

”For Those Who Come After”: A Descriptive and Reflective Framework for Workspace Awareness and Change Reporting Across Groupware Ecologies

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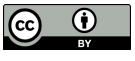
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“For Those Who Come After”: A Descriptive and Reflective Framework for Workspace Awareness and Change Reporting Across Groupware Ecologies

“For Those Who Come After” : Cadre Descriptif et Réflectif pour la Conscience d’Espace de Travail et la Communication de Modifications à travers les Écologies de Collecticiels

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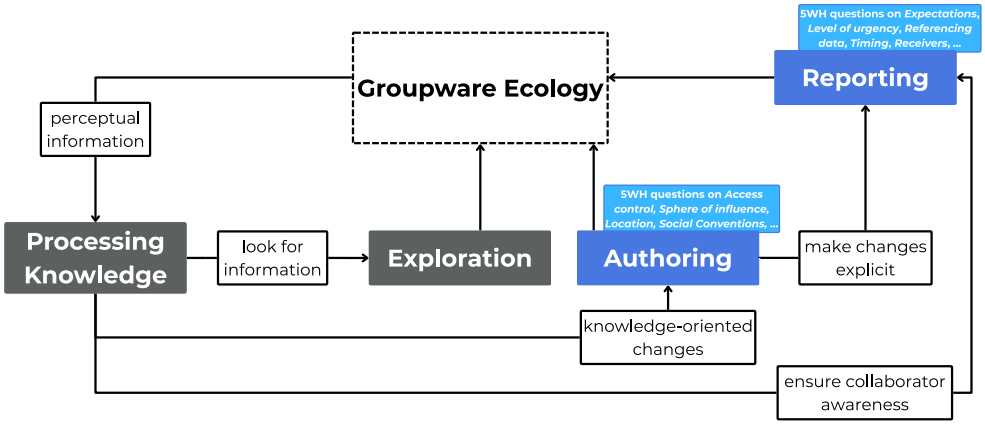


Figure 1: The FTWCA framework describes collaborative actions performed by users of a groupware ecology. It focuses on asynchronous contexts in which collaborators do not have direct means to contact their peers. This framework builds on previous work by detailing the nature of the actions performed (authoring, reporting), and their flow in the user workflow.

Abstract

Collaborative work increasingly involves managing information across multiple *groupware* (i.e., collaborative software). To share awareness of collaborative workspace, team members must often report changes to each other. For example, a programmer may accompany a Git commit with a description of the change, and send a Slack message to explain the rationale to team members working on related tasks. However, reporting changes asynchronously can be difficult as reporting functionalities often: 1) remain confined within application silos (e.g., comments in Google Docs), 2) collapse diverse updates into centralized channels like email or messaging apps, lacking meaningful cross-groupware integration, and 3) depend on tacit social conventions for choosing appropriate channels and formats. We present *“For Those Who Come After”* (FTWCA), a descriptive and reflective framework to support workspace awareness in asynchronous collaboration across *groupware ecologies*: collections of collaborative applications that mediate diverse team activities such as writing, programming, designing, communicating and more. The framework consists of (1) a description of stages of workspace awareness, namely updating knowledge, exploring, authoring and reporting, and (2) reflective questions about authoring and reporting changes targeting both the functionalities available in the ecology and users’ goals. These questions are designed to facilitate identifying challenges in performing these actions by pointing

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out discrepancies between these entities. We illustrate through use cases how designers may apply this framework to structure reflection on challenges in authoring and reporting changes across multiple groupware, and discuss how this framework can benefit researchers and designers of groupware.

Résumé

Le travail collaboratif implique de plus en plus la gestion d'informations disséminées parmi divers collecticiels (i.e., logiciels collaboratifs). Pour partager une conscience d'espace de travail collaboratif, les membres d'une équipe doivent souvent communiquer sur leurs modifications respectives. Par exemple, un programmeur peut accompagner un Git commit avec une description des modifications, et envoyer un message sur Slack pour expliquer ses décisions aux collègues travaillant sur des tâches connexes. Cependant, rapporter les modifications de manière asynchrone peut être difficile car cela résulte souvent en des applications silos, des déversements d'informations et des conventions sociales implicites. Nous présentons "*For Those Who Come After*" (FTWCA), un cadre descriptif et réflectif pour faciliter la conscience d'espace de travail et les rapports de modifications à travers des écologies de collecticiels : des suites d'applications collaboratives qui facilitent des activités d'équipes telles que la rédaction, la conception, la communication, etc. Le cadre consiste en (1) une description des étapes affectant la conscience d'espace de travail, c.-à-d. en prendre connaissance, l'explorer, le modifier et rapporter sur ces modifications ; et (2) des questions réflectives sur les étapes de modification et de rapport, dans le but d'aider à identifier des difficultés liées aux divergences entre les actions supportées par le collecticiel et les objectifs de l'utilisateur. Nous illustrons à l'aide de scenario d'utilisation comment un concepteur de collecticiel peut appliquer ce cadre pour l'aider à identifier des possibles difficultés, et discutons comment le cadre peut être utile aux chercheurs et aux concepteurs de collecticiels.

CCS Concepts

• **Human-centered computing → Collaborative interaction**; **HCI theory, concepts and models**.

Keywords

artifact ecology, groupware, shared information management, reporting, authoring, framework, workspace awareness, computer-supported cooperative work, CSCW

Mots clés

écologie d'artefact, collecticiel, gestion partagée d'information, rapport, édition, cadre, conscience d'espace de travail, travail coopératif assisté par ordinateur, TCAO

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1 Introduction

Software development teams increasingly collaborate across multiple platforms [60, 64]. For example, they share code with GitLab, plan tasks on Trello, author reports on Google Docs, prototype user interfaces on Figma, and communicate on Slack [38, 39, 42]. These collaborative platforms form a collection of *groupware* [28, 31] (called a *groupware ecology* in this work), a collection of collaborative applications that enable teams to share and edit diverse information spanning tasks such as coding, writing, prototyping, and more.

In order to interact and collaborate efficiently within groupware ecologies, collaborators must build a collective mental model, or shared cognition [18, 35, 44]. However, the remoteness of collaboration makes it difficult, especially when working asynchronously or across time zones. In particular, it is challenging for collaborators to maintain *workspace awareness* (WA) [32]: what has changed? where? who made the changes? why? and what are different collaborators supposed to do with those changes? As an example, they can struggle with ensuring all members have access to up-to-date information [25], as multitasking and multicommunication practices exacerbate information overload [5] and make finding information a challenge [38]. Without effective WA, team members may have to invest extra time in understanding how to adapt others' changes into their own tasks, or simply misinterpret these changes resulting in incorrect subsequent work.

Groupware platforms partially support WA, but this support is specific to individual platforms rather than spanning a team's entire ecology. For example, collaborators can leave comments on a Trello card, suggest edits in Google Docs, or write commit messages in GitLab to explain their changes. Additionally, AI-powered task planners are now emerging [1, 3, 48]. However, these communications remain spread out across different platforms, making it challenging to have an overview of the overall progress of the team within its shared workspace, or how progress in different platforms relate to each other. In other words, information and communication is spread across platforms that operate as *information silos* [66], and no single platform provides a unified view of the team's activity and progress. Seminal frameworks for WA [32, 40, 65] provide guidelines to reason about how team members share awareness of their individual changes. However, these are primarily scoped to a single platform and for synchronous contexts where colleagues can directly communicate, offering limited support for analyzing awareness challenges that span an entire groupware ecology used asynchronously, as commonly used today [38, 60].

Indeed, when working asynchronously, team members often engage independently within the shared groupware ecology in what we call a *user session*. Let's take the example of Maelle, a software engineer that needs to implement a new functionality in a software based on new instructions provided in the ecology by a colleague. Before accessing the ecology and engaging in a user session, she is aware that she must work on this new task but does not know the details yet and starts *processing* internally where to look for information before she starts navigating and *exploring* the ecology

to search for more information (see Figure 1). Once she has enough knowledge on what is asked of her, she can start coding and thus *authoring* information. Upon finishing, she can write a *report* to her colleague to clarify what was done and thus end the session. While such changes can be reported to support the WA of collaborators who will engage with the ecology later [26], changes may also be communicated *implicitly*, for example, through automatic notifications and edit histories. This places the burden on the collaborators to piece together what changed and why [32]. When *explicitly* reporting changes, team members can deliberately communicate not just *what* changed, but also *what it means* for the rest of the team's work—signposting useful information *for those who come after*. We argue that *reporting* changes has been overlooked in existing WA frameworks, and we are interested in developing guidelines for identifying challenges and design opportunities related to the explicit reporting of changes across a groupware ecology.

We present *"For Those Who Come After"* (FTWCA), a descriptive and reflective framework for asynchronous collaborative work that focuses on how users engage in authoring tasks and explicitly report the changes they authored across a groupware ecology. This framework builds on Gutwin and Greenberg's framework [32] that describes the flow of information users manipulate, and adapts it by reviewing the types of actions users perform; we define users' actions as either *authoring* (e.g., modifying a document in the groupware ecology) or *reporting* (e.g., adding explicit content describing the actual modifications and their implications) information (see Figure 1). To ensure this framework is actionable, we provide two series of questions about authoring and reporting actions. These questions follow the 5WH model (who, what, where, when, why, and how), are structured with themes issued from the literature WA, and concern both the available ecology features and the users' motivations and goals. Through two use cases, we demonstrate how answering the questions for a specific task and context can help identify discrepancies between the ecology features and the user's intention, facilitating the reflection on these frictions and helping to identify challenges. Overall, the framework and its questions serve as guidelines for groupware designers and researchers to 1) analyze ecologies of existing groupware applications and 2) identify design opportunities for novel means of supporting WA and the explicit reporting of changes across groupware ecologies.

2 Related Work

In this section, we first clarify the terms we use in the paper, then discuss the literature on groupware ecologies (i.e. both artifact ecology and groupware literatures) and how software teams rely on heterogeneous data scattered across silos of information. Lastly, we discuss how multi-factorial is workspace awareness and how it has been characterized to date, and how shared cognition shape the uses of collaborative workspaces.

2.1 Terminology

First, we need to clarify concepts of ***data***, ***information*** and ***knowledge***. We build on Zins's [73] work that views data and information as phenomena external to the users, and knowledge as internal to the users. ***Data*** are "*representations of facts and raw material of information*", while ***information*** "*is data organized to produce meaning*" [73]. ***Knowledge***, conversely, is the interpretation and comprehension of information accumulated through experience. In the context of groupware ecologies, data can be letters or numbers in files, while information can be words and numbers as well as structured files, and knowledge is the interpretation and comprehension of this information, which relates eventually to be aware of what the ecology comprises.

Our work builds on the concept of artifact ecology [29, 45], a set of artifacts that can be digital (virtual and devices) [59], physical or hybrid. This includes the notion of ***groupware***, virtual artifacts that are "*computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment*" [28]. We therefore define the collaborative environment used by a team as a ***groupware ecology***, i.e, a set of groupware used to achieve specific goals. A related notion is ***shared workspace*** described by Gutwin and Greenberg [32] as "*The combination of physical space and artifacts makes a shared workspace an external representation of the joint activity*". In this work, we consider the shared workspace to be only virtual and equal to the groupware ecology.

In order to efficiently interact within the workspace, users need to have a correct ***workspace awareness*** (WA), which "*involves knowledge about where others are working, what they are doing, and what they are going to do next*" [34]. We detail on this concept in Section 2.3.

2.2 Software Teams rely on Artifact Ecologies

Distributed software teams share and manage lots of information across time and space in their artifact ecologies, often compartmentalized in "information silos" [66]. Typically, collaborators chat on *Slack* about pieces of code in *Github* that implement instructions stored in *Google Docs*. This setting in silos makes it challenging to locate information fragmented across multiple tools [38]. On top of this, data is often heterogeneous and span diagrams, documents, code, emails, chat conversations, tabulated data, voice memos and more [14, 16, 62]. More generally, artifact ecologies face multiple challenges, both technical with regard to interoperability between aligned and personal silos [8, 43], as well as perceptual and organizational as users need to structure information and decide on social conventions to respect [66]. Because of their nature, these settings raise many challenges that cannot be fixed with single groupware designs, thus must be addressed holistically.

The artifacts teams use are frequently groupware [41, 49, 71]. Some of them are dedicated to task management such as Trello [4] or Jira [2, 56] to organize their project management [20] and support management methods like agile methods [17, 74] with sprints [36], waterfall methods [6], etc. While these groupware can support cross-disciplinary discussions, reporting, and ultimately management [56] , they remain silos of information that rely on other groupware and the information they enclose to easily track progresses and facilitate reporting of information.

30 years ago, Grudin [31] presented 8 challenges to consider when designing groupware that pointed out collaborators benefit differently from the available collaborative tools, and that they may not be adapted to everyone, leading to issues in adopting them. Furthermore, these challenges underline that groupware

design may conflict with social norms and misalign with needs about information sharing. Duckert and Bjørn [27] revisited these challenges in 2024 through two ethnographic studies. First, their results indicate that groupware are now essential to companies and not only add-ons. Second, while they categorized the 8 challenges in *social*, *organizational*, and *cooperative* challenges and rephrased them, their results suggest that these challenges remain significant.

Overall, this provides evidence that groupware are now crucial for teams and that their design introduce frictions with social norms and conventions. As groupware form ecologies and are rarely used alone, this also indicates that we are currently missing conceptual tools to reflect on what issues arise in these ecologies, why, and what solutions can be implemented. The FTWCA framework belongs in this category and supports reflections when facing issues in asynchronous collaborative work contexts.

2.3 Models and Frameworks of Workspace Awareness

The most important challenge with shared workspaces is how users manage to build an accurate workspace awareness. While groupware enable to navigate and manipulate this information, users must decide on how to structure the semantic space and on rules for accessing and manipulating this information. Fuks et al. [30] put awareness at the center of their 3C (*communication*, *coordination* and *cooperation*) models of *collaboration* whose goal is to support the design of groupware by identifying features dedicated to these aspects. Steinmacher et al. [64] reviewed in 2013 studies on awareness in the context of global software development using this model to identify what aspects were the most investigated and found that communication was largely unstudied.

Gutwin et al. [34] present a framework to characterize the concept of *workspace awareness*, a specific type of awareness different from 3 other types. *Informal* awareness "*is the general sense of who's around and what they are up to*" [34], *social* awareness "*is the information that a person maintains about others in a social or conversational context*" [34], and *group-structural* awareness includes roles, responsibilities and opinions of people. *Workspace* awareness, in contrast, is "*understanding about another person's interaction with the workspace*" and the "*continuous cycle of extracting information from the environment, integrating [it] with existing knowledge, and using that knowledge to direct further perception*" [34]. The framework provides elements of this latter awareness such as *presence*, *activity level*, *sphere of influence* or *expectations* along with relevant questions to analyze related events and information. Omoronyia et al. [57] reuse these definitions while reviewing awareness in distributed collaborative software engineering and add a fifth, transversal type called *context* awareness that is defined as "*The evolving internal and external state information that fully characterizes the situation of each entity in a shared environment*" [57]. Description and components of these types of awareness are conventionally provided as question lists [7, 32, 57, 65], for instance using the 5WH model (what, where, when, who, why and how questions). Our work primarily focuses on workspace and context awareness as means to both investigate and communicate about shared information.

Gutwin and Greenberg [32] proposed a descriptive framework of WA for real-time groupware. The framework builds on Neisser's [52] perception-action cycle (knowledge - exploration - environment) and consists of three-parts: what information makes up WA (knowledge), how is WA information gathered (exploration), and how is WA used in collaboration (action). Knowledge is composed of 5 themes addressing information related to *who* is involved in an activity, *where* and *when* did it happen, *what* does it involve, and *how* was it performed. This approach of structuring knowledge and awareness is now conventional in the literature [21, 24]. Tam and Greenberg [65] completed this WA framework in the context of asynchronous workspaces by presenting *changes* awareness as "*the ability of individuals to track the asynchronous changes made to a collaborative document or graphical workspace by other participants over time*" [65]. Avdic et al. [8] recently target the concept of *trace* to aid and mediate collaboration, as it is capturing connections of technology usage across time, location, people and/or devices. Enabling the expression of *change*, development, interactions, activities and others [8], Battut et al. [12] used *traces* to implement proof-of-concept system, *OneTrace*, making shared histories amongst applications more interactives. These works prove the relevance and possibilities to make change awareness more active and explicit. Despite recent groupware enable notifications of changes and provide summaries for them using machine learning approaches [1, 3], automating this process can only do so much as systems must interpret why changes were made in specific contexts.

We argue that existing frameworks and models do not yet consider enough explicit actions and communications in supporting WA for collaborators. To emphasize this, the FTWCA framework splits the collaborative actions described in Gutwin and Greenberg [32] in two types of action: *authoring* information and *reporting* on it. We then follow the established methods of phrasing questions based on themes to facilitate the analysis of these actions in context.

2.4 Mental Models and Shared Cognition

Collaborators are likely to share different personal views and awareness on a situation, which can lead to issues in communication and understanding. Cannon-Bowers and Salas [18] define levels of sharing (overlapping, similar, complementary and distributed) and list fundamental questions related to theories in *shared cognition*, such as what must be shared, what is shared, and how to measure the amount of information shared. *Distributed cognition* [37] extends this concept by considering more than one person as the intrinsic mechanism of cognition. *Team cognition* [35] builds on this to focus on measures of team efficiency regarding how information circulates in an environment and performing collaborative tasks efficiently. He et al. [35] propose a conceptual model emphasizing the importance of explicit communication and the frequency of interactions in this context. Marlow et al. [46] investigate the frequency ("*volume of communication exchanged between team members over all communication modes*") and quality ("*extent to which communication among team members is effective and clear*") of communication in a meta-analysis of 475 papers and confirm that team communication plays a critical role in furthering team performance, with information elaboration being the most impactful variable, but that the lack of verbal communication can impair team performances.

This is justifying even more the importance of diverse communicative modalities in collaboration, as reporting WA knowledge of changes in asynchronous distributed collaboration.

Team mental models are indeed impactful on their performances and accuracy [44]. In conditions where teams cannot directly communicate, such shared mental models can "*predict the quality of team processes and performance*" [47]. A difficulty asynchronous remote teams can face is that tacit expert knowledge, a variable that impacts team performances, is mostly shared through social interactions [63]. Indeed, Cooke et al. [23] argue that team cognition is rather an interactive process than static, as it evolves through time and human interactions. This highlights that channels for sharing information asynchronously are essential to build team cognition and increase their performance in the absence of more direct means, underlining the need for more conceptual tools that measure and analyze authoring information and reporting on it.

3 Descriptive and Reflective Framework

The FTWCA framework combines 1) a *description* of the stages a team member goes through to build WA when working with a team ecology, and 2) a set of *reflective* questions for identifying challenges that arise from discrepancies between the ecology functionalities and the user's perspective. The framework focuses on user activities such as writing documents, programming applications, graphic design, planning tasks, or communicating, which take place in a collaborative project and are executed in an asynchronous, distributed manner by each individual team member. We call the unit of work during which an individual contributes to the collaborative project through the team ecology a *user session*.

3.1 Stages of a *User Session*

A user session is a period of focused work where a team member works on a collaborative project through their team ecology, typically without direct, real-time coordination with collaborators. For instance, a morning of work that begins with a synchronization of the files and finish with a push of local changes is a user session. Within a session, the user must catch up with the changes that occurred in the ecology [13] since their last session to make progress effectively, building their WA in doing so. They also produce changes that others will later encounter asynchronously. FTWCA breaks down a user session in terms of four stages of action, similarly to Norman's stages of action [54, 55], building on elements from Gutwin and Greenberg's framework [32] as illustrated in Figure 1:

(1) Processing **Knowledge**. The user interpret and comprehend the information the ecology contains, combine this perception with their prior experience, and update their WA knowledge. This could be either a passive or active stage depending on the amount, type and nature of information.

(2) **Exploration**. The user updated knowledge or lack of knowledge may motivate them to explore the ecology in order to better understand the magnitude of changes. They navigate the team ecology and notice changes from authoring or reporting actions (see below).

(3) **Authoring**. The user creates or modifies data in the ecology, without the direct intention to convey information to collaborators.

(4) **Reporting**. The user creates or modifies data in the ecology with the explicit goal of conveying information to collaborators.

These four stages don't aim to be an single iteration during user session; they can be repeated several times and not in same sequence (i.e., different arrow paths in Figure 1). For instance, authoring actions may require to look for specific data in the ecology and draft reports as they make changes to keep track of them.

We explicitly consider two types of actions: authoring and reporting actions. This emphasis points out specific challenges related to reporting changes across multiple groupware and their impact on WA. Reporting actions might, for instance, have their own functionalities in ecologies (e.g., comments in shared documents) and their inherent constraints (e.g., where should reports be and who should have access to it?). We argue that reporting to provide context and meaning of changes (e.g., git messages, comments in change history, etc.) is a different intention for communication than authoring to create new changes (e.g., changing file hierarchy, adding figures, etc.). Therefore, making sense of these changes is crucial in distributed software team collaboration.

Multiple groupware ecologies can be considered in collaborative contexts: the personal ecology of software and groupware used by a user, the ecology of all software and groupware used by all members of the team, and the ecology of groupware used by a set of collaborators. We refer to ***team ecology*** as the union of all team member's personal groupware ecology and their alignment [43]. Figure 2 shows an example of a team ecology, i.e., the union of the two ecologies represented as ellipses. Here is as list of scenarios explaining the differences between these ecologies (denoted by letters in Figure 2): A) implementing software requirement could involve to push local code with VSCode IDE (personal) to git remote (shared) for Trello task completion (shared), and B) changing graphical designs on Figma described in a Google Doc shared by all collaborators could result in C) a notification as an email in a collaborator inbox. A user session considers only the personal ecology of a collaborator, i.e., a single ellipse on Figure 2.

3.1.1 *Processing* ***Knowledge***. At this stage, the user takes in all kind of information (perceptual and rational) about the groupware ecology that is used to build their WA. This process can be independent from the other stages, e.g., by simply recalling the state of the ecology without directly accessing it, or depends on them, as knowledge is primarily built by exploring and manipulating information in the ecology. This knowledge of the ecology may also include knowledge of changes in other software or groupware that a user may not have access to. For instance, a software engineer may have implemented different versions of a functionality *locally* using for instance VSCode and only commit versions that worked on a shared Git repository (see activity A in Figure 2), warning colleagues that these are the best solutions they found.

3.1.2 ***Exploration***. Exploration is beneficial to users *"who come after"*, regardless of the time between sessions, in order to build, reinforce, or keep up-to-date their WA about available shared information within the team ecology. If the time between user sessions is short, it's just a matter of tracking what was recently changed.

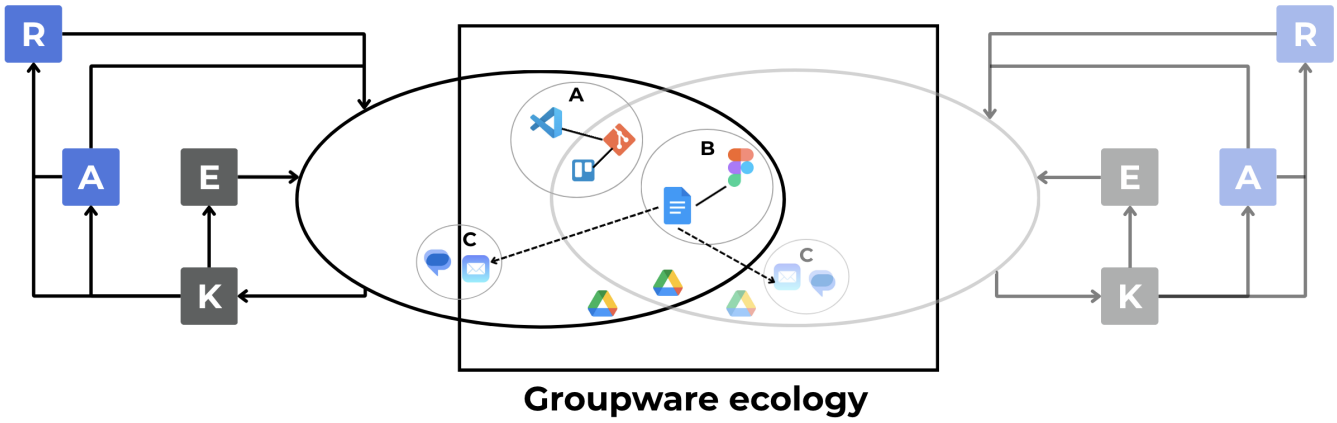


Figure 2: FTWCA, multiple users having their session at different time. Adapted from Larsen-Ledet et al. aligned ecology model [43]. Potential ecology (bold) during user session is composed of its personal ecology (left big circle), aligned ecology shared with others (intersection of the big circles), and available ecology of external tools (square). Activities (A, B, C) are using groupware from different ecologies. Also, one groupware (e.g google drive) could be considered in different ecologies because of its access (personal/shared storage) [72]

Otherwise, the user needs to inspect the context of the shared information, collaborative project and the past WA knowledge. This exploration stage corresponds to the retrieval step of digital curation [68, 70] as it involves searching for information with techniques such as the search bar, scrolling, glancing, sorting, filtering or others [19]. Whatever the searched information and goal of the search, systems need to provide different possible paths for the same destination, and support navigation [67]. Especially when information is spread across silos, human memory may fade over time and users may not understand how search engine works [50].

3.1.3 ***Authoring.*** The authoring stage is related to activities from Activity-based computing [10, 11] that alter the ecology by changing the stored data corresponding to personal or shared information, through actions such as creating, editing, modifying, moving, and deleting among others [39, 49, 64]. Activities are *a set of actions, each again holding a set of operations. Each operation points to a resource, such as a document, a picture, a HTML page, etc.* [9] These activities, that could be sketching, writing [43], coding or chatting would take place in context either of task or of personal behavior, and would change team ecology information. Authoring them spans both the keeping and management stages of digital curation [68] and influences future information finding.

3.1.4 ***Reporting.*** Reporting is the action of communicating on changes made within a team ecology. Like authoring, reporting activity could involve different groupware, like a task planner as Trello [4], or messaging apps like Slack or Discord. Reporting is intertwined with authoring as it is also adding information in the ecology, but with the intention of highlighting WA knowledge "*for those who come after*". It raises question on the underlying intentions behind communication, how collaborators are notified, and what means users have to convey information. Depending on the information they want to report on and the level of urgency of this information in a given context, users have to decide whether explicit reports are necessary to clarify the meanings of actions and changes, or whether implicit notifications handled automatically within the ecology are sufficient to bring attention to the changes.

3.2 Reflective questions for the Authoring and Reporting stages

In this second part of FTWCA framework, we provide lists of questions for the Authoring and Reporting stages. The questions are inspired by Antunes et al.'s work [7], and similarly to Antunes et al.'s list of questions, the questions we propose do not aim at identifying problems exhaustively nor at categorizing problems into themes. Instead, they function as reflective lenses that help designers and researchers reason about ecological affordances and limitations from multiple, complementary points of view.

We build the list of questions based on two established approaches. First, we reuse themes issued from the literature and add our own, in order to build on a the largely used 5WH [7, 32, 65] model of questions to frame questions from these themes. Thus, questions relate to *what* information is being manipulated, *when* and *how long* actions occur, *where* they do, *who* is or did initiate them, *how* these actions where performed, and *why*. Second, we take inspiration from the Human-Artifact Model [15] and split the questions in two types. The first category of questions supports the reflection on users' motivations and goals to perform authoring and reporting actions. The second category targets the functionalities enabled by the groupware ecology. These questions can then be used in pair to identify when goals are not met by the functionalities to identify challenges for authoring and reporting on information in the ecology.

Questions are created by associating a theme to a question type, e.g., *information type* (theme) and *what* (question type) can lead to asking questions such as "*What kind of data can be changed*" regarding the ecology functionalities, and "*What kind of information do I need to author?*" regarding users' goals and motivations. As

Table 1: Table with questions regarding AUTHORING that can be used to identify challenges in use

5WH	Theme	**Ecology** functionalities	**Human**'s perspective
What	**Information type**	What types of data does the ecology support across its groupware?	What types of data do I need to author or combine?
What	Expectations [34, 57]	What expectations does the ecology create about how changes will be noticed?	What am I expecting others to do or understand as a result of my changes?
When	**Timing**	When can changes be made?	When do I want to make changes?
When	**Synchronization**	When are changes across different groupware reflected?	When do I want the changes to reflect or stay in sync with related information elsewhere in the ecology?
Where	Location [32, 57, 65]	Where is data located in the ecology?	Where do I want to make the changes?
Who	Access control [69]	Who can access and make changes across the ecology?	Who should have access and make changes?
Who	Sphere of influence [34, 57, 64]	Who will be affected by the changes?	Who should be affected by my changes?
How	**Data transformations**	How are different types of data constrained or transformed when used across groupware?	How do I want different types of information to work together when combining them?
How	Social conventions [61]	How does the ecology shape the way data is formatted?	How should I format information?
How	**Action sequence**	How many actions must be performed?	How many actions do I want to perform?
Why	Intentions [32, 57]	Why are the groupware in the ecology designed to support authoring in the ways they do?	Why do I want to author information in the way I do?

many questions can be formulated using this method, so we do not claim to be exhaustive. Additionally, while we demonstrate the usefulness of the questions we present in the following to analyze specific use cases in Section 4, their phrasing can be adapted to specific contexts if necessary.

We explain all the themes used in the following sections. Several themes are reused for both authoring and reporting categories. We detail the differences in their interpretation if they must be distinguished.

3.2.1 ***AUTHORING*** *question list.* Table 1 lists the questions for the authoring stage. We either add in this table references for each theme reused from the literature, or use a bold font when they are new to this paper. We explain below all the themes used and their respective importance for this stage, and clarify why we propose new themes.

WHAT questions are split into two themes. *Information type* questions correspond to *WHAT* type of data (e.g., text [43], files [51, 58], etc.) is being authored. Questions in this regard could reveal what data are ecology functionalities not supporting, but also identify misalignment between human goals and current groupware design. This theme particularly emphasizes the central role of the data in authoring activities [9, 43]. *Expectations* [34, 57] relate to the expectations the user has before or while manipulating information and the means available to make this happen. The user could for instance expect collaborators to review their changes shortly after they are done with them, especially if the ecology notifies these collaborators automatically.

WHEN questions are also split in two themes. *Timing* points out that changes might not always be applied, for instance when collaborators are doing tasks that block the system and one needs to wait until they're finished (e.g., batch processes running at night to update databases). This emphasizes the potential gaps between the users' goals to perform changes at a certain time and the possibility to do so. *Synchronization* refers to when the changes should ideally be synchronized and therefore applied in the ecology. This emphasizes the potential need to delay them to a later time if other events have to happen before they are applied, such as waiting for a collaborator to review suggestions in a file and validate them before authoring a novel version. Both these themes contrast with *event histories* [32, 65] by highlighting the user's will to control when changes happen, especially across different groupware [12].

The *WHERE* question refers to the *location* of the changes, corresponding to both the actual virtual place where the information lays in the ecology and where the user would like to perform these changes. This leads to *access control* [69], a theme that underlines *WHO* should have access to specific changes and has access to it.

Another topic addressed by several themes is the social influences of and on the changes. Changes affect collaborators within

Table 2: Table with questions regarding REPORTING that can be used to identify challenges in use cases

5WH	Theme	**Ecology** functionalities	**Human**'s perspective
What	**Information type**	What types of information about a change can the ecology support when reporting?	What types of information about a change should I report?
What	Expectations [34, 57]	What expectations are shaped by the reporting mechanisms available across the ecology?	What do I expect others to understand or do when they encounter my reports?
When	**Timing**	When do collaborators receive the report?	When do I want collaborators to receive the report?
When	**Duration**	How long does the report remain?	How long do I want the report to remain?
Where	Location [32, 57, 65]	Where is the report?	Where do I want the report to be?
Who	**Receiver(s)**	Who is it reported to?	Who do I want to report to?
How	**Referencing information**	How is the data referenced across the ecology?	How do I want to refer to data in reports?
How	**Level of urgency**	How does the ecology convey or obscure the urgency of a report?	How do I convey urgency?
Why	Intentions [32, 57]	Why are the groupware in the ecology designed to support reporting in the ways they do?	Why do I want to report information the way I do?

a *sphere of influence* [34, 57, 64], leading to reflections on *Who* should be affected by the changes and who is. When manipulating information, its format matters to be understandable by collaborators. Restrictions on what type of data and *how* information types are supported in each groupware may require to consider *data transformations* when moving information across the ecology. For example, exporting Figma files into static .PNG images to include in development projects in social media, or exporting Excel spreadsheets into .CSV files to be imported into an analytics platform. *Social conventions* matter on this aspect as rules might be decided to structure information in a specific way beyond what format the ecology enables; e.g., procedural convention [61] might impact *How* to name a document and storage practices to highlight specific types of information, or sharing practice [69].

An *action sequence* refers to *how* many actions should be performed in the ideal case and how many are actually needed to perform in the ecology, which can imply several groupware. The purpose of this theme is to reveal how intertwined can different actions be, especially when authoring data within a groupware ecology.

The last theme concerns the *intentions* [32, 57] of the authoring action, targeting *why* the user wants to perform changes, and why it might be challenging to perform them in the current state of the ecology. This theme would be referenced for motivational and cognitive histories [65]. That being said, intentions are highly personal and might be difficult to study from an external point of view.

3.2.2 ***Reporting*** *questions list.* ***Reporting*** reuses the following themes that are already used in the ***Authoring*** question list: *information type*, *expectations*, *location*, *intentions* and *timing*. The latter is the only one with a slightly different meaning in the context of Reporting, as it refers to WHEN a user wants a report to be received by collaborators and WHEN they actually receive it. This may point out potentially missing features that would enable to schedule the sending of reports during work hours for collaborators in different timezones or wait for certain deadlines to pass.

Another relevant theme regarding time, lies in the *duration* of reports. The user may want the report to be prominently available in the ecology for a certain time until it is archived, which the ecology might not allow to control fully depending on the groupware used.

Other themes exclusive to reporting relate to WHO the report is targeted to (*receivers*), HOW urgent it is (*level of urgency*), and HOW the information is referenced in it (*referencing information*). Reports are intrinsically written for other collaborators, and while it might target all of them, it might also target specific collaborators only, either by placing them at specific locations or explicitly referencing others. Different strategies exist, and questions about WHO the targeted *receivers* are and how to make them explicit arise. Questions on the distribution strategy and the propagation policies (e.g., broadcast, multicast, etc.) [22] are particularly relevant when considering different groupware. The *level of urgency* of the report is a related parameter and, similarly, can be conveyed using several means like placing the report at a location that will be consulted by everyone (e.g., using a pop up on log in) or by targeting specific decision makers. Questions thus address whether the user wants to convey some kind of urgency and how to do so. Lastly, the report

may need to *reference information* from the ecology to contextualize its content. Many challenges can arise in this case, mostly because of the potential lack of interoperability between groupware.

4 Validation through Use Cases

In this section, we validate the utility of the framework by presenting theoretical use cases of collaborative asynchronous user sessions, which are heavily inspired by the literature [5, 41] and the co-authors' experience with groupware ecologies. We illustrate how it supports their analysis to identify missing (interactive) functionalities in the groupware ecology, and how they would support users' motivations or goals in shared information management.

4.1 Context

Let us consider Maelle and Gustave, two collaborators in a small software development team (about 5-10 people) working on the development of a web application to facilitate organizing scientific conferences by managing paper submissions and reviews. Maelle is a *lead software engineer* and has good awareness of the purpose of each code section, but knows little of how the product is being communicated to the target audience, the documents used to publish information online or in newsletters, and what vocabulary and keywords should be used. Gustave is a *product manager* and has better awareness of the advertising documents used to communicate about the product, but heavily relies on Maelle to keep track of the functionalities being implemented and their characteristics, as well as the overall progress the development team is making and features that are ready to be deployed, which helps coordinating interdisciplinary collaborators for release dates.

The team's groupware ecology comprises four primary groupware:

- GitLab, a *code versioning* platform for storing code files
- Figma, a *design* tool for prototyping user interfaces and interactions, as well as produce graphical documents
- Trello, a *task planner* used by the team to share objective and track progress
- Slack, an *instant messaging* application that offers dedicated servers and channels for text-based communication

Maelle and Gustave are targeting a deadline to ship the updated version of the product. Gustave wants to advertise the new features the software engineers have been working on. To do so, he needs to grasp all details on what are the current features and what changed from the previous versions. His goal is to eventually edit a document in Figma with accurate information that he would like to send to the company clients and inform them of the changes (*authoring* stage). Once the Figma document edited, he wishes to *report* to his collaborators about the changes, and ask them to review the content to minimize the risk of advertising incorrect information.

4.2 Use case: Authoring

In this first use case, Gustave wants to change information in a Figma document where he is designing an illustrated email to be sent to clients, communicating information on product feature updates. Overall, he wants the Figma document to contain 1) colorful graphical elements related to the company branding with dates of the feature launches; 2) images, videos and explanations of the new features; and 3) explanations on how these features differ from previous versions. He however struggles to locate the relevant information for each feature, such as video snippets of their use, as well as documents explaining their interactive behavior and what they enable achieving. Once the information is located, he would need to easily reference or paraphrase it in the file he is editing.

Applying the questions from the framework to this use case helped us to identify challenges (a process we summarize in Table 3). Discrepancies between what the groupware ecology supports and what users need are identified, and then grouped into coherent challenges referred as C_{Ax}.

4.2.1 Challenge$_{A1}$ - Lack of Synchronization between Groupware Updates. To achieve his task, Gustave must rely on up-to-date information that is based mostly on information managed by Maelle and other colleagues. While the team could have decided on specific locations and folders to upload the latest information on the features (e.g., in Trello), ensuring that this is always up-to-date requires frequent manual check-ups or dedicated automated pipelines. This challenge arises not from a lack of organisation, but from the way the ecology distributes information, roles and access across multiple groupware, each designed for different purposes and updated under different responsibilities. Relying on data and information managed by others often raises such issues of synchronization, which can be handled through centralized or decentralized strategies. For instance, Gustave could be in charge of ensuring information is up-to-date, which requires to frequently ask colleagues about the state of the product and for a documentation to build on.

4.2.2 Challenge$_{A2}$ - Authoring might go Unnoticed if not Reported. Authoring actions are not communicated consistently across groupware. While some groupware inform explicitly about changes through task states (e.g., Trello), others rely on implicit or passive awareness (e.g., entering Figma), making authoring alone an unreliable way to signal readiness or request attention. Information edited might not be noticed by collaborators that do not have direct access to the file and thus won't be notified of changes, even though they might work on other files that rely on the one Gustave edited. Even when notifications are turned on, they might be too broad and only notify that the content of a file was changed. In particular, Gustave wishes for Maelle to review some parts of the file, which is beyond the scope of the authoring action. A challenge in this case is that authoring and reporting actions can be strongly intertwined. For instance, Gustave may wish to tag specific information for Maelle to review, adding meta-information to the content being edited.

4.2.3 Challenge$_{A3}$ - Need to Decide on Locations and Roles to make Changes. While authoring information, Gustave relies on information external to the current file and information mostly managed by Maelle and other colleagues. This integration raises two primary questions: where should colleagues make changes, and how can they know this? Because the ecology distributes information and editing rights across tools with different access granularities, decisions about where changes should be made and who should make them must be coordinated socially rather than enforced technically.

Table 3: Answers for the framework's questions regarding the AUTHORING case. Challenges are displayed in the Chal. column when discrepancies arose

5WH	Theme	**Ecology** functionalities	**Human**'s perspective	Chal.
What	Information type	*What types of data does the ecology support across its groupware?* Descriptions of features are available as plain text documents in GitLab. Videos and demonstrations of features exist outside Figma and GitLab (e.g., as shared files or recordings). Illustrations of screens and features are on Figma (saved in .FIG files).	*What types of information do I need to author or combine?* Gustave wants to combine videos, illustrations and textual descriptions of features created by colleagues on Figma.	$\mathbf{C_{A1}}$
What	Expectations	*What expectations does the ecology create about how changes will be noticed?* Changes made in some groupware (e.g., Figma) may be noticed by entering the groupware, or by receiving notifications about them. Others only become noticeable to the team when they are signaled explicitly, e.g., with a change of status in Trello or a message on Slack. The ecology therefore sets uneven expectations about how and when authored work draws others' attention.	*What am I expecting others to do or understand as a result of my changes?* Gustave expects colleagues to review this document later to verify its information. For others to know that he completed his task, he expects to change the status of his task on Trello, moving it from "In Progress" to "Needs Review". He expects colleagues to pay attention to Trello.	$\mathbf{C_{A2}}$
When	Timing	*When can changes be made?* The groupware in the ecology allow changes at anytime. Gustave manages the Figma document, so he can author changes whenever he pleases. Within the ecology, information about whether the feature descriptions and videos are ready to be used is conveyed through task states in Trello.	*When do I want to make changes?* Gustave wants to edit the document as soon as possible, however, he can only do this once the necessary information is produced by others. For this, he pays attention to relevant task statuses on Trello.	
When	Synchronization	*When are changes across different groupware reflected?* After changes are made in Figma, subsequent changes in related groupware (e.g., GitLab or Trello) are not automatically reflected in the document, and viceversa. For example, the feature descriptions may change in Gitlab, resulting in out-of-sync information until Gustave manually updates Figma.	*When do I want the changes to reflect or stay in sync with related information elsewhere in the ecology?* Gustave wants his changes in Figma to remain consistent with ongoing work by others, but recognizes that later changes by colleagues may invalidate parts of the document without his awareness.	$\mathbf{C_{A1}}$
Where	Location	*Where is data located in the ecology?* Data on the features are scattered across multiple groupware (e.g., Gitlab, Trello).	*Where do I want to make the changes?* Gustave wants to author and integrate all relevant content directly within the Figma document used to compose the illustrated email, even though much of the information he relies on is located in other groupware.	$\mathbf{C_{A2}}$
Who	Access control	*Who can access and make changes across the ecology?* Access rights vary across the groupware involved in the activity: Gustave can edit the Figma document used to design the email, and Maelle has full access to making changes to the project in Gitlab. Figma allows access to collaborators, but limiting access to a specific section of the file is challenging, if not impossible.	*Who should have access and make changes?* Gustave wants Maelle to have access to the document, but only to the parts that relate to the content about features she is responsible for, so that this information can be verified without affecting unrelated parts of the email design.	$\mathbf{C_{A3}}$
Who	Sphere of influence	*Who will be affected by the changes?* When Gustave edits the document, it's not influencing others' coding tasks	*Who should be affected by my changes?* Gustave's changes are based on the work of software engineers, but his changes are not meant to influence their ongoing tasks; instead, Gustave's changes should reflect their work accurately.	
How	Data transformations	*How are different types of data constrained or transformed when used across groupware?* Figma illustrations are exported as .PNG files (e.g., for composing emails, developing user interfaces or including in the product website). Text descriptions are often copy-pasted from one groupware to another (e.g., from Gitlab to Figma). Files are often shared as links (e.g., sharing the latest version of the description of features in Gitlab in a Slack conversation).	*How do I want different types of data to work together when combining them?* Gustave wants to embed—or "transclude" [53]—information with dynamic links so that they update on their own if the information changes.	$\mathbf{C_{A2}}$
How	Social conventions	*How does the ecology shape the way data is formatted?* Different groupware offer more or less structured ways of authoring information. For example, Trello structures tasks into "cards" with checklists, expected deadlines, responsible team members and more, and Figma allows for the creation of visual templates.	*How should I format information?* The content should follow the visual identity established for the product (e.g., color palettes, fonts, logos) and use established templates.	
How	Action sequence	*How many actions must be performed?* Referencing information might require to use other groupware to locate it first and include it in the file.	*How many actions do I want to perform?* Gustave wants to incorporate information from features (1^{st} action) then add more information justifying these features (2^{nd} action)	
Why	Intentions	*Why are the groupware in the ecology designed to support authoring in the ways they do?* The groupware artifacts in the ecology are primarily designed to support specific activities and expertise (e.g., code/text versioning in GitLab, task tracking in Trello, visual design in Figma).	*Why do I want to author information in the way I do?* Gustave wants to author this content to communicate recent product changes accurately to an external audience (clients). He wants to design the email in Figma because it fits with the production of visual content, but it requires adapting and assembling information that was originally produced in groupware targeting different expertise (e.g., Gitlab).	C_{A2}

Table 4: Answers for the framework's questions regarding the Reporting case. Challenges are displayed in the Chal. column when discrepancies arose

5WH	Theme	**Ecology** functionalities	**Human**'s perspective	Chal.
What	Information type	*What types of information about a change can the ecology support when reporting?* Across the ecology, reporting mechanisms primarily notify that a change occurred (e.g., status update, or notification), but provide limited support for representing its rationale, scope, or dependencies across different groupware. Free text is a flexible way of explaining these considerations in a report, however, it would likely be separated from where changes were authored (e.g., in Slack about changes in Figma).	*What types of information about a change should I report?* Gustave wants to report on the summary of the information he authored in the Figma file, with instructions on what Maelle should review as a priority	C_{R1}
What	Expectations	*What expectations are shaped by the reporting mechanisms available across the ecology?* Reporting mechanisms shape different expectations about potential follow-up actions: email notifications indicate that something changed, comments on specific elements express localized feedback or instructions, and task updates in Trello convey progress and occasionally include required actions and deadlines. These expectations are not consistently available across the ecology. For example, Gustave can leave a localized comment on Figma to tell Maelle what exactly to review, but cannot leave a comment on a Gitlab file to point her to the descriptions he had to slightly adjust to fit within the design.	*What do I expect others to understand or do when they encounter my reports?* Gustave expects Maelle to review only specific content in the file concerning explanations of the new features. He expects her to consider his explanations of how and why he adjusted some of the feature descriptions so that she contributes to solving the issue rather than seeing it as a mistake. He would like to write a comment on the Gitlab file to explain why some descriptions are too long for including in visual media, but he cannot, so he includes a link to the general file in his comment on Figma hoping Maelle understand which descriptions he refers to.	C_{R2}
When	Timing	*When do collaborators receive the report?* The reports are made available to colleagues as soon as they are created. When reporting actions involve comments, reactions and other expectation-setting details across groupware (e.g., a comment on Figma and a deadline on Trello), different pieces of a report may appear as the user creates them. For example, an authoring action requiring the use of multiple groupware may lead the author to leave comments as they work, in each groupware, rather than only once when the task is complete.	*When do I want collaborators to receive the report?* Most of the time, the report should be available as soon as they are created. In some occasions, collaborators may want to schedule when a report is sent, for example, if they create it outside office hours and do not want to make this evident, or if they are writing partial reports as they progress in a task.	C_{R3}
When	Duration	*How long does the report remain?* The reports remain indefinitely until some decides to archive it. This requires someone (likely Gustave) to decide when it becomes obsolete. In cases where a reporting action involved multiple groupware, archiving should be done across all relevant comments, notes and notifications.	*How long do I want the report to remain?* The report should be prominent until Maelle and all relevant colleagues have checked the correctness of the information advertised. Reports of finished tasks should be accessible in the future in case it is necessary to trace back why a decision was made, but should also be archived as tasks are completed to avoid confusions and cluttered content.	C_{R3}
Where	Location	*Where is the report?* If the report is in Trello, it might not point at specific information in Figma. If it is only in Figma, it might be siloed and less accessible to certain colleagues that may not be collaborators on the shared file. Reporting actions involving multiple groupware may also be challenging to track and archive, since they are not explicitly linked.	*Where do I want the report to be?* The report should be accessible to anyone in a place where the team can keep an overview of current/recent tasks (e.g., Trello), but also point to specific information that collaborators should review. Receiving a report should immediately clarify where and how to proceed.	C_{R1}
Who	Receiver(s)	*Who is it reported to?* He can tag Maelle in all reports he is writing across groupware	*Who do I want to report to?* Gustave specifically want to report to Maelle and other software engineers to double check the information he summarized	
How	Referencing data	*How is the data referenced across the ecology?* Some groupware in the ecology support precise references (e.g., comments anchored to elements in Figma), but across groupware, references are typically limited to links or file-level pointers that do not preserve context (e.g., a link from Trello to a Figma file, rather than the visual element the task is about).	*How do I want to refer to data in reports?* Gustave needs to reference specific locations within the Figma file and relate them to corresponding descriptions in GitLab so that collaborators can easily identify what was changed and why.	C_{R1}
How	Level of urgency	*How does the ecology convey or obscure the urgency of a report?* The groupware used to convey the report might indicate its urgency based on social conventions (e.g., a designated emoji for urgent issues), but not all groupware have specific features for this. For example, urgency may be conveyed in Trello by setting a deadline or having an "Urgent" column, but this is lost in the groupware where the review needs to happen.	*How do I convey urgency?* Urgency can be explicit in the wording of the report, and by repeating expressions of urgency across comments and explanations multiple groupware, but it depends on what each groupware allows.	C_{R2}
Why	Intentions	*Why are the groupware in the ecology designed to support reporting in the ways they do?* The authoring groupware in the ecology are primarily designed to support local reporting and awareness within individual applications (e.g., comments in files, task updates, notifications), rather than to support explicit coordination and expectation-setting at the level of the ecology. Other groupware are therefore used for cross-tool coordination (Slack, Trello), though this leads to coordination happening outside of the tools where changes are authored.	*Why do I want to report information the way I do?* Gustave wants to ensure he introduced no mistakes in the document, and for that he needs the expertise of Maelle and his colleagues.	C_{R1}

This highlights the challenge linked to siloed information and what impact authoring actions have in the team's WA within the ecology.

4.3 Use case: Reporting

After authoring the Figma file, Gustave wants to report to Maelle that he adjusted some of the information about the new features in the Figma file and that she should review the content to ensure that, despite the different phrasing, his descriptions align with the ones she wrote on Gitlab. Most importantly, he wants to make sure to clarify the context of the changes to Maelle and clarify where the information he is referencing in the new document comes from.

Table 4 lists the answers to the questions for the reporting of the framework. Discrepancies are once again identified and grouped into coherent challenges referred as C_{Ax}.

4.3.1 Challenge$_{R1}$ - Confusions about Where to Report and How to Reference Information. Collaborators often receive a report outside of where the information needs to be reviewed, for example through an email notification or a task update in Trello that points to a Figma file. This can introduce a virtual and cognitive gap that collaborators must compensate. This can be done by creating multiple reports for the same authoring action, e.g., notifying a user in a direct message to check the comments in a shared file, eventually scattering partial reports in multiple groupware without explicit links between them. These location gaps are exacerbated by limited support for cross-groupware referencing, which prevents reports from pointing precisely to the information they concern.

4.3.2 Challenge$_{R2}$ - Conveying Expectations and Urgency Explicitly. Direct communication may be strongly limited in asynchronous contexts. Through reports, collaborators attempt to convey not only that changes occurred, but also what is expected from others, such as whether a task requires review or urgent attention. Urgency is a particularly salient instance of this broader challenge, as it must often be inferred from report details and context that are outside the groupware where the changes happened (e.g., task status changes in Trello, scheduled milestones and deadlines, a Slack conversation). As a result, even when one collaborator's report changes explicitly, others may need to reconstruct expectations by combining information from multiple groupware as well as reporting back on what they did and how it affected the ecology for expectations to be considered fulfilled. Without this additional feedback, collaborators may be left waiting for reactions that are not made explicit, eventually requiring him to ping collaborators again. This highlights that current reporting mechanisms are not designed to make expectations of urgency or of how a task should be addressed explicit and durable at the ecology level, instead relying on additional explanations distributed across groupware (e.g., in planning documents, Slack conversations, and local comments).

4.3.3 Challenge$_{R3}$ - Managing the Duration and Validity of Reports to Avoid Cluttering the Informational Space. While reports can be critically useful in a given context, they may quickly clutter the informational space if their relevance fades but they remain visible. In a groupware ecology, this issue is amplified because a single reporting intent often results in multiple report fragments distributed across different groupware, each with its own visibility and persistence, making it challenging to manage the duration of "the report" as a unit. Task management groupware such as Trello are designed to support persistence and progression of work, and can help keep reports visible over time. However, they do not provide robust means to determine whether collaborators have actually seen, understood, or acted upon a report, especially when relevant context is distributed across other groupware. Consequently, collaborators may have to keep reports visible longer than necessary or repeatedly ping colleagues to confirm reception and action, making decisions about archiving or retaining reports a coordination problem rather than a purely technical one. While report durations can sometimes be handled automatically or manually within individual tools, ensuring that reports remain salient only while needed across the ecology relies on additional social conventions and effort.

5 Discussion & Conclusion

We presented *"For Those Who Come After"* (FTWCA), a descriptive and reflective framework to support workspace awareness and change reporting across groupware ecologies. FTWCA combines two approaches. First, a formal characterization of the stages involved in maintaining users' *Workspace Awareness* (WA), highlighting the reporting stage used to explicitly convey information to collaborators about contexts of changes and upcoming instructions. Second, a set of questions associated to themes that guide the reflection on discrepancies between the ecology functionalities and the users' goals and motivations, both at the authoring and reporting stages. These questions enable designers to pinpoint challenges to consider how new features in one groupware may interact with other groupware within an ecology, and what strategies for information management across multiple groupware should be primarily supported. We validated the utility of FTWCA through two use cases, one focused on authoring and the other on reporting, demonstrating how the questions can guide the reflection to identify challenges.

Our methodology enabled to identify multiple challenges that are generic to authoring and reporting information in groupware ecologies. Keeping information up-to-date, for instance, requires efficient collaborative information management and communication which is currently lacking dedicated means. Authoring actions can be notified in an ecology but details on the changes and what should matter for who remain open challenges to tackle through interactive features. The significance of the changes and the urgency to take actions require dedicated reports to convey detailed contextual information and explain one's intentions and expectations. How this information is then concretely conveyed through groupware and the entire ecology highlights that their visibility and their duration play a critical role, two parameters that should be controlled by collaborators. The location of the reports within an ecology and its groupware also remains an open challenge as reporting information often requires pointing at various locations within the ecology and scatter informational landmarks across groupware, introducing challenges to track where these reports are and whether to handle them in a distributed or centralized manner.

The list of questions presented is not exhaustive and was not designed to be. FTWCA provides a set of themes to guide the formulation of questions and purposefully does not propose a definitive,

one-size-fits-all set of questions that can be directly applied to all groupware ecologies. We designed the questions in line with the literature [33, 34] to be sufficiently generic to be relevant across contexts. We encourage researchers and designers using the FTWCA framework to rephrase these questions to better match the intricacies of unique groupware ecologies and domains, and also to identify new questions relevant to their case studies within the listed 5WH questions and themes.

In contrast with previous work, this framework focuses on asynchronous contexts and particularly distinguishes authoring and reporting actions. The purpose is to emphasize the significance of reporting information in groupware ecologies to better support team cognition [23] and workspace awareness [34]. We acknowledge that the boundary is not clear-cut, and that in certain rare cases, reporting could be considered as authoring, and vice versa (e.g., writing a personal to-do list as a comment in a code file). Still, the stage of reporting refers to the specific actions to communicate information *explicitly* to collaborators, and this emphasis is a first step towards recognizing it as a core and important stage of collaboration in groupware ecologies.

In conclusion, FTWCA is only one of the first building blocks in exploring users' workspace awareness in asynchronous contexts when authoring and reporting across groupware ecologies. We illustrated it through theoretical uses cases, raising questions about its usage "in the wild". While we did not empirically validate the questions with groupware designers or software teams working with groupware ecologies, the theoretical validation we propose illustrates potential of the framework to reveal challenges to tackle, both at the human (strategies to adopt, social conventions to clarify) and ecology level (implement critical features to support specific goals). The theoretical validation we propose illustrates the potential of the framework to reveal challenges to address at both the human level (e.g., strategies to adopt and social conventions to clarify) and the ecology level (e.g., the alignment and scope of features supporting reporting and coordination across groupware).

Building on this contribution, future work should focus on empirically validating the framework through case studies of real-world projects and teams, identifying how questions can be adapted to different groupware ecologies and projects, and examining how they can inform design decisions at the ecology-level. An aspect the framework is currently not covering, for instance, is the potential team dynamics in play and how they may conflict with a single user point of view within a groupware ecology. This work also does not provide clear guidelines on how to transform the dynamics between groupware in an ecology to solve issues on communicating about changes, but rather provides a tool to reflect on current challenges. Future empirical work could focus on such guidelines to inform the design of interactive means to facilitate communications between team members. We also encourage future work to more systematically consider the reporting stage as a key component of workspace awareness in asynchronous collaboration. Future research may explore how reporting could be better supported across groupware ecologies, for instance through mechanisms for summarizing or tracing changes across tools, visualizing relationships between content from different groupware, or more explicitly exploring the spectrum between implicit and explicit reporting.

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