately correspond with the scope of the thesis. The **table of contents** reflects the structure of the thesis and, consequently, reveals possible shortcomings in this area – gaps, unbalanced section sizes, different levels of detail, etc. The **introduction** presents the subject of the thesis from a broader perspective, and it should develop the information given in the abstract. As the last element, the **summary** significantly affects the reader's overall impression and should be concise, specific and exciting, like the abstract.

A proven way to ensure that the abstract is consistent with the summary is to revise (and possibly correct) the initial sections of the thesis once the whole text is created.

Review and defense

Submitting a thesis for review starts the activities related to the graduate exam, and a written confirmation of thesis acceptance by the supervisor is the formal prerequisite of this step. The submission should be made to the secretariat of the Institute, with a deadline related to the semester's schedule. The thesis reviewer is appointed by the Deputy Director for Teaching, who customarily asks the supervisor for a recommendation. It is also a good practice to agree on such a recommendation with a potential reviewer in advance.

In addition to getting acquainted with the thesis and the content of the attached medium, the reviewer may meet with the author to clarify doubts and obtain additional explanations supporting a reliable assessment. The practical outcomes of the thesis may also be presented during such a meeting, and the supervisor may be its additional participant.

The examination committee consists of the chairman, the supervisor, the reviewer and another member. The supervisor and reviewer present their written reviews to the chairman and justify their assessments in case of discrepancies. The exam lasts about 30 minutes and includes a presentation of the thesis and answers to two questions about the course of studies – one from the reviewer and one from an additional committee member.

The presentation lasts about 10 minutes, and it should smoothly introduce the goal, scope and the most important outcomes of the thesis, taking into account its main assumptions and technical constraints – e.g. tools or methods used. Immediately after the presentation, committee members can ask questions about the thesis. It is worth anticipating such questions and preparing additional materials (diagrams, charts, etc.) to facilitate the answers. It should be kept in mind that the time allowed is only enough to present a few slides and quickly demonstrate key practical results. A successful presentation ensures a high grade for the first part of the exam and the student's well-being in the second part, so good preparation and practicing the presentation are doubly justified.

Additional questions may concern any topic related to studies, but the subject of the thesis or the professional interests of committee members often inspire them. Therefore, it is worth getting to know the committee's composition and recapitulating knowledge from the respective areas. The questions usually relate to fundamental concepts, typical problems in a given field, or relations between different methods or technologies. If necessary, the questioner usually formulates additional questions or moderates the answer in another way. The good mental condition of the student is at least equally important as knowledge in this exam phase.

The grade for the thesis is the agreed or averaged grade from the reviews. The grade for the exam is the average of the grades for the presentation and answers to the questions. The final grade for studies is calculated according to the formula: 0.6 * cumulative average grade for studies + 0.3 * grade for the thesis + 0.1 * grade for the graduate exam. In the case of co-authorship, the chairman decides on the method of organizing the exam, but usually, each person is examined separately.

Do's and Don'ts

First, do no harm (lat. *primum non nocere*). This medical principle should be obeyed in one's interest because the comfort of the reviewer while reading the thesis and the comfort of the committee members during the exam is a value that cannot be overestimated.

The thesis should be logical, well-structured, compact and exciting, and the minimal requirements are correctness and comprehensibility, determining the value of individual sections. It should also be emphasized that an excess of information hinders perception. So if some fragments are hard to read, not necessary to understand the following sections and not essential for other reasons, it is worth considering removing them.

The mentioned rule also applies to the graduate exam. In the first part of the defense, practically everything depends on the student, so a chaotic presentation or poorly prepared demonstration of results is like shooting one's leg. In the second part, panic is the biggest enemy, and silence is the worst-case scenario. One may ask for a comment or other wording if the question is unclear. As a last resort, one can paraphrase the question, turn toward more familiar areas and observe the reaction of the questioner or directly ask for a hint. An incomplete or incorrect answer at least gives room for a discussion, while the lack of an answer must be assessed negatively.

Second, do verify. Although practice shows that regardless of possible extensions, the thesis is usually submitted in a hurry, considering the evaluation criteria, the author should ensure the appropriate quality of the text.

Typical shortcomings that appear in graduate theses are:

- improper use of sources – using the results of someone else's work (fragments of text, research results, illustrations, etc.) without indicating sources is illegal; on the other hand, referring to outdated or inadequate sources and, in particular, their biased selection is a serious methodological error;

- improper citation of sources – e.g. copying large fragments literally or lack of references in the text to a given item; the basic rule is to list in the bibliography the sources cited in the thesis to justify some assumption, decision, etc., and the reference itself is usually in the form of an identifier of a specific item;

- improper documentation of sources – the bibliographic description should be complete and unambiguous enough for the reader to reach the cited source material;

- incorrect thesis structure – lack of logical continuity, gaps or repetitions, unjustified assumptions, requirements, criteria, decisions, etc.; unjustified disproportions between the sizes of individual sections of the thesis, e.g. domination of the text by a review of the domain or appendices;

- terminological errors – errors in the translation of names, introducing one's terms, lack of terminological precision or consequences (e.g. unjustified or interchangeable use of the terms *speed* and *velocity*), abuse of synonymous terms; such risks grow in the absence of established area-specific terminology;

- heterogeneous narration – changes in the style of narration (singular vs. plural, present vs. past); passive or impersonal forms seem to be the safest, but any convention is acceptable in principle, as long as it is used consistently;

- various types of language mistakes – e.g. *allow* vs. *enable*, *quantity* vs. *number*; incompatibility of grammatical forms, sentences that are too long or built improperly, etc. ;

- typos – although they do not reduce the substantive value of the thesis, they do not serve the interests of the author, and their mass occurrence indicates a lack of elementary diligence; the expected minimum is automatic spelling verification, but it is also worth reading the final version carefully or better yet – asking someone else to read it;

- careless formatting – unjustified changes in typeface and font size, different styling of similar text fragments, incorrect numbering or references to figures, tables, etc. – all this, like typing errors, can hinder the reception of the thesis; the author should update the table of contents and other lists, take care of the appropriate location of figures, tables or equations and the corresponding descriptions, avoid separating section heading and content, etc.