Preparing a Ph.D. Thesis Proposal in Informatics

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Abstract

This document discusses the thesis proposals in informatics submitted at the Faculty of Sciences of the University of Lisbon. The thesis proposals are developed after six months of supervised research and are discussed by a group of examiners who decide if you (the student) can proceed with your research. Considering the short time frame allowed for submission, you must rapidly develop certain skills regarding research design and communication. The purpose of this document is to help you build such skills.

Keywords: Research Design, Thesis Proposal, Ph.D. in Informatics.

1 Introduction

A thesis proposal (TP) is a written document articulating the following **research design** elements:

- Proposed research problem;
- The scientific framework of the research;
- Methodology and research design;
- The solution to explore;
- Expected contributions.

Developing a TP is difficult despite the apparent linearity and clarity hinted above. This happens because you must address various quality dimensions, including the quality of the research proposition (e.g., novelty, relevance), the quality of the research process (e.g., soundness and adequacy), and the quality of the communication (e.g., clarity and consistency).

Communication about the research is often neglected when preparing the TP as you immerse in and gain familiarity with the research domain. On the other hand, examiners can be highly sensitive to communication issues, amplifying perceived problems and concerns. This divide between your and the examiners' viewpoints can frustrate both parties.

The main purpose of this document is to help you understand that good communication is an essential, inseparable part of research at the Ph.D. level and to help think strategically about it from the beginning. Several aspects are discussed: strategy, worldview, methodology, literature review, problematization, research questions, propositions, solution artifacts, expected contributions, and document structure.

2 Strategy

Having strategic clarity about what is involved in conducting research at the Ph.D. level is a pre-condition for writing a TP. The canvas approach can be useful to delineate and summarize the proposed research's **key points** and check overall consistency and completeness. Figure 1 shows a thesis proposal canvas. The canvas offers two advantages: 1) it helps to comprehensively and systematically address all elements required by the TP; and 2) it helps to contemplate the TP as a coherent whole, where all elements must be articulated and harmonized.

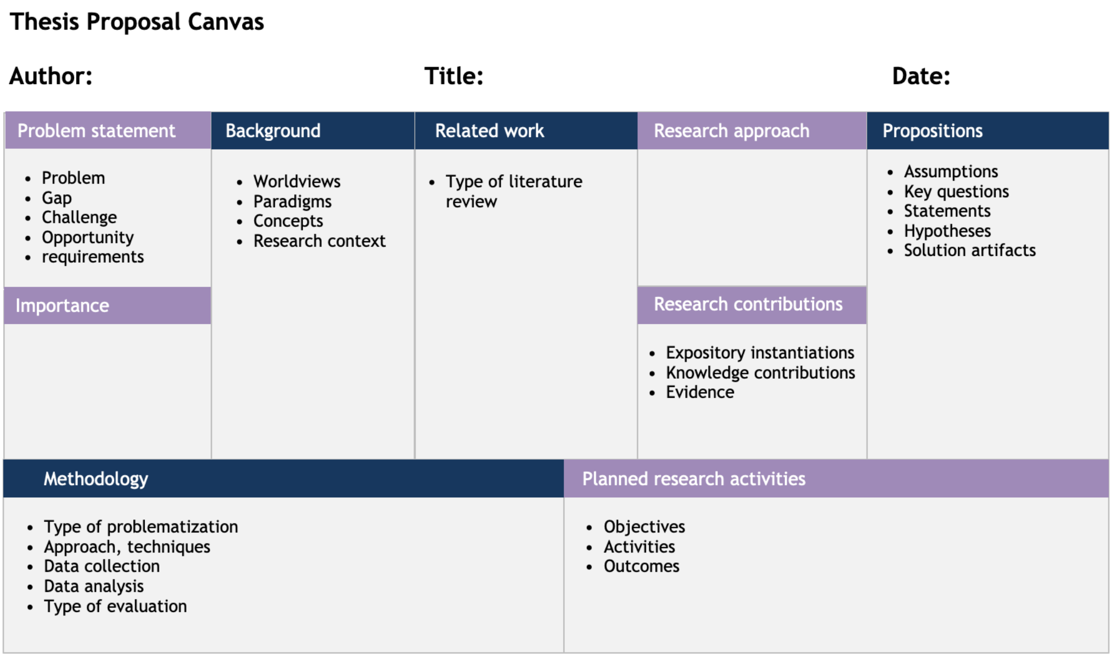

Figure 1. Thesis proposal canvas (template)

Of course, the canvas in Figure 1 is just a template. Other canvases may be adapted to specific research areas (e.g., Gregor, 2017). Informatics is a diverse field; therefore, different research practices may require fine-tuning the canvas. Furthermore, the examiners will also be diverse; therefore, whatever type of canvas is adopted, it should cater to a wider research community.

3 Worldview

Scientific research is framed by competing worldviews (e.g., quantitative versus qualitative research, positivism versus pragmatism, design versus use) and research communities built around these worldviews. Therefore, you must carefully position yourself within a research community.

The *worldview* concept differs from the *domain* concept. On the one hand, the domain situates the research problem. For instance, the problem may relate to systems architectures, programming languages, user interfaces, etc. On the other hand, the worldview identifies the unique set of values, paradigms, theories, methods, and experiments adopted by a research community that permits a specific set of solutions (Kuhn, 1970). For instance, the sensemaking construct has been researched from two very different worldviews: organizational, which emphasizes how organizations make sense of situations (Weick *et al.*, 2005) ; and individual, which centers on how individuals make sense of situations (Klein *et al.*, 2006).

Understanding the different worldviews in a research domain can be overwhelming. This is an area where the supervisors' expertise is critical to position the TP in an expeditious way.

The **adopted worldview** should be identified early on to avoid misconstruing the TP. The selection of references helps readers identify which research community the TP is aligning with. That selection should be consistent to avoid constantly moving between worldviews. Provide examples of relevant studies stemming from the adopted worldview and discuss the affinities and similarities to your research. The TP should seek recognition from the selected research community.

4 Methodology

Methodology concerns the philosophical discussion about how research is done (research models) and the development of research methods and techniques (Stol and Fitzgerald, 2018). Methodology scaffolds the research design, i.e., selecting a particular research process (e.g., algorithm optimization, application development, simulation), activities (e.g., modeling, design, prototyping), and techniques (e.g., field observations, lab tests, beta tests). As quoted by Stol and Fitzgerald (2018), "The proper place to study elephants is the jungle, not the zoo. The proper place to study bacteria is the laboratory, not the jungle". Decisions regarding selected research methods and the adopted research design must be discussed and justified in the TP.

Based on anecdotal evidence examining a wide range of TPs, methodology is a complicated matter in informatics. Often, what is presented as methodology is merely a research plan delineating a series of research steps. In other cases, methodology is regarded as unspoken in specific research domains. As some research communities often do not explicitly discuss it, it must be inferred from currently accepted practices.

A starting point for considering research methodology is to define what **genre of research** will be adopted. The literature on research methodology discusses numerous possibilities. The following list lacks structure and is incomplete but highlights some common genres:

- **Experimental research** (Stol and Fitzgerald, 2018): Focuses on evaluating something (e.g., algorithms, systems, tools) under controlled conditions. Usually, there is an emphasis on quantitative evaluation and comparative analysis (e.g., before-and-after, this-versus-that).
- **Exploratory research** (Stol and Fitzgerald, 2018): Focuses on exploring possibilities brought by new ideas, technologies, and applications. Exploration is often done in poorly controlled conditions or artificial environments. Usually, it seeks to understand the challenges of a particular setting and gather qualitative findings about "what was going on."
- **Descriptive research** (Creswell, 2009**)**: It is highly theoretical. A set of variables is defined, and their relationships are studied, which helps describe and ideally explain a phenomenon of interest (e.g., database optimization, protocol efficiency). This type of research is highly sought after in the information systems field, but it is less common in the wider informatics landscape.
- **Developmental research** (Richey and Klein, 2005): It is pragmatic and practice-oriented. The main focus is developing a first-of-a-kind artifact (e.g., new language, algorithm, interaction device, software framework). It involves careful articulation between the problem, requirements, design, development, and evaluation. The primary evaluation focus is on successful use.
- **Design (science) research** (Hevner *et al.*, 2004): It is focused on creating novel and innovative artifacts (e.g., methods, constructs, algorithms, architectures, systems, and processes) that resolve identified organizational problems (e.g., security, privacy, performance). Design involves iterative build-evaluate cycles anchored on relevant needs and a rigorous understanding of the existing knowledge base (e.g., models, methods, designs). The primary evaluation focus is on utility. Design science research is very common in informatics. For instance, decision-support systems are often researched using design science (Arnott, 2006).
- **Action research** (Baskerville, 1999): It is grounded in immediate and practical action to solve an immediate problem based on useful knowledge. It involves an intervention from the researcher in a real-world organization, such as introducing a new technology or software development practice in a company. The evaluation focus is on observing and analyzing the impacts of the intervention.
- **Case study research** (Ketokivi and Choi, 2014): Focuses on a detailed understanding (thick descriptions) rather than a generalized understanding of a phenomenon. It considers a particular case or a set of cases and their empirical contexts, which are then analyzed and compared in detail (e.g., introducing a privacy-preserving mechanism in a hospital).
- **Applied research** (Niiniluoto, 1993): Focuses on the practical application of existing knowledge (including technological solutions) into a new domain. The outcomes are usually focused on effectiveness towards the intended uses. Applied research is very common in informatics, as ideas developed in some fields are constantly tested in other fields. However, care is necessary to provide substantive knowledge contributions from new applications.
- **Simulation research** (Stol and Fitzgerald, 2018): It models a particular system or phenomenon. It provides a detailed understanding of the model construction, explains the targeted system or phenomenon, and contributes measurements.

Understanding methodology is essential to communicate research at the Ph.D. level. A Ph.D. thesis is a theoretical (knowledge) contribution that must be adequately grounded and substantiated. Sheppard and Suddaby (2017) suggest that making and communicating a theoretical contribution is like telling a good story. The authors suggest the following structure, which underlines good theoretical contributions (Figure 2):

- **Narrative setting**: The time and place where the story starts. In other words, the particular **research context** of the TP. In informatics, this often corresponds to technology, system, or application;
- **Characters**: The elements that participate in the story. I.e., the research **core constructs** (e.g., assumptions and propositions). This depends on the research domain. For instance, the core constructs may refer to a system, system architecture, set of algorithms, requirements, users, assessment criteria, and parameters;
- **Narrative conflict**: The tensions that drive the story and make it interesting and relatable. Any good story requires a good conflict. This refers to the **research problem** and/or **research gap**. They must be compelling, exhibiting a certain level of drama and urgency in problem-solving;
- **Narrative arc**: Where the story goes. In other words, having identified a research problem/gap, you must explain what must be done to tackle it, which requires a set of **research activities** (e.g., build and evaluate).

This storytelling approach provides the necessary scaffolding for discussing methodology and articulating the research context, core constructs, research problem/gap, and research activities.

Figure 2. Theoretical contribution

Instead of scaffolding the methodology on storytelling, it can be scaffolded on the research process. For instance, the process shown in Figure 3 provides a logical structure for discussing methodology in a TP (Thuan *et al.*, 2019).

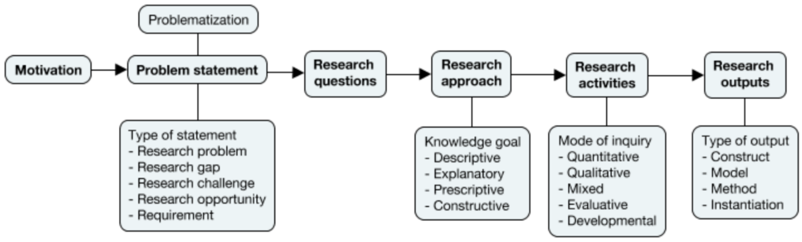

Figure 3. Research process

Another alternative is to scaffold the methodology on a coherent set of research questions, as shown in Figure 4 (Thuan *et al.*, 2019). The questions in Figure 4 scaffold the design science research paradigm, which is common in informatics (Hevner *et al.*, 2004).

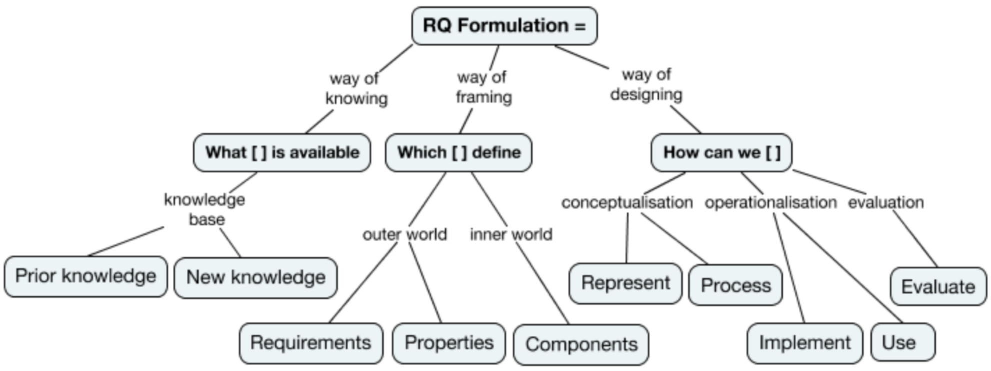

Figure 4. Research questions

Methodology is not the same as a research method or research design. Methodology relates to the philosophical principles adopted to conduct the research. Methods apply methodology to accomplish defined goals.

The TP should describe and justify the adopted research genres, associated methodology, and methods. Examples of studies using these elements to address similar problems should be provided. They give confidence in the TP.

Methodology and methods support the **research design** (plan). The research design consists of defining and articulating a set of research activities, which instantiates a concrete research method following a defined research methodology in a particular research context. The research design is a direct consequence of the adopted research genre, methodology, and methods, not vice versa. The TP should demonstrate that the research design can implement the adopted research genre, methodology, and methods.

In general, you are expected to contribute knowledge related to the identified research problem/gap using existing methodology. You are not expected to contribute new research genres or methodologies (as they are defined over time by the research community). Existing methods may have to be adapted or extended to the specific research context, and analyzing these adaptations and extensions could be a potential knowledge contribution.

5 Literature Review

The literature review is an essential component of research. Unfortunately, a common approach to literature reviews in informatics is to build a "laundry list," where items of interest (studies, methods, algorithms, software components) are listed with no particular structure. Another approach that should be avoided is the "historical overview," where items of interest are discussed chronologically. Historical overviews are not very interesting in TPs because they usually reveal more about your learning process than exactly where the research field stands today.

Systematic reviews are trendy nowadays (Paré *et al.*, 2015). They require the definition of a specific set of search criteria and systematic search in databases such as Scopus, ACM, and Google Scholar. The search is followed by screening, where well-defined inclusion and exclusion criteria are consistently applied. Systematic reviews are highly recommended. However, they may not be completed in time for the TP.

A good literature review should not just account for prior research. It should also clarify and structure the current state of the art. Two excellent ways to do this are (Kuorikoski and Ylikoski, 2015):

- **Build a conceptual framework**: Define a set of concepts and relationships (using boxes and arrows) that position the research problem, highlight different concerns, issues, and sub-problems, and emphasize the research gap. A conceptual framework summarizes your viewpoint about the state of the art.
- **Model**: Characterize the state of the art using a known modeling approach. The model highlights typical relationships, such as cause-effect, input-process-output, parent-child, and before-after.

Antunes et al. (2022) explains the significant properties of these types of artifacts.

6 Problematization

Problematization concerns identifying research problems/gaps in existing knowledge (Alvesson and Sandberg, 2011). It derives from a critical analysis of the literature review. There are several well-known approaches to problematization:

- **Critical research**: Identify a phenomenon of interest, characterize the existing explanations, and then challenge those explanations;
- **Problem-solving**: Identify an existing problem (with theoretical and practical implications) and then explore and test an innovative solution (e.g., a better-performing algorithm);
- **Gap spotting**: Characterize an existing body of knowledge and then discuss what specific knowledge is missing;
- **Requirements definition**: Characterize a future artifact and its operating environment (e.g., method, process, software component). Show that developing that artifact requires meaningful research.

Problem-solving and requirements definition are common problematization approaches in informatics, an applied research domain.

7 Research Questions

There must be more than a good idea to pursue a Ph.D. study. That idea has to be translated into good **research questions**. Research questions are the cornerstone of a TP. They represent the facets of research that will be explored in the study.

Miles et al. (2014) identify the following types of questions addressing different kinds of knowledge:

- **Questions of 'what'**: For instance, "What is the impact of X on Y" and "What are the components of X." They focus on describing something, e.g., system components and tools.
- **Questions of 'how'**: For example, "How is X developed" and "How X affects the quality of Y." They focus on processes.
- **Questions of 'why'**: For instance, "Why is X better than Y." They focus on understanding something based on good reasons, explanations, and causation (cause-effect and influence-affect relationships).

Since informatics is an applied, constructive, and exploratory research domain, the TP may involve a variety of questions covering the three categories.

Bordens and Abbott (2014) note that research questions should fulfill some important criteria:

- They should be **answerable**. Not all questions can be answered;
- They should be **answerable by scientific means** (i.e., they should be objective and precise, reproducible under the same conditions, and confirmable by others);
- They should be **relevant**, not trivial, or already established questions. A question is relevant if it allows one to discriminate between several competing answers.

Research questions are significantly more important than **research objectives**. Research objectives are part of the research plan, which instantiates the research design. Research objectives define milestones in a research project (the "definition of done"). On the other hand, research questions outline the plan as they determine how to acquire knowledge. Research questions are mandatory, while research objectives are secondary in a TP. Consider the following dependencies:

- Research design → Research plan
- Research questions → Research objectives

Considering the TP, the research design and research questions are essential, while the research plan and objectives are subsidiary.

8 Propositions

Propositions are intended to answer the research questions. They are part of the theoretical research discourse, where you argue for propositions treated as **objects under study** (Ravitch and Riggan, 2016).

Propositions are logical building blocks. Some building blocks are taken at face value by the study (e.g., assumptions, pre-conditions, pre-existing findings) as they are thought to exist. In contrast, other building blocks are **explicitly evaluated** by the study for success and failure, a process known as falsification (Popper, 1972).

Propositions should be stated formally and concretely. Vague propositions must be avoided because they are formulated in a way that cannot be reproduced. Bad examples include:

- "I will explore the adoption of X in…": Expresses an intention, not a proposition. The knowledge contribution is vague. Therefore, it cannot be falsified.
- "I will develop X for…": It seems too practical. There is no commitment to a specific knowledge contribution.
- "X can be used to develop Y": The suggested impact of X on Y is unclear and cannot be precisely evaluated.
- "Can I build X?": It is a question, not a proposition.
- "The adoption of X can improve Y": The suggested impact of X on Y is unclear and cannot be precisely evaluated.
- "Using X will promote Y": The suggested impact of X on Y is unclear and cannot be precisely evaluated.

Good examples include:

- "The adoption of X improves Y using criterion Z": Proposes a causal relationship between X and Y, which can be explicitly evaluated using Z.
- "By changing X in Y, the design of Z will improve using criterion W": Proposes causal relationships and an evaluation criterion.

A **hypothesis** is a specific type of proposition. Hypotheses are educated guesses about the answers to the research questions (Marczyk *et al.*, 2010).

A hypothesis operationalizes a proposition in a way that can be tested using a set of clearly defined boundary conditions, variables, and indicators (Shepherd and Suddaby, 2017). Formulating a hypothesis is a complex task that requires argumentation, explanations, and justifications anchored in existing literature. Considering this level of detail and sophistication, you cannot simply present a hypothesis in an introductory chapter and say, "This is what I'm going to research." Hypotheses have to be formulated after the literature review, discussion about methodology, and formulation of research questions.

Formulating hypotheses is not a requirement for a Ph.D. in informatics. Many theses in informatics do not formulate hypotheses. This happens because hypotheses are particularly adequate for some research genres (e.g., descriptive research) but not for the diversity of research genres in informatics. For instance, many studies in informatics tend to be exploratory or focus on design and development (e.g., building algorithms and architectures), where answers may be challenging to establish a priori. Focusing on sound research questions seems more advisable than flaky hypotheses. A hypothesis that states, "I can build X," is a disservice to research in informatics.

9 Solution Artifacts

A large body of research in informatics involves designing and building solution artifacts. Unlike other research domains where the main goal is to generate knowledge, in informatics, the solution artifacts are an essential part of knowledge. In particular, solution artifacts provide **expository instantiation**, i.e., they illustrate how a problem can be solved, assist in understanding the solution, and provide the means for purposes of testing (Gregor and Jones, 2007).

Solution artifacts cannot be completely black-boxed by the TP. In particular, details about the nature of the artifact, properties, inner components, and behavior are essential for others to be able to recreate solution artifacts and apply them in different contexts (Simon, 1996; Walls *et al.*, 1992). Therefore, these details are essential elements of knowledge in informatics and should be briefly overviewed by the TP.

Furthermore, expository instantiation should not be considered the sole aspect to consider when discussing solution artifacts. Other aspects to consider in the TP include:

- Requirements and meta-requirements (classes of goals to which the solution artifact applies) (Walls *et al.*, 1992);
- Justificatory knowledge shaping the design and construction of solution artifacts (Gregor and Jones, 2007);
- Adopted design and construction principles and methods (e.g., Agile principles, user-centered design);
- Set of criteria adopted to validate the solution artifacts.

10 Expected Contributions

Assume that the examiners will conduct a cost-benefit analysis of the study. The expected contributions of the study should be discussed against the opportunity and cost of doing the research. If a greater weight comes to the researcher's side, then the research is justified.

As noted earlier, in informatics, there is a strong tendency to consider solution artifacts as the main contributions of a study. However, the expected contributions should extend beyond these artifacts to focus on valuable knowledge. For instance, it is essential to consider the replication and extension values of both the artifacts and the design and evaluation processes.

11 Document Structure

A recommended structure for the TP is as follows:

- Abstract
- Introduction
- Methodology / research design / research approach
- Background / literature review / related work
- Research questions
- Research activities / research plan
- Conclusions
- References

11.1 Abstract

The abstract should provide a concise summary of the research. It is preferable to use a structured abstract, for example:

- **Problem/gap**: Either identify the research problem or the research gap. Avoid focusing on objectives. In a Ph.D. thesis, problematizing is usually better than simply stating a list of objectives.
- **Methodology/research design**: Position your research design in existing methodology. Summarize and justify the adopted research design.
- **Originality/contributions/results**: Explain how the research advances knowledge.

The abstract should have around 200-500 words.

11.2 Introduction

The introduction should be linear and concise (usually taking 1-2 pages). Avoid waffle speech, i.e., too many grand ideas, open issues, digressions, unclear directions, and lack of meaning. Sometimes researchers start with a grand idea (e.g., climate change) and finish with a minor goal (e.g., building a software tool for recycling). Calibrate the challenges and goals so that the examiners can easily understand the general viewpoint, goals, and pathway. Remember that the examiners may not know the research field in detail. Talk to a broad audience. Avoid bringing in too many technical details.

Position the research, identifying the wider and specific domains (e.g., wider: information systems, specific: microservices) and identifying the adopted worldview.

Do not present research questions, propositions, or hypotheses in the introduction. These essential elements of research require significant contextualization and precision, which are impossible to achieve in an introduction.

Finish the introduction with a paragraph describing the structure of the remaining parts of the document.

11.3 Methodology / research design / research approach

Summarize the adopted methodology and methods and explain why they have been selected. Describe the research design in a linear way. Give examples of similar research adopting the same methodology, methods and research design.

This section should have 1-2 pages.

11.4 Background / literature review / related work

Summarize the existing literature on the selected topic. Refrain from digressing much. You do not need to go way back. Check the quality of the selected references. Also, check the overall recency of the citations. Too many old references may indicate that the topic is well-known or abandoned.

Identify who has been leading the research on the selected topic. These researchers should take center stage. Discuss existing reviews and meta-reviews on the chosen topic. Synthesize the literature review and point out the research gap.

The size of this section is highly variable but consider 10-20 pages.

11.5 Research questions

Carefully draft a set of questions that clarify exactly what will be researched. The questions should be precise and clear. They should relate to the research gap identified in the previous section.

11.6 Research activities / research plan

This section is intended to explain how the research design is operationalized, considering, in particular, how the research questions will be answered. Each research question has to be researched, and an answer has to be found. Provide enough details for the examiners to determine if everything is cohesive and sound.

For each research question, define the **research objectives** (in relation to knowledge, e.g., understand, explain, describe), **research activities** (in relation to inquiry, e.g., conceptualize, build, evaluate), and **research outputs** (e.g., algorithm, prototype, system component, data). Explain how the research will enfold, articulating the set of objectives-activities-outputs. The whole research process should be easily understandable. Note that some research outputs may result in solution artifacts or parts of solution artifacts (e.g., software components), while other parts may result in the validation of solution artifacts.

Since propositions must be tested, discuss what evidence (logical or empirical) will be gathered. Evidence can be related to truth (either a proposition is true or false) or utility (e.g., utility of a software component for developers). Explain how evidence will be gathered (e.g., lab data, simulation, questionnaires).

This section should have 5-10 pages.

11.7 Conclusions

A TP does not require a conclusion; if there is one, it will necessarily be light. Demonstrate that the research plan addresses the statements in the introduction.

11.8 References

References are essential and should be managed appropriately. Sloppy references tell a lot about your research. Use an adequate referencing tool. Zotero is highly recommended.

The most common citation scheme for a Ph.D. thesis is (Author-Date). Do not use the [Number] scheme, often found in conference papers.

Be careful about what you cite. Check the quality of the study and venue before you cite. Avoid at all costs using shady and obscure venues. Stand on the shoulders of giants.

Carefully calibrate the number of references provided. Having too many references supporting a specific topic is useless and suggests a lack of selectivity.

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