

# Consolidation in Collaborative Design: An Exploratory Case Study

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***Abstract.** In collaborative software design scenarios, Consolidation is a key process for contributions from diverse participants to be understood, reviewed, and integrated into a coherent set of design objects. However, this process is complex because it acts at different times and objects throughout a design process, and few works in literature are devoted to addressing this process and its inherent complexity. This paper presents an exploratory case study to investigate Consolidation in a Design Thinking-inspired process. As results, remarks about dimensions of Consolidation, activities where Consolidation occurred and strategies used to consolidate were identified, which can be a source for designing technical features for supporting Consolidation practices.*

## 1. Introduction

Consolidation is a process of combining, integrating or transforming something into something else that is more complete, effective, coherent or elaborated. Consolidation is a common activity in software design and implementation processes and can be applied in several contexts, such as consolidating an idea [Aiken and Carlisle 1992] or usability problems [Hvannberg et al. 2019].

In collaborative software design, Consolidation is a key process for contributions from different participants to be understood, reviewed and integrated into a coherent set of design objects. However, this process is complex due to its occurrence in various activities and manipulation of various objects in a design context. Also, the collaborative design context considers the purposes, understandings and human interactions of various participants, implying in sociotechnical challenges: individual and collective aspects of participants and technical tools that make the work feasible.

Existing literature usually approach Consolidation mainly as an automation challenge in software modeling or source-code merging. Few papers investigate Consolidation as a coherent whole and as a challenge for design processes composed not only of technical aspects (e.g., performance), but also of human and organizational aspects (e.g., purpose, communication)[Law and Hvannberg 2008, Oppl 2015].

This paper presents an investigation of main dimensions, strategies and occurrence of Consolidation through an exploratory case study with observation technique. The case study occurred in a Requirements Engineering discipline where a Design Thinking-inspired process was instantiated to lead students from problem-understanding to solution prototyping and evaluation. The main contribution of this paper is a characterization of Consolidation through remarks, such as the objects it manipulates and the dimensions it involves. This preliminary characterization of Consolidation can inform the design of interactive systems that require features to facilitate collaborative Consolidation.

## 2. Theoretical Background

In collaborative design, different activities such as Brainstorming, Braindrawing and Brainwriting [Wilson 2013] may include a Consolidation step. Particularly, in the Human-Computer Interaction (HCI) area, other activities also include Consolidation in its process, as in Contextual Design [Rogers et al. 2013] and HCI evaluation methods where Consolidation is a basic activity [Barbosa and Silva 2010]. When elaborating design alternatives in HCI, the adopted solution usually combines elements from different alternative solutions [Barbosa and Silva 2010].

In usability evaluation, Hvannberg et al. (2019) divide Consolidation into filtering duplicate usability issues from one list and merging usability issues that could be retained, merged or discarded. For Pohl and Sikora (2007), Consolidation is a sub-process of requirements co-design and software architecture composed by: (1) categorization, (2) prioritization, (3) correction of inconsistencies and (4) a stage of comparison and refinement where visions are integrated and new ideas are generated.

Consolidation in usability and requirements engineering indicates that the context influences the way Consolidation occurs. On the one hand, common practices and activities in Consolidation differ between the two views. On the other hand, in both cases, several similar objects (in this paper, “object” or “design object” means information produced or modified during design practices) are present and the purpose governing the action is the same: to integrate different objects in a single coherent set of objects that is elaborated or complete and solve inconsistencies, adjusting what is necessary for that purpose. This last Consolidation view is the one we adopt for this paper.

## 3. Research Method

Exploratory case studies are used to explore any phenomenon in data which serves as a point of interest to the researcher [Zainal 2007]. The case study was considered appropriate for our context because the objective is exploratory, the type of data collected is qualitative and the study design is flexible [Runeson and Höst 2009], to deal with the complex and dynamic characteristics of a real-world phenomenon [Wohlin et al. 2012].

The study used observation as the main technique for data collection [Marconi and Lakatos 2004]. Observation can be classified as individual, when only one researcher (first author) is involved in the observation and where researcher subjectivity can be projected on the record and the reasoning [Marconi and Lakatos 2004].

### 3.1. Planning

For investigating Consolidation in a design process, the 5W1H (What, Why, Where, When, Who, How) questions were used to characterize the study:

- *What*: to investigate Consolidation in a design process to propose computing solutions for promoting adoption and awareness about abandoned animals.
- *Why*: the objective was to identify how Consolidation was carried out by students in a Design Thinking process, without the support of computational tools for Consolidation, identifying possible features to support Consolidation.
- *Where*: classroom activities in a Requirements Engineering discipline.
- *When*: from February 2019 to June 2019.

- *Who*: 57 students, 46 from Computer Science and 11 from Biomedical Informatics of the Federal University of Paraná; the 2 authors.
- *How*: an exploratory case study with data collection through observation, noting aspects of Consolidation (strategies, arguments, mentions).

The following *research questions* guided observations: What are the strategies to achieve consolidation in the design process? What are the main dimensions of Consolidation? In what moments of the design process does Consolidation occur?

As *data collection method*, the observation technique was applied. The first author acted as a teaching internship for the discipline, and supported students in solving doubts during their activities. Observation can be classified as systematic, as it was carried out under somewhat controlled conditions: the subject, format and activities of the discipline were known *a priori*. Design objects produced from practical activities (*e.g.*, solution requirements and prototypes) were also used for analysis. A diary was used to register what objects were created or modified in Consolidation activities, how the participants structured the Consolidation process, what tasks they carried out and what was the dynamics of collaborative work among them. Participants' notions for the word "Consolidation" were also noted. *Data analysis* was conducted under a qualitative approach. Figure 1 shows a record of the classroom (left) and a picture of the observation diary (right).



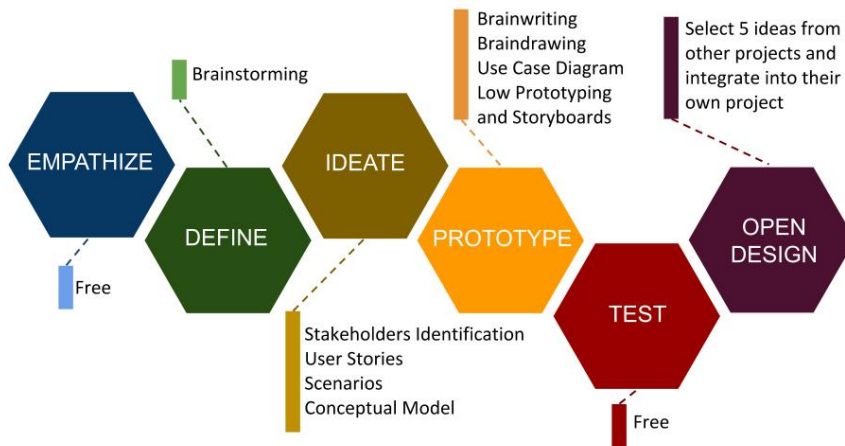
**Figure 1. Students in classroom and diary picture**

*Participants* were students of Computing undergraduate courses, therefore, future professionals who will be able to work in the field of software design that may work in Consolidation activities.

### 3.2. Requirements Engineering Discipline

The discipline lasts 60 hours distributed into 30 classes. The discipline's activities involved collaborative work and reuse of design objects. Practical activities were organized in a design process inspired by Design Thinking where participants worked in 14 groups with 3-5 students. The project was conducted in two cycles: (1) doing the stages of Design Thinking (Empathy, Definition, Ideation, Prototyping, and Testing) to produce a solution; and (2) refinement of projects and encouragement of open design work [Silva Junior et al. 2019] based on the exchange and reuse of information between groups. For the second cycle, students should select at least five ideas or elements (*e.g.*, requirements, user stories) from other projects, different from the original project ideas. Students should freely conduct an analysis and selection process, recording in a software requirements specification why and how the ideas were chosen and integrated into their projects.

Figure 2 presents the activities according to the Design Thinking stages with the addition of an open design stage. In free activities, students had autonomy to determine what techniques studied in the classroom would be used.



**Figure 2. Activities accomplished at each process stage.**

Observing and capturing information about Scenarios, Use Case Diagram and Conceptual Model activities was not possible as they were not carried out in the classroom but in group labs and external practices. Activities were collaborative, and for Consolidation they mainly involved: (a) individual work that should be collaboratively consolidated; (b) Consolidation from the reuse of ideas or requirements from other projects.

## 4. Results

To answer our research questions, a remark is presented for each of the most important participants' behavior and Consolidation strategies observed. All remarks are results of the observation.

### 4.1. What are the Consolidation strategies and when do they occur in the Design Thinking process?

The activities in which it was possible to observe Consolidation were: a) stakeholder identification; b) user stories; c) Brainwriting; d) Braindrawing; e) reuse. A remark related to the occurrence of Consolidation is pointed out:

**Remark 1.** *Consolidation in design may occur when multiple versions of objects of the same type are created.*

Consolidation can occur in the design process when there is parallel design creation among a group of participants and when many objects of the same type are generated. In stakeholders identification, for example, we identified an opportunity for Consolidation to produce a final list of stakeholders, merging similar stakeholders or discarding stakeholders that do not make sense.

A remark related to strategies of Consolidation was observed:

**Remark 2.** *Provide visibility to what each individual is creating, to reduce duplicate work. If two or more individuals are going to design for the same aspect, there may be a discussion to define who does what.*

When creating user stories one group used the following production strategy: to avoid rework, students created user stories individually, marking on a post-it visible to everyone in the center of the table which story and stakeholder each one was producing. If more than one member were going to create a user story, there was a discussion about which aspect of the stakeholder they would represent so that two or more participants would not do redundant rework.

Two remarks (3-4) related to a discussion aspect of Consolidation are indicated:

**Remark 3.** *Present the pros and cons of each design object. Discussion of the raised points. Deliberation on which objects will be part of the consolidated set.*

In Brainwriting, several ideas were generated that eventually passed to Consolidation. In Consolidation, participants should present the pros and cons of each idea they produced. The points are based on individual opinion, so there were informal discussions to understand what each point meant and whether there was an agreement or not. Participants presented questions, opinions and responses of agreement or disagreement as “it makes sense or it does not make sense”.

**Remark 4.** *To arrive at the consolidated solution, participants can offer possibilities for how the consolidated object may be. These possibilities can be modified/adjusted.*

Some groups used questions/hypotheses to guide their activity: someone presented a possible consolidated solution that other members could agree or disagree with — “what if we do that?” or “how about this?”. These two remarks are an indication of the social nature of Consolidation, where participants make informal discussions, show opinions or beliefs and build understanding about the Consolidation process.

Two remarks (5-6) related to Consolidation procedure are indicated:

**Remark 5.** *Convergence was decided by discussing a subset of design objects (pre-selected individually).*

In Brainwriting, some groups went directly to the proposals that had already converged quickly in a previous discussion, without fully considering the ideas produced in previous steps. They selected only the ideas that came close to their initial solution proposal and discussed from that subset how the solution should be.

**Remark 6.** *Reflection with a more democratic process, evaluating each individual contribution; or a systematic selection and discussion process, evaluating each object created and producing the rationale for the result of Consolidation.*

In Braindrawing, a group carried a reflection process first, evaluating all the ideas, selecting the most relevant points and checking what they would “take from each idea (individual screen)” and where they would insert the idea in the final prototype. These remarks represent that a Consolidation process can be structured in different ways.

A remark about the challenges of Consolidation is indicated:

**Remark 7.** *There is a difficulty and complexity for Consolidation when those involved do not reduce the number of candidate ideas for the solution and do not structure their*

*discussions. Proposing an idea that brings all the relevant ideas together may not be possible.*

One group in particular experienced difficulty in accomplishing Consolidation: there were many ideas and interesting elements that the group could not discard, but at the same time could not converge the points into a final proposal that would please everyone. Thus, one must consider a dimension of difficulties or risks that affects Consolidation, although known consensus techniques could be used to facilitate the resolution of this particular challenge.

A remark about the operations of Consolidation is indicated:

**Remark 8.** *Consolidation has operations such as adding, discarding and merging design objects. Criteria for discard can be duplicate and incomprehensible objects.*

In Braindrawing, groups selected and combined layouts and figures from individual prototypes, drawing on a paper cardboard the consolidated interface. A group mentioned disposing of two individual prototypes because they were “*almost the same thing*” and because they “*were not so well explained*”. This group also mentioned “*merge two screens*”, to join the “*side navigation bar and top bar*”. Thus, these operations can be candidates of a technical dimension of Consolidation.

The following remark represents a modify operation of Consolidation:

**Remark 9.** *Modify a design object to see what the Consolidation result will look like. A draft can occur in which adjustments and corrections are made without restricting creative thinking.*

In Braindrawing, while some groups consolidated individual screens directly on a paper cardboard intended for the “consolidated proposal”, another group used an alternative paper sheet to create a “*draft consolidation*” and then to produce a “*consolidated prototype*”. The sketch was made on an alternative sheet instead of the material (paper cardboard) intended for the consolidated prototype. This remark represents that individuals must be free to explore Consolidation.

Given all the remarks, Consolidation strategies are composed of activities (*e.g.*, selection, discussion) and operations (*e.g.*, merge, discard). These represent a dimension of the Practice of Consolidation, meaning how the Consolidation is accomplished. Design objects related to each design activity also impacts Consolidation process, as these objects suffer operations to reach the intended result. Also, individuals should be able to adapt Consolidation to their needs: flexibility and participants’ autonomy are both essential requirements for Consolidation.

Answering the study question (In what moments of the design process does Consolidation occur?), Consolidation may occur when multiple versions of objects of one same type are created, such as collaborative activities. For the next question (What are the strategies to achieve consolidation in the design process?), observed strategies always involved considering design objects created during some activity, discussions to define the expected result, and an effective modification of these objects to reflect a consolidated state.

The strategies may also consider an evaluation of design objects produced, for example, by raising pros and cons or presenting personal opinions. There are discussions

of design objects, in which doubts are solved and opinions are adjusted. Finally, there is a deliberation on the Consolidation decision and a modification of design objects. Individuals explore the Consolidation process from operations, such as merge and discard of design objects, until they reach an expected result (the consolidated object).

#### 4.2. What are the main dimensions of Consolidation?

The next remark is related to the Consolidation context:

**Remark 10.** *Consolidation must take into account the design object it handles and the design activity it involves.*

In stakeholders identification an artifact called Stakeholder Diagram [Baranauskas et al. 2013] was used. For this artifact, Consolidation must consider that a stakeholder may be in more than one layer of the Diagram and assume different roles depending on the layer. In the Consolidation of prototypes, the discussion of object attributes was observed (*e.g.*, size of icons), reinforcing that the constituent attributes of the objects also undergo discussion and are subject to Consolidation.

Given the Consolidation context and its strategies, the main observed dimensions for Consolidation were:

**Remark 11.** *Consolidation must consider dimensions such as: i) design activity, object and its attributes; ii) semantic (meaning), syntactic (organization and form) and physical (material, such as paper or software environment) aspects; iii) composition of object attributes, whether of similar or different types.*

i) In Braindrawing, as each individual prototyped screen had different shapes and attributes, students consolidated the final prototype from different elements of the individual prototypes.

ii) Consolidation discussions involved the physical aspect of the material that was provided to students (paper cardboard). One group in particular was afraid that the information they wanted to represent would not fit on the paper cardboard. If we apply this aspect to software, the idea of limitation (*e.g.*, screen size, resources) that the software transmits to Consolidation can also be a dimension that influences the process. Comparing the Braindrawing with the Brainwriting Consolidation, while Consolidation in Brainwriting dealt mainly with the convergence of the semantic content (meaning, content) of written ideas, Consolidation in Braindrawing dealt particularly with the semantic and syntactic aspect (arrangement, organization, structure).

iii) Consolidation in Braindrawing approaches a “composition”, insofar as it composes a final interface joining several semantic and syntactic elements in an organized and coherent way, while discarding or overlapping others.

Answering the remaining question, the main dimensions of Consolidation are the Object, Activity and Practice of Consolidation. A design activity has an associated design object which, in turn, has constituent attributes. A design activity changes the nature of Consolidation, as it determines which objects will be manipulated. A Consolidation of meanings (semantic aspect) and structures (syntactic aspect) was observed, indicating that, depending on the activity, different levels of Consolidations can be accomplished. The physical aspect was also related to Consolidation, as it defined restrictions on how Consolidation could occur in activities.

In order to know the scope (generalization) of the remarks beyond the academic context, new investigations must be carried out. We are limited by our context (classroom learning and practical activities) and by our study population (students), which had limited experience and understanding of software engineering. However, as the discipline involved the development of a solution to a real problem, with future professionals in the field of Computing, there is an indication that the remarks may make sense in other contexts of the same nature of collective work and technological development.

Regarding the reliability of the study [Wohlin et al. 2012] the case study protocol was defined and presented so that data collection and analysis procedures can be replicated. Individual observation by a single researcher is a limitation of this study. If others had performed the observation and analysis, new remarks or interpretations could have been made. To mitigate this limitation, the planning and the “chain of evidence” of the conclusions obtained were presented.

### 4.3. Implications for technical resources to support Consolidation

Remarks point to Consolidation characteristics and how it can be structured by its main dimensions, enabling an understanding of Consolidation that reveals requirements for resources intended to support it. Table 1 presents Consolidation requirements divided by social, formal and technical aspects (interface and infrastructure). For example, when designing a feature to support Consolidation activities for a specific system, designers should consider that those who will consolidate can structure the Consolidation process each one in specific ways; and there are challenges in understanding design objects and to reach convergence between participants. For the development of Consolidation features a sociotechnical view is required, considering a broader and deeper understanding of Consolidation, its context and the participants.

**Table 1. Requirements for Consolidation resources.**

<b>Social Aspects</b>	People can have differences in vocabularies, understanding, purposes and beliefs	People may have difficulty finding convergence	Consolidation is mediated by communication and can be preceded by questions, construction of meanings and consensus
<b>Formal Aspects</b>	Flexibility for those involved to structure their Consolidation process	Awareness resources are relevant to reduce the cognitive effort of Consolidation	Each design activity/object requires different resources to support Consolidation: semantic (meanings) and syntactic (form and structure)
<b>Interface</b>	Individual spaces for free exploration of Consolidation	Suggestions of automatic operations to favor Consolidation	Synchronous and asynchronous means of communication (chat, comments, etc.)
<b>Infrastructure</b>	Storage of objects, modifications, discussions and rationale	Algorithms for finding similarities between objects	Algorithms to identify overlapping changes in the consolidated object

The social aspect of Consolidation is related to human and collaborative challenges, such as differences in understanding and lack of standardization in the production of design objects. This social aspect adds complexity for Consolidation but can also promote innovation, for example identifying strategies of a group of individuals in the real world, which could be formalized in procedures or guidelines (formal aspect) and then implemented in technical aspects, such as metaphors and other elements of interaction.



## 5. Related Works

Law and Hvannberg (2008) compared individual and collaborative Consolidation of usability problems and found human aspects in the Consolidation process, such as social pressure to reach consensus. Our discussion is not restricted to usability, presenting information about Consolidation in various collaborative activities and how this information represents the main aspects of Consolidation. Oppl (2015), in turn, presents a scheme for the collaborative Consolidation of business process models. However, the scheme is also restricted, intended only for modeling business process models. Also, the result of the Consolidation “does not play an active role, but serves as a shared artifact for reference and clarification purposes”. For our paper, Consolidation and its result are key aspects of design activities. Finally, other papers [Klatt and Küster 2013, Rubin and Chechik 2013] have a technically oriented view and focus on specific operations of Consolidation, such as merge, concerned mainly in finding optimal algorithms and automation of Consolidation operations. We view Consolidation as a broad process and recognize the social and formal aspects necessary for supporting Consolidation.

## 6. Conclusions

This paper presented an exploratory case study for observing Consolidation in a collaborative context inspired by Design Thinking. A series of remarks and requirements were pointed out, that can serve as a starting point for other empirical studies on Consolidation, as well as a source of information for the design of Consolidation features for collaborative interactive systems.

Social aspects observed, such as informal discussions that permeate Consolidation, are an indication that Consolidation cannot be focused on just technical resources. An overview of a sociotechnical view of Consolidation was indicated by means of social, formal and technical requirements. We conclude that: i) Consolidation can occur in collaborative activities where participants create many objects in one same activity; ii) the identified strategies were constituted by activities and operations that made Consolidation occur in practice by manipulating design object; and iii) the remarks represent the Practice, Activity and Object dimensions for Consolidation. Activity and Object indicate that the context affects the nature of how Consolidation will occur. Practice indicates that Consolidation can be accomplished by different strategies, for example involving different sets of operations depending on the desire of the participants.

In our study, Consolidation was developed manually and synchronously in the same place and time by a group of individuals. However, when it comes to distributed, virtual and asynchronous contexts between individuals, the complexity increases and developing Consolidation resources demands a comprehensive view of the social, formal and technical aspects of domain. From our study, Consolidation is then marked as a sociotechnical challenge and a broad phenomenon that is not restricted to a specific design activity or focused on technical operations. Our study opens new possibilities for investigating Consolidation, using the remarks and dimensions observed as a guide for new empirical explorations or for proposing supporting artifacts. For future works, to enable technical solutions to be designed and developed it is critical to know and analyze Consolidation in a structured and systemic way.

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