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Usa-DSL: a Process for Usability Evaluation of Domain-Specific Languages

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Abstract: Software architects and developers often use Domain-Specific Languages (DSLs) to model or code applications. However, designing a DSL that effectively represents its domain can be a challenge, potentially contributing to poor uptake and usage. To the best of our knowledge, one issue is that DSL designers may evaluate their language's usability using *ad hoc* processes, due to a lack of expertise in usability evaluation. Additionally, current approaches lack well-defined processes and may not yield the desired results for DSL designers. Therefore, DSL designers require a well-defined usability evaluation process to assess how architects, developers, and end users perceive their DSL. This paper introduces Usa-DSL, a Usability Evaluation Process for Domain-Specific Languages. Usa-DSL aims to assist DSL designers in evaluating their languages in terms of ease and quality of use, without requiring deep knowledge of usability evaluation. We analyze the feasibility of Usa-DSL and show that it is a useful and user-friendly tool for evaluating DSLs.

Keywords: Domain-Specific Language, Evaluation, Process, Quality, Usability
Categories: D.4.1, I.1.3, L.0.0
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1 Introduction

The development of computer systems has expanded into various domains, including Social Sciences and Engineering, leading to the creation of Domain-Specific Languages (DSL) tailored for these specific fields [Mernik et al., 2005]. Regarding the origin of a DSL, it can be internal and external. Designers create an internal DSL by establishing syntactic and semantic rules based on the grammar of an existing language, which could

be a general-purpose language or another DSL. An external DSL is a distinct syntax language that relies on its infrastructure for lexical, syntactic, and semantic analysis, interpretation, compilation, optimization, and code generation.

[Fowler, 2010] classifies DSLs based on their appearance dimension, dividing them into four categories: textual, graphical, tabular, and symbolic. When presented in textual format, a DSL enables the domain to be expressed using characters that are combined to produce words, expressions, sentences, and instructions that adhere to the grammar rules established in the language. Non-textual DSLs follow the same logic but use graphical elements to allow the user to express domain knowledge at a higher level of understanding and use symbols, tables, figures, and connectors. Although the number of DSLs has increased, many fail to gain traction due to a lack of proper usability evaluation.

Due to the increased concerns about the usability of such languages, different evaluation frameworks have been provided [Barišić et al., 2018, Poltronieri et al., 2018]. Usability refers to a set of methods to allow a user to understand and identify elements that make it easier to use a language [Rosenzweig, 2015]. However, to the best of our knowledge, most DSL designers still evaluate their languages in an *ad hoc* manner, which usually does not capture the actual perception of DSL users and, therefore, those languages are not successful [Hesenius and Gruhn, 2019] [Rodriguez-Gil et al., 2019]. An *ad-hoc* evaluation of a Domain-Specific Language (DSL) without clear methodologies or criteria may jeopardize validity and reliability. Without established criteria, subjectivity and biases can affect assessments, potentially leading to inconsistent and unreliable evaluations. The absence of a structured approach raises reproducibility concerns and may overlook critical DSL components. Clear evaluation criteria are crucial to prevent biased assessments. To mitigate these risks, adhering to established methodologies, precise criteria, standardized metrics, and user feedback ensures reliability and validity in DSL evaluations. Hence, to capture the real DSL user perception, it is fundamental that DSL designers use a well-defined usability evaluation process. Although these frameworks exist, they are not driven by a systematic process with explicit steps to guide DSL engineers to evaluate DSLs with appropriate concepts from the Human-Computer Interaction (HCI) field. This can help DSL designers to create well-defined experiments, case studies, or surveys, and apply usability evaluation methods, *e.g.*, Heuristic Evaluation [Nielsen and Molich, 1990] or Usability Testing [Sharp et al., 2019].

Therefore, this paper presents a usability evaluation process, named the Usa-DSL process, which intends to help DSL designers during the development and conduction of usability evaluation of their DSL. The main goal of the Usa-DSL process is to facilitate the whole usability evaluation and, at the same time, to avoid the need to have deep knowledge of usability methods.

To build this process, we used concepts from well-established metamodels and notations and a usability evaluation framework. Those concepts were used to describe steps, activities, tasks, and guidelines in our research. Thus, the DSL designers can perform their evaluation in a systematic and efficient manner Basically, Usa-DSL is described using Software and Systems Process Engineering Metamodel (SPEM) [OMG, 2018], Business Process Model and Notation (BPMN) [OMG, 2019], and Usa-DSL Framework [Poltronieri et al., 2018].

We use the Usa-DSL framework in this work since it seems, to the best of our knowledge, to be the only complete DSL usability evaluation framework. It was evaluated through interviews and focus groups and presented the need for a process to help systematize the conduction of a DSL usability evaluation. Hence, in this paper, we provide a full support process to guide all phases, steps, and activities of such Usa-DSL framework [Poltronieri et al., 2018] to aid the systematized conduction of usability evaluations.

Furthermore, we also provide an evaluation of our process through the Technology Acceptance Model (TAM) [Davis, 1989]. This model assists in verifying the perception of ease of use and the perceived usefulness of our process.

It is important to point out that, although the Usa-DSL process might seem dense due to the number of activities it contains, these activities will not be used all at the same time, but according to the context and need for the evaluation. Furthermore, the process will be assisted by a tool that will provide templates to speed up the generation of usability artifacts. Examples of activities are: Define Evaluator Profiles (Planning phase), Develop and Conduct Protocol (Execution phase), Analyze the Developed Protocol (Analysis phase), and Report Data Analysis (Reporting phase). Its structure was planned to be customized depending on the evaluation needs, *i.e.*, different Steps, Phases, or Activities.

This paper is organized as follows. Section 3 presents Usa-DSL process in terms of structure, method content, life cycle, and guidelines. Section 4 presents and discusses the evaluation of our process. Section 2 presents the related work. Finally, Section 5 presents some final remarks and directions for future work.

2 Related Work

Several researchers have applied different usability evaluation methods to assess DSLs. In this section, we discuss some works that, somehow, are related to our proposal. Some of the works are related to usability evaluation frameworks and others to process modeling notations.

[Melody and Hearst, 2001], for example, introduced the state of the art in automating usability evaluation of user interfaces. To do so, they propose a taxonomy for classifying usability evaluation automation. Then, based on the taxonomy the authors present a survey conducted to analyze 132 usability evaluation methods.

In a different perspective, Karsai *et al.* [Karsai et al., 2009] investigated useful guidelines for designing DSL, largely based on their experience in developing languages as well as relying on existing guidelines on general purpose and modeling languages. Such guidelines help DSL developers to achieve a better quality of language design and acceptance. Similarly, Kahraman and Bilgen [Kahraman and Bilgen, 2014] presented a framework for the qualitative evaluation of DSLs.

[Gilson, 2018] and [Abrahão et al., 2017] discuss how usability is dealt with in Software Engineering. While Gilson reports his attempt to teach software language engineering and usability using the peer review method with students, Abrahão *et al.* discuss challenges and future directions of User eXperience (UX)-related research in the Model Driven Engineering (MDE) community. [Barišić et al., 2018] introduced a conceptual framework that helps the usability evaluation into an iterative incremental development process of DSLs. The purpose of the framework is a systematic approach based on User Interface experimental evaluation techniques.

[Mosqueira-Rey and Alonso-Ríos, 2020] presented a set of usability heuristics for DSLs and introduced a case study to evaluate their approach. The approach is based on the usability taxonomy proposed by [Alonso-Ríos et al., 2009], which is composed of the *Knowability*, *Operability*, *Efficiency*, *Robustness*, *Safety* and *Subjective Satisfaction* attributes. The authors argue that their heuristics can aid in identifying real problems of usability, including even simple DSLs.

Over the past years, some research papers have emerged as literature reviews and evaluations in Software Process Modeling Languages (SPMLs) [García-Borgoñón et al.,

2014] [García-García et al., 2019]. Nonetheless, guidelines for choosing the better SPML to instantiate a process are still missed.

[García-Borgoñón et al., 2014] presented a systematic literature review with trends in SPMLs. The authors presented various software process modeling languages that have been built up in the past decade and argued that model-based SPMLs are currently a prominent trend. As a result, the study summarizes an overview of the relations and technologies of existing SPMLs. Furthermore, they presented the benefits and drawbacks of different SPML paradigms.

[García-García et al., 2019] proposed a quality evaluation framework set for model-based SPMLs. In summary, this quality model is composed of nine features: (i) semantic richness and expressiveness; (ii) understandability; (iii) conformity to standards such as UML; (iv) granularity; (v) executability and orchestrability; (vi) measurability; (vii) business rules support; (viii) support tools; and (ix) validation in real environments. They instantiated their quality model for comparing and characterizing 10 representative SPMLs of different approaches, which represented initiatives from industry and academia.

Although different papers present ways to evaluate DSL usability, the Usa-DSL process, to the best of our knowledge, is the only complete process that helps a DSL designer to choose different methods, *i.e.*, experiments, case studies, or surveys, and also usability evaluation methods, *i.e.* Heuristic Evaluation or Usability Testing. The Usa-DSL process contains evaluation concepts, activities, and their respective performers responsible for performing them. Furthermore, DSL designers can follow a clearly defined evaluation life cycle provided by the Usa-DSL process.

Unlike the mentioned related work, the Usa-DSL process does not involve only evaluations based on metrics and features to be used but also encompasses the entire building process of an empirical assessment using, in a clear way, the aspects of a usability evaluation. Our proposal was built with a complete life cycle in mind, encompassing the development of a formal protocol with defined steps drawn from the Empirical Software Engineering area [Wohlin et al., 2012] and considerations for Usability [Preece and Rombach, 1994] and Heuristic Evaluation [Nielsen and Molich, 1990].

2.1 Research Timeline

Before we present what will be discussed in this paper, it is important to understand the context of our research. Our work is divided into three parts: (i) the design of a usability evaluation framework, called Usa-DSL framework, which was previously published [Poltronieri et al., 2018]; (ii) the development of a usability evaluation process, called Usa-DSL process, which will be described in this paper and follows the Usa-DSL framework; and, (iii) the implementation of a tool to assist the design of DSL usability evaluation artifacts, which will follow the Usa-DSL process. Each part is briefly described next:

Previous Work: our previous work presented the main motivation for the development of the Usa-DSL framework, *i.e.* the need to evaluate a DSL created for performance testing. We will briefly describe the Usa-DSL framework in Section 2.2. The main aspects described in our previous work are related to the framework concepts and requirements, and also a focus group evaluation. One of the aspects pointed out by the focus group was the need to provide an execution flow (process) for the DSL designer. This process would aid the DSL designers to understand the order of the tasks they would have to execute when building the usability evaluation of their DSL.

This Work: this work will present the Usa-DSL process and a survey-based evaluation. Notice that our process is based on the Usa-DSL framework built in our previous

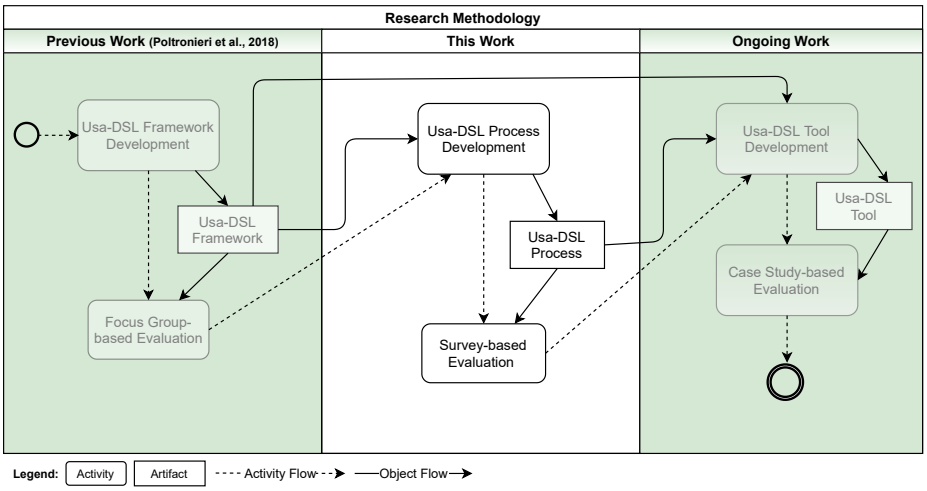

Figure 1: Research Timeline

work. Aspects related to "Who will do what, when and how?" will be presented in Section 3.

Ongoing Work: to speed up the process of building the needed artifacts described in our process, we are implementing a tool to aid DSL designers in building their usability evaluations. The tool, called Usa-DSL tool, will generate all artifacts, based on templates, for example, invite e-mails, questionnaires, informed consent terms, and so on.

2.2 Usa-DSL Framework: Usability Evaluation Framework for DSL

The Usa-DSL framework provided by [Poltronieri et al., 2018], *"takes into consideration the aspects of Human-Computer Interaction and applies them to the evaluation of the usability of DSLs"*. The framework structure is composed of Steps, Phases, and Activities. Its structure is based on the process life cycle projects [Stone et al., 2005]. There are 11 Steps (Evaluators Profiles, Ethical and Legal Responsibilities, Data Type, Empirical Study Method, Evaluation Method, Metrics, Gathering Instruments, Evaluation Instructions, Evaluation Conduction, Data Packaging, and Evaluation Reporting), Phases are composed of four execution cycles (Planning, Execution, Analysis and Reporting - PEAR), and Activities are formed by a set of 32 concepts that are distributed throughout the Phases (see Figure 2).

The Usa-DSL framework was designed to be adapted to the needs of each evaluation. A DSL designer can start the "Planning" phase from any of the steps present in the Usa-DSL framework. For example [Poltronieri et al., 2018], the evaluator can start the evaluation planning by the "P1 Define Evaluators Profiles" activity, or by the "P3 Define Data Type" activity. This will improve the framework flexibility since it allows the different evaluators to start the evaluation based on the activities that they feel more comfortable with, the ones that they already have some data, or even the activities that are easier to perform for a specific DSL. Furthermore, not all steps have to be performed. Some of them might not be executed, for example, the "4 - Empirical Study Method (SE)" step is only needed if the end user will be involved.

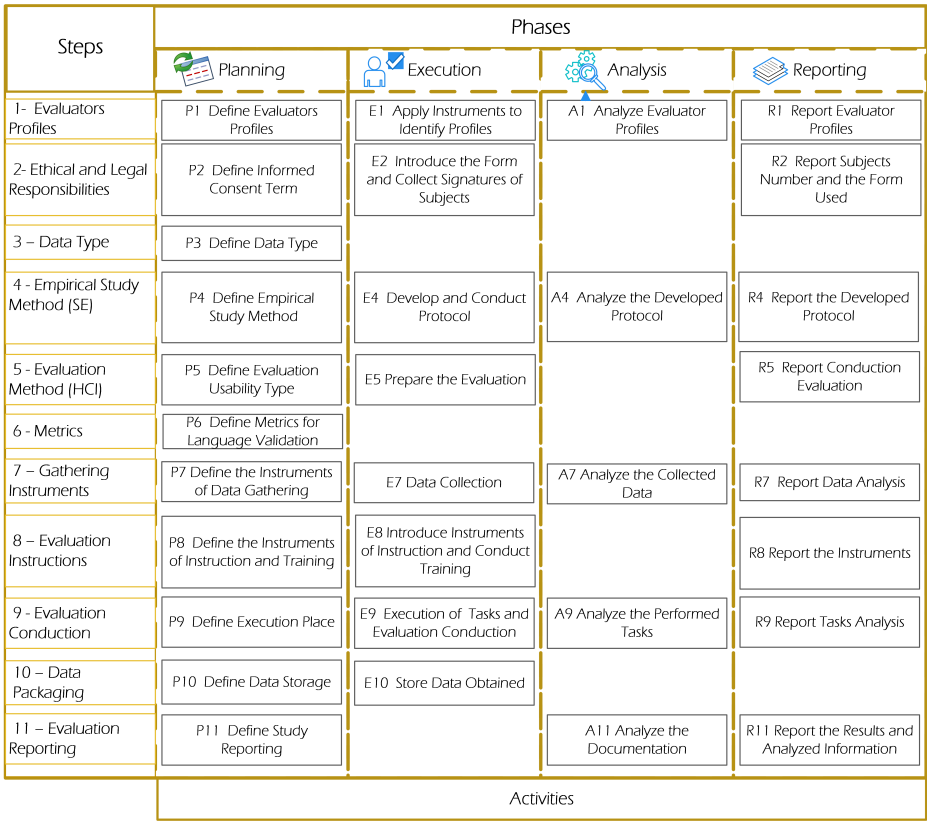

Figure 2: Usa-DSL Framework Structure [Poltronieri et al., 2018]

The Usa-DSL framework Steps and Activities will not be presented in this work, which has been described in our previous work [Poltronieri et al., 2018][1]. On the other hand, to understand our process, it is important to understand the four Phases of the Usa-DSL framework: Planning, Execution, Analysis, and Reporting (PEAR phases) [Poltronieri et al., 2018].

Each phase has a set of activities that are related to a respective step: *Phase 1 - Planning*: in the planning phase, the evaluator organizes the aspects that will be used to evaluate the DSL. In this phase, documents must be designed and created. Furthermore, in Phase 1, data that has to be collected or what kind of user will be part of the evaluation have to be defined. In a nutshell, Phase 1 defines the structure and planning of the evaluation that will be performed; *Phase 2 - Execution*: in the execution phase, the created documents are used, subjects are recruited, environments are configured and the evaluation is performed; *Phase 3 - Analysis*: in this phase, an analysis of the users' profiles, documents, questionnaires, the whole protocol is performed; and, *Phase 4 - Reporting*: in this phase, the DSL designer will register the used protocol, the artifacts, and analyzed data. Figure 2 shows the activities that compose each of the Usa-DSL

[1]For more details about Usa-DSL framework, visit: https://github.com/Ildevana/Usa-DSL/wiki

framework phases.

However, during the evaluation of the Usa-DSL framework, it became evident that a well-defined, replicable process was needed to guide its application effectively. This necessitated the development of a process that adheres to established best practices while ensuring predictability and detailed guidance for various aspects, including steps, workflows, roles, activities, and tasks, along with the provision of guidelines and tools for tasks carried out during the assessment [Poltronieri et al., 2018]. Despite the some Software Engineering processes available for developing systems that meet user needs, we have not, to the best of our knowledge, identified a specific process designed to guide the usability evaluation of Domain-Specific Languages (DSLs) [Poltronieri, 2021].

During the assessment of the Usa-DSL framework, it became apparent that an explicitly defined and replicable process was indispensable to effectively steer its application. This prompted the development of a method adhering rigorously to established best practices, ensuring predictability, and offering comprehensive guidance on diverse facets such as steps, workflows, roles, activities, and tasks. This process further extends support by providing guidelines and tools crucial for executing tasks during assessments [Poltronieri et al., 2018]. While numerous Software Engineering methodologies exist for crafting user-centric systems, our investigation has not uncovered a dedicated process tailored to guide the usability evaluation specifically for Domain-Specific Languages (DSLs) [Poltronieri, 2021].

Usability evaluation methods find broad applicability across varied systems. However, the absence of a dedicated process catered to evaluators lacking Human-Computer Interaction (HCI) experience, particularly DSL specialists, constrains the effective utilization of these methods within their development contexts. Consequently, Usa-DSL not only aids evaluators in the practical implementation but also recommends the most fitting method pertinent to the DSL context. It proffers meticulous guidelines delineating the activities to be executed by each profile during the evaluation. Moreover, Usa-DSL presents an inclusive suite of work products encompassing questionnaires, interview scripts, and usage scenarios, pivotal for conducting comprehensive usability evaluations.

Within the purview of Poltronieri's thesis, a bespoke usability evaluation process has been formulated. The primary objective of this method is to streamline the usability evaluation process, alleviating the necessity for Language Engineers to extensively engage with and navigate through the intricacies of usability methods.

3 Usa-DSL Process: Usability Evaluation Process for DSL

The Usa-DSL process is a usability evaluation process for Domain-Specific Languages (DSL) that, over time, is expected to cover a broad set of needs of DSL designers concerning the usability evaluation of DSLs.

We designed Usa-DSL based on four principles [Sommerville, 2001]:

(i) **Supporting**: to aid the performing of usability evaluation practically and efficiently;

(ii) **Continuous feedback**: to assist DSL designers and to promote continuous improvement of the language;

(iii) **User-centered evaluation**: throughout all the building phases, to minimize the DSL rework and misuse [Nielsen and Molich, 1990];

(iv) **Productivity**: to make DSL evaluation easier and more productive, aiming to reach usability criteria and user satisfaction.

We modeled Usa-DSL using SPEM [OMG, 2018] and BPMN [OMG, 2019]. Software and Systems Process Engineering Metamodel (SPEM) is a process engineering metamodel and a conceptual framework that makes it possible to provide the necessary concepts to model, document, present, manage, change, and execute development methods and processes. The implementation of this metamodel is aimed at process engineers, project leaders, project managers, and developers who are responsible for maintaining and implementing individual processes or for their organizations.

[Poltronieri, 2021] asserts that "SPEM is used to define software and systems development processes as well as their components. It aims to support a wide variety of development methods and processes from different styles, cultural backgrounds, levels of formalism, life cycle models, and communities. This metamodel enables the developer to choose the generic behavior modeling approach that best meets their needs. It even provides a specific framework to enhance those generic behavior models that are characteristic for describing different processes, focusing on providing the necessary additional information structures about processes modeled with UML or BPMN activities, to describe a real process". SPEM was adopted to describe most of the process (see Section 3.5) and BPMN to represent the life cycle flows of our process (see Section 4 and Figure 3[2]. Even though SPEM provides a way to represent flows through UML diagrams, we decided to use BPMN, since it provides a straightforward way to represent sub-activity flows for each phase and the possibility to represent task flows as sub-processes of each of its activities.

One of the main characteristics of the SPEM metamodel is the possibility of specifying different processes from a common knowledge base independent of the specific process. For this, a clear separation between Method Content and Process is defined. The first represents a knowledge base, while the second represents a lifecycle of a specific process. In other words, the knowledge base stores all the information necessary to be consumed in the process life cycle.

The Method Content describes what is to be produced, the skills needed, and a step-by-step explanation of how development goals will be achieved, regardless of where these steps are placed within a development life cycle. The Method Content is composed of the elements: Work Product Definition, Role Definition, Definition, Category, and Guidance.

Process defines sequences of how the work is being performed by functions/roles, as well as the work products being produced and evolved, that is, they describe their life cycle. A process allows you to express the Task Use, Role Use, Work Product Use, Activity, Process, and Guidance elements.

Furthermore, as mentioned in Section 1, the Usa-DSL process was developed based on the Usa-DSL framework [Poltronieri et al., 2018], which is composed of *Phases*, *Steps* and *Activities*.

Usa-DSL is an iterative usability evaluation process [Stone et al., 2005] to assist the process executor in answering questions like "Who will do what, when, and how?" [Sharp et al., 2019] during the evaluation. The main goal is to provide systematic procedures to perform DSLs usability evaluation, through methods, techniques, and activities. The Usa-DSL process deals with the performing of evaluations using methods such as *Heuristic Evaluation* and *Usability Testing* [Nielsen, 1993] to increase productivity and reduce cost.

Usa-DSL structure is composed of Method Content and Process [OMG, 2018]. Method Content is a knowledge base that contains the information that will be con-

[2]A better quality figure can be found at https://doi.org/10.5281/zenodo.10005345

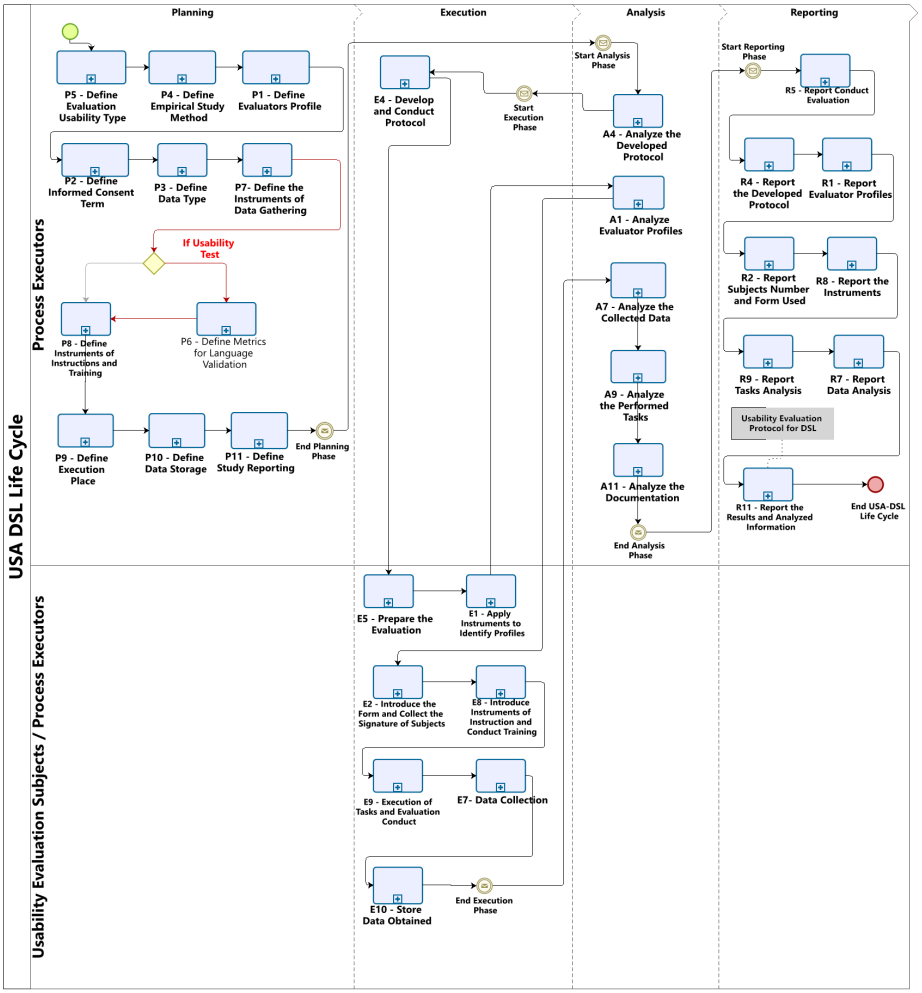

Figure 3: Usa-DSL Life cycle (PEAR PHASES)

sumed by the Process. The information stored in Method Content is organized into Work Products, Profiles, Tasks, and Steps. The process deals with the organization of the elements of the Method Content, relating these elements in a partially ordered sequence and customized for each specific project. The process has the following basic structural elements: Phases, Activities, Profile Use, Task Use, and Work Product Use.

Usa-DSL contains groups of elements that act as guidelines, that is, templates for documents (Informed Consent Term, Heuristic Checklist, Usability Questionnaire) that will be consumed, generated, or modified throughout the evaluation life cycle. These templates will be used by both Method Content and Process. Our Process provides several artifacts used during the execution of a task: Informed Consent Term (ICT), Profile Questionnaire, Usability Questionnaire, Heuristic Checklist, Glossary, Documentation, DSL Guide, Usage Scenario, Training Documentation DSL, Study Protocol, and others.

Usa-DSL also defines different Profiles in the Process. A Profile is an element of Method Content that defines the roles played within the Process. Profiles are used to define who executes each Task, as well as those responsible for a set of Work Products. There are eight (8) profiles in the Usa-DSL process, which are grouped into three (3) Profile Sets. The grouping was organized by the type of execution. The main profile sets are:

- **Process Executors**: it encompasses the Usa-DSL users, who plan and conduct the analysis. These profiles are part of the group that designs, develops, and applies the DSL evaluation: DSL Analyst, DSL Developer, and DSL Tester;
- **Usability Evaluation Subjects**: it is composed of the Domain Analyst, Domain Developer, Domain Tester, and End User. They are those who will contribute to the DSL designers, pointing out the improvements or corrections that must be made to achieve a more pleasant user experience;
- **Heuristic Evaluation Subjects**: this Profile is composed only of the HCI Expert, the heuristic evaluation expert. They aim to evaluate the DSL and aid the DSL developers in finding errors pointed out during the evaluation. They help to improve usability and user experience before presenting the DSL to end users.

To understand the Usa-DSL process, it is important to understand its core principles, its profile sets, its structure, and all activities that compose it. The next sections will present the Usa-DSL process structure, Method Content, Process, guidelines, and process life cycle.

3.1 Structure

The elements from the Usa-DSL process are presented in Figure 4. Those elements are related and compose the process life cycle. The evaluation focus is the DSL that was developed, hence, the evaluation executor must take into consideration the whole DSL engineering cycle. This cycle is composed of its design, implementation, validation, deployment, maintenance, and also problem identification, data collecting, and evidence evaluation. Based on that knowledge, the life cycle is oriented by a set of 4 (four) phases - planning, execution, analysis, and reporting [Figure 3] and organized by a set of 11 (eleven) steps [Figure 2]. Each phase constitutes a series of activities, while a step encompasses fundamental concepts. Both steps and activities are delineated by tasks, which break down broader activities into manageable units, simplifying the allocation, monitoring, and fulfillment of diverse steps. Tasks offer precise directives or actions required to execute an evaluation [Figure 5]. A profile performs tasks and is responsible for work products. The execution of tasks in the specified profile is detailed, emphasizing their composition with distinct work products (*i.e.* Guidelines, Checklists, Supporting Materials, Compiled Data or Templates), forming an integral part of the evaluation process. These work products are inputs/outputs to/from the tasks.

The range of work products encompasses essential tools such as guidelines, checklists, and templates. Furthermore, Usa-DSL not only furnishes these resources but also furnishes profiles responsible (*i.e* DSL Tester, DSL Analisty, HCI Expert) for executing tasks linked to the manipulation of these work products. This involves tasks like modifying templates or support materials, alongside the selection and distribution of checklists to designated evaluators (*i.e* Usability Questionnaire, Script Interview, and Profile Questionnaire).

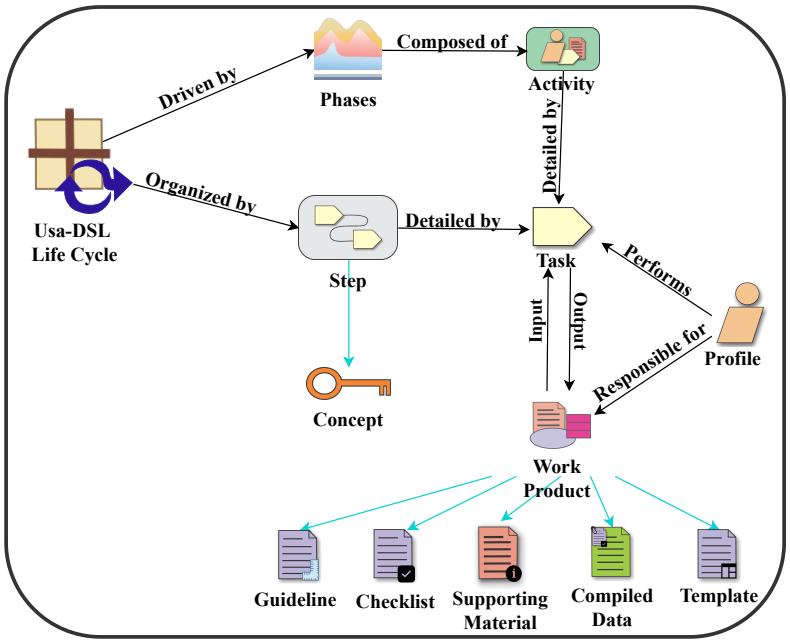

Figure 4: Structure of the Usa-DSL Process

3.2 Method Content

Method Content follows the SPEM metamodel mapped to the Usability Framework:

- `Work Product` represents data consumed or generated during tasks execution;
- `Profile` defines the roles played during the process. Profiles are used to define who executes each task and to define who is responsible for a set of work products;
- `Task` describes a work unit assigned to an activity and a profile, to achieve a well-defined goal. It contains a complete specification to meet a goal. Work product and guidelines (see Section 3.4) are described in a task to achieve the goal. Tasks are presented in the context of the activity they belong to;
- `Step` is a flexible way to define different grouping for content categories. A step is defined by its discipline element, which is derived from the category in the SPEM metamodel. A step is composed of concepts, which are similar concerns and work efforts.

3.3 Process

The Usa-DSL process provides the process life cycle of a usability evaluation through elements derived from the SPEM metamodel. The process is composed of *Phase*, *Activity*, *Profile Use*, *Task Use*, and *Work Product Use*.

- `Phase` is an activity-type element from the SPEM metamodel. In a phase, the execution of activities is prepared. Phases are oriented by steps that specify which and when activities will be executed. Usa-DSL contains 4 phases: *Planning*, *Execution*, *Analysis*, and *Reporting* (Figure 5). It is important to emphasize that each process phase is finished when a set of artifacts has been generated by the subjects that have executed the evaluation.

- `Activities` are represented the same activity elements from the SPEM metamodel. Each activity contains a set of tasks that define the basic work unit in the process. An activity represents a general work unit that can be designated to a Profile Use and can have inputs and outputs. It represents a grouping element for other elements, such as *Tasks Use*, *Profiles Use*, and *Work Products Use*. In the Usa-DSL process, activities group together tasks from a step in a phase from the process life cycle. Hence, each activity contains an identification composed of the initial letter of the phase, a number that identifies a step, and a description of the activity. In Figure 5, for example, "E1 - Apply Instruments to Identify Profiles" is an activity from the "(E)xecution Phase" and "Step (1) - Evaluation Profile".

- `Profile Use` is the Role Use element from the SPEM metamodel. This element represents the executor or participant of an activity. Profile Uses are defined in the profile knowledge base. In Profile Use, the profiles are associated with the tasks they will execute.

- `Task Use` is a work division element that represents a task that will be used by a specific profile in the context of a specific activity. For example, in Figure 5, "P1a - Choose the Profile Evaluator", which is associated with "P1 - Define Evaluators Profiles" activity, will be executed by a DSL designer, for example, *Profile DSL Developer*, which is part of the profile set from "Process Executors".

- `Work Product Use` is an artifact defined in *Work Product* and that will be used during the process execution. This artifact can be a product or a document, that can be consumed, generated, or modified during the execution of a task from an activity. For example, "Profile Questionnaire" is an artifact that must be selected and executed by the profile DSL Developer, or any other from the "Process Executors". In Figure 5, this artifact will be consumed in "E1b Apply Profile Questionnaire" and modified in "E1c Complete Questionnaire Pre-Evaluation".

Figure 5 shows an example of the phases, tasks, and work products for one step of the Usa-DSL process (the whole process can be found at http://lesse.com.br/usa-dsl).

3.4 Guidelines

Guidelines are descriptive elements that provide additional information associated with the process elements. They can be templates, guides, checklists, samples, and papers, among others. These elements are defined in *Method Content* (see Section 3.2), and generated or consumed in *Process* (see Section 3.3). The Usa-DSL process contains different guidelines that can be used in the context of an activity, during the execution of a task by a specific profile.

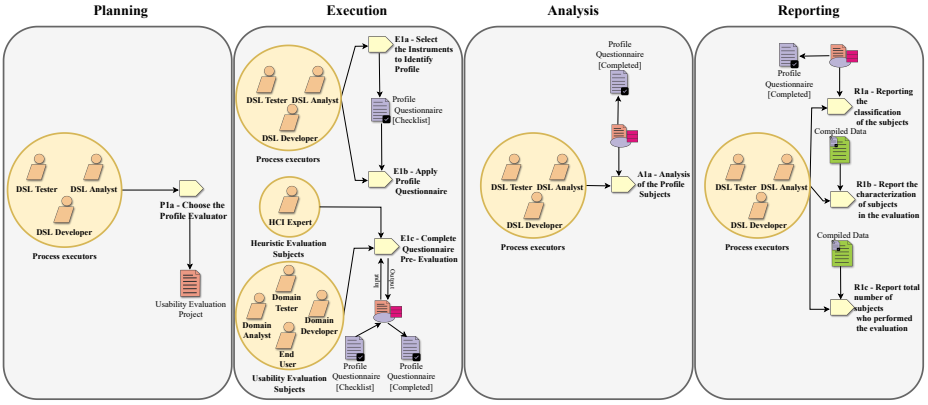

Figure 5: The Process - Step 1

3.5 Usa-DSL Process vs. SPEM

Several elements, or groups of elements, from the SPEM metamodel are mapped to the Usa-DSL process. Tables 1(a) and 1(b) show this mapping. Notice that some of the terms are slightly modified, thus they maintain the same one used in the Usability Framework [Poltronieri et al., 2018].

Table 1: Mapping from the Usa-DSL Process to SPEM

(a) Method Content

SPEM	Usa-DSL
Work Product Definition	Work Product
Role Definition	Profile
Task Definition	Task
Category/ Discipline	Step
Category/ Role Set	Profile Set
Guidance	Guidelines

(b) Process

SPEM	Usa-DSL
Work Product Use	Work Product Use
Role Use	Profile Use
Task Use	Task Use
Activity	Activity
Activity	Phase
Guidance	Guidelines

Regarding SPEM and the Usa-DSL process Method Content, the mapping presented in Table 1(a) is:

`Work Product Definition` was renamed as `Work Product`. Thus it also maps direct to the Eclipse *Process Framework Composer* (EPF) [Eclipse Foundation, 2018]; `Role Definition` was renamed to `Profile` to keep the Usability `Framework` nomenclature; `Task Definition` was renamed to `Task` to keep the Usability *Framework* nomenclature; Elements `Discipline` and `Role Set`, from the Category element in SPEM, were mapped to `Step` and; `Profile Set` in the Usa-DSL process to keep the same nomenclature used in the Usability Framework.

Regarding the Process shown in Table 1(b), the Usa-DSL process maintains the SPEM nomenclature. The difference is Role Use, from SPEM, which is mapped to Profile Use, from the Usability Framework [Poltronieri et al., 2018].

3.6 Usa-DSL Life Cycle Modeling

To describe the Usa-DSL process life cycle, as mentioned before, we have used BPMN. This modeling was performed in three levels: the first level describes the interactions among the process Phases; the second level describes the interaction among Activities; and, the third level presents the interactions among process Tasks.

- **Level 1 - The Usa-DSL process Phases**: in Level 1 every interaction among the phases is represented. The PEAR diagram defined in the Usability Framework [Poltronieri et al., 2018] represents sub-activities that will be executed in each phase of our process. In the Planning phase, the usability designer can execute several activities or can execute another activity in the Execution phase. From each phase, it is possible to execute an activity in that phase, go to the next phase, or go back to any previous phase. Only after executing an activity in the Reporting phase, the whole process be finished;
- **Level 2 - The Usa-DSL process Activities**: At this level, there are BPMN diagrams that represent all activities in each phase. One simple example could be "E4 - Develop and Conduct Protocol" and "A4 - Analyze the Developed Protocol" activities. The former belongs to the Execution phase and the latter belongs to the Analysis phase[3];
- **Level 3 - The Usa-DSL process Tasks**: in this level, there are BPMN diagrams that represent task interactions for each activity. Furthermore, these diagrams include the decision elements that determine the task flows as well as their input and output artifacts, *e.g.* guidelines, checklist, or the messages exchanged among tasks. One example would be "E1 - Apply Instruments to Identify Profiles" activity that is composed of tasks: "E1a - Select the Instruments to Identify Profile", "E1b - Apply Profile Questionnaire" and "E1c - Complete Questionnaire Pre-Evaluation". Each one of these activities (subprocess) is detailed in another diagram as shown in Figure 5.

3.7 The Usa-DSL Example of Use

Due to space constraints in the article, this subsection presents a link directing the reader to a document hosted on Zenodo[4]. This document details all phases, activities, and work products used in evaluating the DSL Teasy. Initially, we outline the used workflow, the performed activities, and the used artifacts to elucidate the contribution of the Process Executer to the evaluation employing the Usa-DSL process.

4 The Usa-DSL Process Analysis

Preliminary assessment is an essential step, as its application helps verify the initial results and the feasibility of the study [Rogers et al., 2013]. Therefore, this evaluation aimed to understand respondents' perceptions regarding the content and presentation of the Usa-DSL.

[3]All diagrams are available at https://doi.org/10.5281/zenodo.10005345
[4]All examples of use are available at https://doi.org/10.5281/zenodo.10005345

4.1 Planning

To first introduce the Usa-DSL process to the community, we invited experienced researchers on DSL to analyze Perceived Usefulness (PU) and Ease of Use (EoU) based on the Technology Acceptance Model (TAM) [Davis, 1989]. The methodology employed for evaluating the Usa-DSL Process involved conducting an online survey, which gathered both quantitative and qualitative data. To conduct the study, we initially established the strategy for respondent selection and invitation. This was achieved by searching for references to researchers and research groups related to DSL development and evaluation. After identifying potential respondents, we sent them an email containing the invitation and instructions for completing the survey.

Before starting the evaluation, we provided the respondents with the following documents[5]:

(i) Informed Consent Form (ICT) and Profile Questionnaire: According to [Rogers et al., 2013], ethical considerations are a fundamental aspect of any research. Consequently, our approach follows CNS Resolution 510, which exempts research aimed at the theoretical deepening of situations that arise spontaneously and contingently in professional practice from CEP/CONEP registration or evaluation, provided it does not reveal data that could identify the subject. Additionally, we adhered to the principles outlined in Resolution CNS 466/12, emphasizing the provision of a comprehensive document outlining the research objectives to participants. We prioritized participant safety by safeguarding the confidentiality of their data, ensuring its dissociation from their identities, and excluding it from any document associated with the research report. Furthermore, we included a description to inform users that they have the option to terminate the evaluation at any time if they feel uncomfortable with any aspects of the assessment process. The ICT was presented only to respondents who agreed to answer the profile questionnaire. This questionnaire consisted of six questions about their area of expertise and experience in DSL. At the end of this stage, participants signed the document to signify their understanding and agreement with the presented terms;

(ii) The Usa-DSL process Survey Guidelines: After completing the profile questionnaire, the respondent would access the Usa-DSL process Survey Guidelines, which contain a brief description of the process. Finally, we asked respondents to freely explore the Usa-DSL process and to analyze and give their feedback during a survey;

(iii) Conduction: We sent an e-mail with the dates that the survey would be available, the estimated duration of the survey, information about the number of questions, and information that the respondents would be anonymous.

4.2 Study Questions

To enhance our comprehension of respondents' perceptions regarding the Usa-DSL Process, we employed the Technology Acceptance Model (TAM) [Davis, 1989] as a foundation, which provided us with guidance in formulating the following questions:

[5]All documents are available at https://doi.org/10.5281/zenodo.10005345

– **Perceived Usefulness (PU)** is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance":

  PU1. The documentation provided by the Usa-DSL process helps me understand what should be done. **PU2.** The Usa-DSL Process helps me understand how to perform a DSL usability evaluation. **PU3.** The elements that make up the Usa-DSL process help me understand what the Process proposes. **PU4.** The Usa-DSL process improves the quality of planning, execution, analysis, and reporting concerning DSL usability evaluation. **PU5.** Although Usa-DSL process is long, its benefits outweigh. **PU6.** Overall, I find the Usa-DSL Process useful in performing usability evaluation for DSL.

– **Perceived Ease of Use (EoU)** is defined as "the degree to which a person believes that using a particular system would be free of effort":

  EoU1. The Usa-DSL process is objective. I often do not become confused when using it. **EoU2.** Usa-DSL process is easy to use for fully documenting elements of a usability evaluation for DSL. **EoU3.** The process flow is easy to use when performing a usability evaluation for DSL. **EoU4.** The process has a lot of information, but it is easy to plan, execute, analyze, and report a usability evaluation for DSL using it. **EoU5.** Browsing Usa-DSL Process pages is easy. **EoU6.** It is easy to find the necessary elements to perform usability evaluation for DSL in the Usa-DSL process. **EoU7.** Interaction with the process requires a little of my mental effort. **EoU8.** Overall, I find the Usa-DSL process easy to use.

– **Open-ended Questions (OQ):**

  OQ1. What is your opinion/statement on the Usa-DSL process for developing and conducting a usability evaluation for DSL? Please, provide details in your answer.

  OQ2. Would you adopt Usa-DSL process evaluating the usability of a DSL? Please, provide details in your answer.

  OQ3. Would you recommend a colleague Usa-DSL process to support performing usability evaluation for DSL? Please, provide details in your answer.

The first step before conducting the research involved conducting a pilot test to ensure respondents' comprehension of instructions and the clarity of the study's instruments, questions, and objectives. During this phase, we invited two researchers experienced in DSL development. These experts examined the Usa-DSL process and the research documents in use. Their findings and insights are detailed in Section 4.3. After the configurations identified in the pilot test, the research execution stage began.

4.3 Pilot Study

Two experts executed the pilot study. Both of them (E.1 and E.2) are lecturers-researchers and have two and nine years of experience in designing DSLs. They followed a document guiding them on the Usa-DSL process, then they took a seventeen-question survey[6].

Concerning PU, they agreed with all questions by answering "Agree" or "Strongly agree", on provided documentation, process comprehensibility, process elements comprehensibility, and improvement of planning, execution, analysis, and reporting DSL

[6]Readers can take our survey at https://doi.org/10.5281/zenodo.10005345

usability evaluation. The only question they did not agree upon was the question that asks whether the benefits outweigh the time required, E.1 did not agree and E.2 was neutral.

On the EoU, both experts answered "Agree" or "Strongly agree", *i.e.* they consider Usa-DSL objective, easy to use for documenting the DSL evaluation process, easy to follow, easy to plan, execute, analyze, and report, ease to follow its documentation, and ease to find the requested information. The only question they did not agree upon was the question on Usa-DSL requiring little effort, in which E.2 agrees and E.1 is neutral.

We also asked three open questions to the experts. One of them regarding their opinion/statement on the Usa-DSL process for developing and conducting a usability evaluation for DSLs. E.1 agrees that the process might be used for "...any other usability evaluation. It is a nice guide and provides good accessibility to fast-checking information". E.2 mentioned that "It is a very well-defined process... there are clear steps to facilitate its adoption.".

Another question was related to the adoption of the Usa-DSL process for DSL usability evaluation. E.1 would adopt it as "it saves a lot of learning time. It is also quite objective and it is quite easy to interact with. The pages had many links to go in any direction. I liked the flowcharts since they gave an overall idea of the section.". E.2 said he would "definitely adopt it if I had to make an important decision regarding the choice of a long-term use for a DSL".

The last question was about the recommendation of the Usa-DSL process to a colleague to support DSL usability evaluation. E.1 mentioned that "I will recommend to my students and collaborators since it can save learning time and can be used as a guide/manual to fast checking the doubts". E.2 would also recommend it "due to the detailed description and completeness".

Both DSL designers also suggested improvements to our process. Based on the pilot study, we improved the Usa-DSL process and invited more experts to evaluate it.

4.4 Profile of Respondents

We received responses from 20 DSL designers representing eight different institutions and companies. Notably, one respondent (R.9) disclosed a dual commitment to both professional work at 'Fractal Engineering and Systems and academic pursuits at a university. Three respondents (R.4, R.9, and R.10) maintained professional affiliations with three distinct companies: DJukic Software GmbH, Fractal Engineering and Systems, and Porthal Systems. It is worth highlighting that 55% of respondents hailed from Unipampa (Federal University of Pampa), while 20% were affiliated with PUCRS (Pontifical Catholic University of Rio Grande do Sul). Additionally, respondent R.1 indicated dual affiliations with two higher education institutions, SETREM and PUCRS. Among the 17 (85%) respondents with educational ties, they collectively represented five different higher education institutions in Brazil.

Regarding their roles within their institutions or companies, respondents were categorized as follows: (i) 20% (4) as Professors, (ii) 60% (12) as Students, (iii) 20% (4) as Professionals, (iv) 5% (1) as Researcher. Notably, respondent R.9 identified as both a Professional and a Student. In terms of experience, respondents averaged 3.5 years of experience in using or designing DSLs. Two respondents (R.4 and R.18) stood out as seasoned professionals with a decade of experience. The vast majority of respondents, 95% (19), were based in Brazil, with only one (5%) respondent (R.4) representing Germany/Serbia. It is worth mentioning that respondent R.19 did not disclose their affiliated

institution or company. For a comprehensive overview of the respondents' profiles, please refer to Table 2.

Respondents	Institution or Company	Roles	Experience (Years)	Country
R.1	SETREM/PUCRS	Professor	5	Brazil
R.2	UFMS	Professor	4	Brazil
R.3	PUCRS	Student	2	Brazil
R.4	DJukic Software GmbH	Professional	10	Germany/ Serbia
R.5	UTFPR	Researcher	0.5	Brazil
R.6	Unipampa	Student	5	Brazil
R.7	Unipampa	Student	3	Brazil
R.8	Unipampa	Student	5	Brazil
R.9	Fractal Engineering and Systems / Unipampa	Professional / Student	2	Brazil
R.10	Porthal Systems	Professional	5	Brazil
R.11	Unipampa	Student	0.5	Brazil
R.12	PUCRS	Student	2	Brazil
R.13	PUCRS	Student	4	Brazil
R.14	Unipampa	Professional	4	Brazil
R.15	Unipampa	Student	1	Brazil
R.16	Unipampa	Student	1	Brazil
R.17	Unipampa	Professor	4	Brazil
R.18	Unipampa	Professor	10	Brazil
R.19		Student	0.5	Brazil
R.20	Unipampa	Student	1	Brazil

Table 2: Profile Data of Survey Respondents

4.5 Analysis and Discussion of Results

We analyzed Perceived Usefulness (PU) based on six questions and 20 respondents in two perspectives: internal cohesion of responses by applying Cronbach's Alpha [Cronbach, 1951] analysis, and mode of the responses per respondent and question.

We applied Cronbach's Alpha to PU answers to measure their internal cohesion. Therefore, we came up with $\alpha = 0.8805237$, *i.e.* respondents tend to answer the same way for all PU questions (PU.1 through PU.6). Figure 6 summarizes the stacked results regarding each PU question.

Analyzing .6, which represents the overall perceived usefulness of the Usa-DSL process, we observed that 17 (80.9%) respondents found the Usa-DSL process useful for performing usability evaluation for DSL, whereas three (14.3%) were neutral. Concerning PU.1, 81% of the respondents confirmed that the Usa-DSL process helps them to understand what should be done for evaluating the usability of a DSL, *i.e.* nine (42.9%) responded "Strongly agree" and eight (38.1%) "Agree". PU.2 focuses on whether Usa-DSL helps someone understand how to perform a DSL usability evaluation. In this aspect, 76.2% of respondents "Agree" that the Usa-DSL process helps, *i.e.* five (23.8%) responded that they "Strongly Agree" and 11 (52.4%) "Agree". With relation to whether

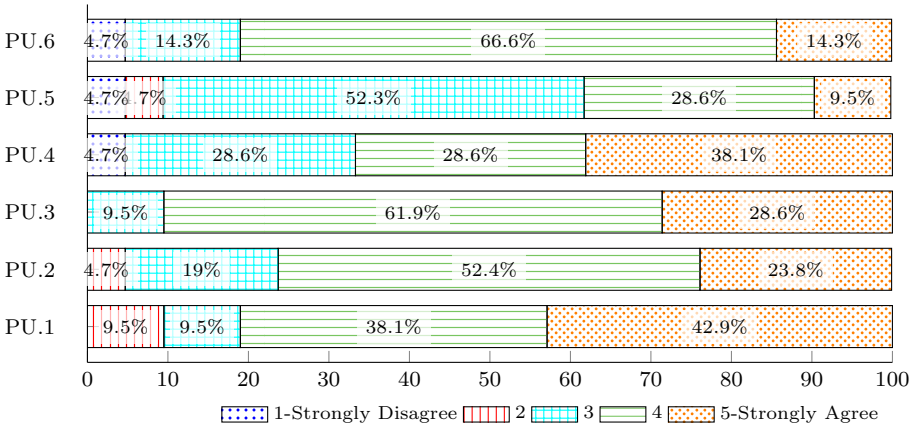

Figure 6: Perceived Usefulness Results of Usa-DSL

it is possible, based on its elements, to understand the Usa-DSL process (.3), 90.5% of respondents believe that that is the case, *i.e.* six (28.6%) responded that they strongly agree and 13 (61.9%) agree. 66.7% of respondents confirm that planning, execution, analysis, and report of DSL usability evaluations is improved when using the Usa-DSL process (PU.4), *i.e.* eight (38.1%) responded that they strongly agree and six (28.6%) agree. We also asked respondents whether they found the Usa-DSL process long, but its benefits outweigh that (PU.5). Only 38.1% agreed with that, *i.e.* two (9.5%) strongly agreed and six (28.6%) agreed. This is the least well-evaluated aspect of our process. Nonetheless, 11 (52.3%) respondents were neutral. This might not be conclusive since respondents did not have a chance to use the Usa-DSL process in an actual DSL usability evaluation.

To analyze the Ease of Use (EoU), first, we applied Cronbach's Alpha to EoU answers to measure their cohesion. Results showed $\alpha = 0.8370315$, which means that respondents tend to answer the same way for all EoU questions (EoU.1 to EoU.8).

In general, most of the respondents (76.1%) found the Usa-DSL process easy to use (EoU.8). Three respondents (14.3%) strongly agreed that Usa-DSL is objective (EoU.1), and nine (42.8%) agreed. For Question EoU.2, 71.4% agreed that Usa-DSL is easy to use to fully document elements of a usability evaluation for DSL, *i.e.* five (23.8%) respondents strongly agreed and ten (47.6%) agreed. For Question .3, 61.8% of the respondents agreed that the process flow was easy to use when performing a DSL usability evaluation, *i.e.* four (19%) respondents strongly agreed, and nine (42.8%) agreed.

As a matter of facilitating planning, execution, analyzing, and reporting a DSL usability evaluation (EoU.4), 71.3% agreed that the Usa-DSL process has this capability, *i.e.* six (28.5%) responded that they strongly agreed and nine (42.8%) of them agreed. Question EoU.5 asked about how easy is to browse the Usa-DSL process pages and 66.6% of respondents confirmed it was easy, *i.e.* ten (47.6%) respondents strongly agreed and four (19.0%) agreed. 80.9% found it easy to find the necessary elements to perform usability evaluation for a DSL using Usa-DSL (EoU.6), *i.e.* seven (33.3%) respondents strongly agreed and ten (47.6%) of them agree. Question EoU.7 asked whether respondents found that interacting with Usa-DSL required little mental effort

or not. Eleven (52.3%) respondents agreed with that and seven (33.3%) of them were neutral to this question. Again, this might have happened because respondents did not use the Usa-DSL process in an actual DSL usability evaluation. Figure 6 shows the stacked results regarding each EoU question.

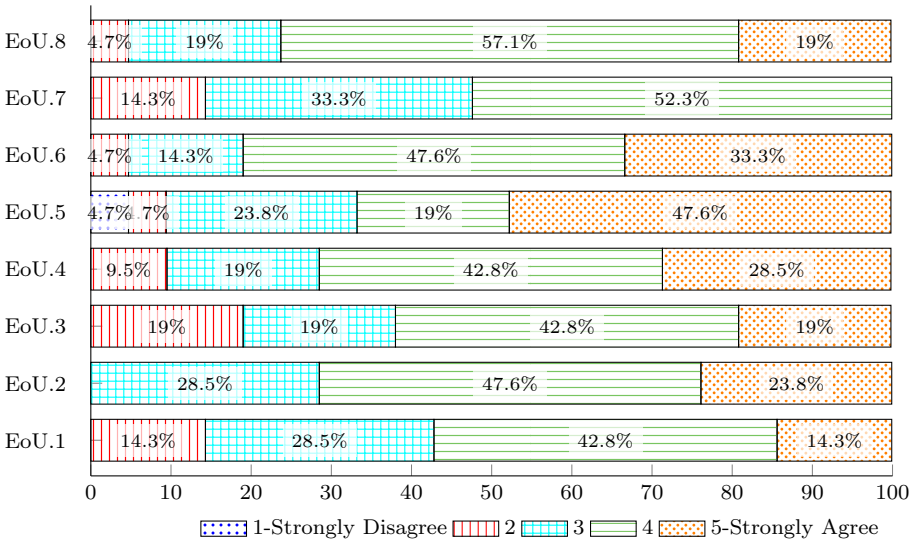

Figure 7: Ease of Use Results of Usa-DSL

Open-ended Questions. We adopted Deedose[7] to aid us in organizing respondents' quotes and identifying open and axial codes from the three open-ended questions responded by each respondent. Based on what they said, we identified and categorized their words and sentences. In total, we came up with 10 codes in four categories: Positive Aspects, Aspects to Improve, General Usability Evaluation, and Prospective Recommendation. Guidance of Usa-DSL was the most mentioned by the respondents, with 15 quotes, followed by Prospective Recommendation with 13, Learning and Usage with 12, and Adoption with 11 quotes. We analyzed the identified categories and respective codes exemplifying them with respondent quotes next.

Positive Aspects. This code represents the aspects that respondents believe would make the Usa-DSL process a success. R.7 claimed that Usa-DSL "comes to aid in an important gap in the domain-specific language development process, which is the usability concerns, that feature has being put aside in DSL community". R.1 would recommend Usa-DSL to students and collaborators, whereas R.12 said that "the process seems relevant to be used".

– `Learning and Usage`: R.1 affirmed that the process is quite objective and easy to interact with, as well as he/she likes the process flowcharts as they provide the process overall idea. R.2 corroborates R.1 as he/she found that the process steps clear, which facilitates its adoption. R.3 agreed that the process is consistent, corroborating R.6

[7]Available at: https://www.dedoose.com

who said "process documentation is well detailed", as well as activities and artifacts, which guide new Usa-DSL users. R.10 and R.14 also mentioned the importance of process details and documentation. Presentation and explanation of the process using charts are highlighted by R.15, whereas R.16 emphasizes process iterative and incremental characteristics.

- `Guidance`: R.1 found that the process has nice guidance as it provides good accessibility and fast information checking. R.2 commented that the process is well-defined and complete. R.3 highlighted that the process seems natural to evaluate DSLs and R.14 said it is clear who does what. R.6 and R.9 focused their quotes on the ease of navigability and intuitiveness throughout its website. R.8 and R.16 found that the process could be used in medium and large companies and it adds value to the company solutions.

- `Adoption`: nine respondents said they would adopt Usa-DSL. R.2 and R.15 claimed the process of clear steps eases its adoption. R.12 mentioned that "if the usability of a given DSL would be a priority" then the process would help. R.8 found that in projects with more people, this process would be adopted. R.7 and R.10 agree on the adoption of Usa-DSL as it might bring useful feedback from DSL users and could also be a development checklist.

- `Recommendation`: R.3 would recommend the process if the development of a DSL is the central objective. R.17 found the process helpful for non-experts on DSL, thus R.17 would recommend it. R.19 would also recommend the process.

Aspects to Improve. This code represents the negative comments from the respondents and, therefore, must be improved in the Usa-DSL process, otherwise, they might be a risk for its success. R.4 mentioned that the Domain Specific Modeling (DSM) approach and the architecture of the DSM solution are not identified from the Usa-DSL process and, therefore, should be clearer. Furthermore, R.1 recommended "to provide links to use cases examples for each step, phase, and activities, as well as planning, execution, analysis and reporting". She/he also suggested that tools should be indicated for each experiment phase.

- `Conditional Adoption`: R.4, R.14, and R.16 would consider adopting the Usa-DSL process but depends on the context and language. R.14 said "Yes, but it depends on the context and complexity of the language domain". R.4 concluded that he/she might adopt the Usa-DSL process if the DSM methodology was expressed in a simple way, and R.16 claimed that "It depends on the scope size, as the application of the process can be very demanding for a small scope". R3 would not adopt because he/she did not feel like an expert on DSL and R.18 responded that it is not possible to adopt it if the benefit is not perceived, that is, she/he can only affirm after using the Usa-DSL process in an actual case.

- `Evaluation/Validation`: all respondents mentioned that they could only evaluate after performing/using the process. R.14 said "I still believe that it is necessary to execute the process to be validated" and R.18 responded "It is only possible to give a return when the process is used. In the time dedicated to the survey I believe it is impossible to evaluate the process with only the guidelines".

- `Massiveness`: respondents believed that the process is extensive and that for someone who does not have prior knowledge of usability evaluation it still requires some

time to be executed. R.13 said "I believe that for very small languages it is not necessary, even if it is useful". R.8 mentioned that "Otherwise I think the process could be very expensive, depending on the scenario, to be carried out in its exact completeness". Meanwhile, R.3 claimed that "add a considerable layer of work when compared to creating an *ad-hoc* questionnaire and testing usability with users".

- `Navigation`: respondent R.6 mentioned that "the documentation helps to ease navigation/analyze", but R.1 commented that the webpage had many links to go in any direction and R.17 said "Concerning process website, I think that it is a good idea to integrate the BPMN diagrams with the EPF-Composer framework. However, navigating through the activities diagram was difficult, impacting site usability".
- `Novice Users`: had only one respondent quote, R.6 said "This version would aid experienced users who only need to 'remember' or validate few aspects of the process".
- `Supporting Tools`: two respondents believe it would be good to have supporting tools. R.15 mentioned that "I believe that with the use of the tool, it helps many when checking aspects of usability of DSL" and R.6 claimed "Yes, however, it would be good to use a supporting tool as it may reduce the effort of managing the artifacts (reports) generated".

General Usability Evaluation. This category had only one excerpt in which he/she believes that the Usa-DSL process can be used for any usability evaluation not just for DSL.

Prospective Recommendation. This category has thirteen excerpts, all recommending the Usa-DSL process to other researchers or colleagues. For example, R.9 said "I would recommend it because usability is a crucial factor to ensure the adoption of your DSL according to domain experts with less technical knowledge"; R.8 said "I would recommend it. By checking the documentation that I accessed it seems to me to be an extremely detailed process, able to provide all the support as a guide in usability evaluations"; R.12 mentioned that "Likely, the proposed evaluation process is certainly relevant for those interested in usability"; and R.2 quoted "I recommend it due to the detailed description and completeness".

4.6 Usa-DSL Process Evolution

Based on the evaluation analysis of the improvements category the next changes to be prioritized in the Usa-DSL process will be the inclusion of examples of use cases that exemplify each stage, phase, and activity. In addition to the availability of links, we aim to develop a tool to support the execution of the process as a whole. Moreover, we also plan to develop usability evaluations involving all steps, phases, activities, and tasks that comprise the process.

Specifically, regarding the code `Massiveness`, we emphasize that the process is executed in flows and that the Process Executors do not need to go through all activities to evaluate its DSL. Instead, the Process Executors choose activities that correspond to the usability evaluation that they want to perform. It is worth noting that the process was designed to be used for users who do not know usability evaluation. Therefore, it is highly recommended that all process elements store the necessary instructions, step-by-step, on how the user executes them.

Concerning the general evaluation analysis, we understand that most respondents said they would use and indicate the process to their colleagues and other researchers. Nonetheless, a small number of respondents believe that the process should undergo enhancements to be used in all contexts, such as to evaluate simpler DSLs. In this context, we believe that with the development of the process supporting tool, this suggestion will be solved soon.

4.7 Threats to Validity

In this section, we discuss the main threats to the validity of our study and present the strategies we used to mitigate them [Wohlin et al., 2012]:

(i) Internal Validity: To reduce the internal validity of our study, one of the goals for our evaluation was to have a limited number of questions and to use multiple-choice questions as much as possible. This is intended to avoid the respondent's tiredness and to motivate them when answering our questionnaire. Furthermore, we organized our questionnaire into sections to avoid the perception of time spent responding to it. Moreover, we included questions related to the respondents' training and experiences with the instrument;

(ii) External Validity: To have a representative sample in the evaluation, we provided an open questionnaire that could be answered by DSL researchers and practitioners conveniently. We had 20 DSL designer respondents who had, on average, 3.5 years of experience in DSL development. We believe that the obtained sample is not as representative as we expected, but they give some good insights into our process;

(iii) Construct Validity: To avoid instrumentation problems, we adopted PU and EoU from TAM for organizing and preparing the questionnaire. Besides, we conducted a pilot test to validate our questionnaire, to provide further adjustments on the questions' clarity, and to anticipate possible issues;

(iv) Conclusion Validity: Even though obtained data are important to establish that Usa-DSL process is viable, these results cannot be generalized. Nonetheless, the results provided empirical evidence that our process is designed correctly.

5 Final Remarks

This paper presented Usa-DSL as a process to drive the usability evaluation of DSLs. To analyze its feasibility, we performed a qualitative study based on a survey with 20 experienced respondents who freely used and explored our process to provide feedback on the usefulness and ease of use dimensions of the TAM model. Results demonstrated that our process is feasible to evaluate DSL usability.

Hence, to ensure a positive user experience with a DSL, designers must conduct a well-defined usability evaluation to avoid any potential deployment failures. In that direction, the Usa-DSL process provides means to facilitate the planning, execution, analysis, and reporting of the usability evaluation of a DSL.

While the proposed process represents a significant advancement in the field, there is still room for improvement. Currently, we have been working on: (i) performing improvements suggested by the feasibility analysis respondents; (ii) applying our process

to evaluate DSLs through experiments with experienced DSL designers; (iii) developing a graphical and interactive tool to support the customization of our process to help DSL designers to plan and conduct usability evaluations.

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References

[Abrahão et al., 2017] Abrahão, S., Bourdeleau, F., Cheng, B., Kokaly, S., Paige, R., Stöerrle, H., and Whittle, J. (2017). User experience for model-driven engineering: Challenges and future directions. In *20th International Conference on Model Driven Engineering Languages and Systems (MODELS)*, pages 229–236. IEEE.

[Alonso-Ríos et al., 2009] Alonso-Ríos, D., Vázquez-García, A., Mosqueira-Rey, E., and Moret-Bonillo, V. (2009). Usability: A critical analysis and a taxonomy. *International Journal of Human-Computer Interaction*, 26(1):53–74.

[Barišić et al., 2018] Barišić, A., Amaral, V., and Goulão, M. (2018). Usability driven DSL development with USE-ME. *Computer Languages, Systems & Structures*, 51:118–157.

[Cronbach, 1951] Cronbach, L. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, page 297–334.

[Davis, 1989] Davis, F. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, 13(3):319–340.

[Eclipse Foundation, 2018] Eclipse Foundation (2018). Eclipse Process Framework Project - EPF Composer.

[Fowler, 2010] Fowler, M. (2010). *Domain Specific Languages*. Addison-Wesley Professional, 1 edition.

[García-Borgoñón et al., 2014] García-Borgoñón, L., Barcelona, M., García, J., Alba, M., and Escalona, M. (2014). Software process modeling languages: A systematic literature review. *Information and Software Technology*, 56(2):103–116.

[García-García et al., 2019] García-García, J., Enríquez, J., and Domínguez-Mayo, F. (2019). Characterizing and evaluating the quality of software process modeling language: Comparison of ten representative model-based languages. *Computer Standards & Interfaces*, 63:52–66.

[Gilson, 2018] Gilson, F. (2018). Teaching software language engineering and usability through students peer reviews. In *21st International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings*, MODELS'18, page 98–105, New York, NY, USA. ACM.

[Hesenius and Gruhn, 2019] Hesenius, M. and Gruhn, V. (2019). Gesturecards-a hybrid gesture notation. *Human-Computer Interaction*, 3:1 – 35.

[Kahraman and Bilgen, 2014] Kahraman, G. and Bilgen, S. (2014). A framework for qualitative assessment of domain-specific languages. *Software & Systems Modeling*, 14:22.

[Karsai et al., 2009] Karsai, G., Krahn, H., c. Pinkernell, Rumpe, B., Schindler, M., and Völkel, S. (2009). Design guidelines for domain specific languages. In *9th OOPSLA Workshop on Domain-Specific Modeling (DSM'09)*, page 7.

[Melody and Hearst, 2001] Melody, Y. and Hearst, M. (2001). The state of the art in automating usability evaluation of user interfaces. *ACM Computing Surveys*, 33(4):470–516.

[Mernik et al., 2005] Mernik, M., Heering, J., and Sloane, A. (2005). When and how to develop domain-specific languages. *ACM Computing Surveys*, 37:316–344.

[Mosqueira-Rey and Alonso-Ríos, 2020] Mosqueira-Rey, E. and Alonso-Ríos, D. (2020). Usability Heuristics for Domain-Specific Languages (DSLs). In *35th ACM Symposium on Applied Computing*, pages 1340—1343.

[Nielsen, 1993] Nielsen, J. (1993). *Usability Engineering*. Morgan Kaufmann, San Francisco, USA.

[Nielsen and Molich, 1990] Nielsen, J. and Molich, R. (1990). Heuristic evaluation of user interfaces. In *Conference on Human Factors in Computing Systems*, pages 249–256. ACM.

[OMG, 2018] OMG (2018). Object Management Group - Software and Systems Process Engineering Metamodel Specification - SPEM.

[OMG, 2019] OMG (2019). Object Management Group - Business Process Model and Notation - BPMN.

[Poltronieri, 2021] Poltronieri, I. (2021). *Usa-DSL process: a usability evaluation process for domain-specific languages*. PhD thesis, Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, Brasil.

[Poltronieri et al., 2018] Poltronieri, I., Zorzo, A., Bernardino, M., and Campos, M. (2018). Usa-DSL: Usability evaluation framework for domain-specific languages. In *33rd Symposium on Applied Computing*, pages 2013–2021. ACM.

[Preece and Rombach, 1994] Preece, J. and Rombach, H. (1994). A taxonomy for combining software engineering and human-computer interaction measurement approaches: towards a common framework. *Journal of human-computer studies*, 41(4):553–583.

[Rodriguez-Gil et al., 2019] Rodriguez-Gil, L., Garcia-Zubia, J., Orduña, P., Villar-Martinez, A., and López-De-Ipina, D. (2019). New approach for conversational agent definition by non-programmers: A visual domain-specific language. *IEEE Access*, 7:5262–5276.

[Rogers et al., 2013] Rogers, Y., Sharp, H., and Preece, J. (2013). *Design de interação: além da interação humano-computador*. Bookman.

[Rosenzweig, 2015] Rosenzweig, E. (2015). Chapter 6 - usability inspection methods. In *Successful User Experience: Strategies and Roadmaps*, pages 115 – 130. Morgan Kaufmann.

[Sharp et al., 2019] Sharp, H., Preece, J., and Rogers, Y. (2019). *Interaction Design: Beyond Human - Computer Interaction*. Wiley Publishing, 5th edition.

[Sommerville, 2001] Sommerville, I. (2001). *Software Engineering*. Addison-Wesley.

[Stone et al., 2005] Stone, D., Jarrett, C., Woodroffe, M., and Minocha, S. (2005). *User Interface Design and Evaluation*. Interactive Technologies. Elsevier Science.

[Wohlin et al., 2012] Wohlin, C., Runeson, P., Höst, M., Ohlsson, M., Regnell, B., and Wesslén, A. (2012). *Experimentation in Software Engineering: An Introduction*. Springer - Verlag.