

CoFra: Towards Structurally Selecting ICT Tools and Methods in Multidisciplinary Distributed Projects

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ABSTRACT

ICT tools and working methods are important to effectively work together in cross-organizational, multi-disciplinary projects. At the moment, there is no or very limited support to enable sharing knowledge about which ICT tools to use for collaboration and how to use them. In this paper we propose CoFra, a collaboration framework that facilitates stakeholders to share knowledge about ICT tools and work practices to improve the collaboration in dispersed multidisciplinary teams. CoFra supports two main mechanisms: collaboration variables identifying characteristics of ICT tools and workflow to express best practices. Two prototype applications were created based upon the framework. A first user evaluation of these prototype applications shows that (1) the defined collaboration variables used are relevant and useful in the selection of ICT tool support and (2) that workflow depiction can improve knowledge sharing practices over traditional wiki usage.

KEYWORDS : Collaboration, Framework, ICT, Workflow, Tool Selection

1. INTRODUCTION

The realization of a user-centered software development project is a highly complex task. It involves many project activities, sub-activities and stakeholders with different backgrounds (software developer, usability engineers, project manager, business analyst etc).

Stakeholders always have to meet the collaboration and communication needs of their partners, employees, clients,

and other stakeholders that are involved in the project development process. These needs, however, are beyond e-mail capabilities, as they typically involve document sharing, virtual meetings, and information and knowledge exchanges [7]. To fulfill these needs one has to achieve high quality coordination, communication and collaboration. Effective communication and collaboration highly depends on the usage of ICT tools [2]. By selecting and providing suitable ICT tools for the project activities, stakeholders are more likely to effectively collaborate, which is especially needed in dispersed multidisciplinary teams [2]. Collaboration efficiency could thus be increased by structurally sharing knowledge about ICT tools and their recommended use for different activities in the project.

ICT tool selection in multidisciplinary teams is recognized as a challenging decision-making activity that requires support. Several frameworks [8, 11, 20, 23] have been created that categorize ICT tools for collaboration. Although some of these provide categorizations that would help in identifying tools, none also takes the process into account during which these tools are used. I.e. they only consider the moments of collaboration, not the complete process during which the collaboration takes place. Despite of several frameworks, there is still a lack of evidence of which factors, criterion, or variables to consider when selecting ICT tools, since each multidisciplinary team has different requirements and prohibitions. One reason for this may be that multidisciplinary teams work with stakeholders from different backgrounds in different contexts, and it is difficult to measure and report individual preferences of stakeholders. In addition to this, it is difficult to measure tool-related variables (such as interoperability and notification support) and user-specific variables (such as ease of use) due to lack of conceptual framework or tool support. The tool-related and user-specific variables are discussed in section 4.

Another challenge when working in multidisciplinary teams is to manage work processes effectively and efficiently in a distributed environment [17]. The few important tasks (such as sharing knowledge, approved or review document request, reminder or notification) are still done using ad-hoc techniques (such as email) or very limited support is available. To improve the collaboration process in multidisciplinary teams it is important to define the method or workflow which facilitates stakeholders to perform these tasks according to a (loosely) defined process.

This paper addresses this problem by proposing CoFra , a collaboration framework that considers the whole process including selection of ICT tools and methods as well as their usage (see section 3) in multi-disciplinary project teams that are distributed in both space and organizations. The framework is conceived as part of a project CoCoNuT, studying the usage of ICT tools for collaboration, communication and coordination within this type of multidisciplinary projects. Besides the usage of the workflow techniques to describe best practices (work methods). The framework provides (1) a checklist to facilitate decisions related to how to select ICT tools in a suitable way (i.e. what variables to measure) and (2) provide workflow support that apply best practices to improve a collaboration process in distributed teams.

To illustrate the use of CoFra we developed two applications. These applications are considered as instantiation of CoFra. In this context, the framework instantiation applications describe how the framework can be used. The applications are based on the functionalities provided by CoFra. These describe the specific problem that occurs in the collaborative projects (For example selection of ICT tools) and how the problem is solved. The applications show example solutions and details of the CoFra design. CoFra is a generic solution to an existing problem, the instantiations transform the generic solution to the real world applications. To test these applications, we performed two user studies on these instantiations, which will be discussed and analyzed in section 5 and following. The details about the applications are mentioned in section 6.1 and section 7.1.

2. RELATED WORK

In this section we discuss the different frameworks that have been proposed in literature with the purpose to improve collaboration practices in multidisciplinary teams.

Nutt [20] proposes a model for workflow systems on the basis of: (1) the required level of compliance to the workflow specification, (2) the degree of detail of the description and (3) the operational character of the model. His observation that a workflow is not necessarily a rigid description

of a work process is something we agree with and the usage of the term workflow should be understood as such in this paper.

Sarma et al. [23] propose a need-based collaboration framework adapted from Maslow's [19] theory of needs. Their framework categorizes different collaboration tools based on collaboration needs of developers. Grudin [11] classifies collaboration tools based on time and space: tools are categorized based on whether time or place are the same, predictable or unpredictable. Malone et al. [18] designed a framework to study coordination. The framework is based on the dependencies (e.g. shared resources, task assignment, user etc.) and identification of the coordination processes (that can be) used to manage these dependencies. The dependencies used in their framework are analyzed and similarities across multi disciplines are identified. Their framework is applied when classifying collaboration tools based on a coordination process.

Bolstad and Embley [2] postulate a taxonomy of collaboration. In their taxonomy they categorize collaboration tools (e.g. face to face, audio, video, file transfer) and investigate collaboration characteristics (time, predictability, place and interaction), tool characteristics (recordable, identifiable, and structured), information type (verbal, textual, spatial, emotional, photographic and video) and processes (planning, scheduling, tracking, brainstorming, document creation, data gathering, data distribution and shared situation awareness). The taxonomy helps in identifying collaboration tools (tool category) and exchanging information depending on the situation. However, it does not identify which particular ICT tool is useful for a particular situation. We explain in the remainder of this paper how CoFra facilitates stakeholders to select ICT tools based on their own preferences and those of their colleagues.

3. COLLABORATION FRAMEWORK

This section presents our conceptual collaboration framework (CoFra). It aims to gather and promote the use of knowledge about appropriate technology and methods for collaboration based on experience, general information sources (e.g. about tool-related properties of ICT tools) and organizational policies.

CoFra, shown in Figure 1, extends our previous work [22]. Four of the central entities of the initial framework were inherited: *Stakeholder*, *ICT Tool*, *Collaboration Variable* and *Activity*, marked with a white background in Figure 1. Three entities extend the coverage of the framework so that it also includes preferences. Preferences can relate to ICT tools or can be described as a *best practice*, which can be expressed as a *workflow*. Additional entities give more

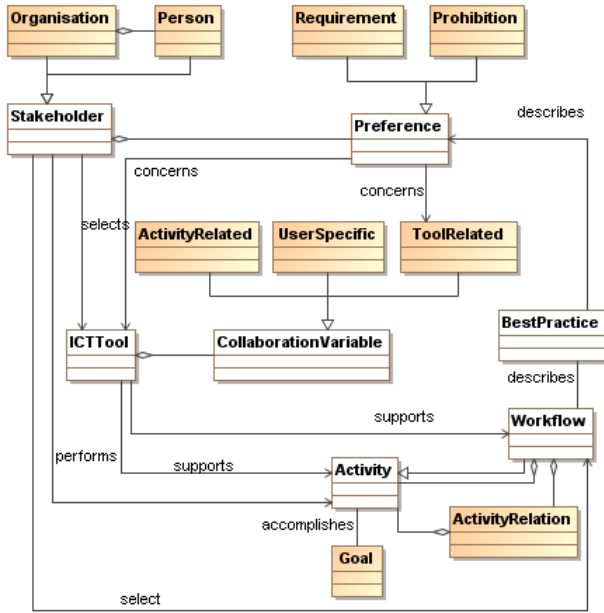


Figure 1: The CoFra Collaboration Framework

detail to the framework and provide some links between the central entities. *Stakeholders* are individual persons or groups of people that are affected by or affect the outcome of a project. Examples of stakeholders are people working on the project, the project leader, a sponsor of the project or even the IT head of an involved organization. Stakeholders have preferences, a preference can also be mandated and as such become a *requirement* or a *prohibition*. E.g. the sponsor of a project can mandate the use of certain tools to monitor progress of the project but on the other hand they may prohibit certain tools because of the associated license requirements. Preferences can be described as *best practice* or can relate to properties of *ICT tools* (such as interoperability or whether they are open source or not). These properties are described using *collaboration variables*. Collaboration variables are discussed into more detail in section 4. A *best practice* can be expressed using a *workflow*, which can but does not need to be executable through a (set of) *ICT tool(s)*. In this regard it is important to note that workflows are not only rigid expressions of how work should be performed [20]. A *workflow* contains one or more activities which are connected through relations. An *activity* accomplishes a goal (set by a *stakeholder*).

The use of CoFra is not limited to the selection of appropriate ICT tools. It also facilitates stakeholders to design the *workflow* based on project activities and to share best practices. Best practices are used in selection of tools and design of *workflow* to improve the communication and collaboration among multidisciplinary teams.

We discern three types of collaboration variables: activity-related, user-specific and tool-related variables. Activity-related collaboration variables describe for which kind of activity a certain category of tools can be used. Bolstad and Embley [2], as discussed in section 2, already give a set of activity-related variables (i.e. the collaboration characteristics and the process characteristics). The other two types of collaboration variables can be used to express tool-related characteristics, which can be generic for a type of tool (e.g. those given in [2]) or technical for specific tools. *User-specific* variables and stakeholder preferences cover the social perspective. The choice for the three types of collaboration variables is motivated by the fact that tools should not only be suitable for a specific task, but they also should fit the preferences, requirements and prohibitions (technical and social) of the stakeholders that are involved.

4. COLLABORATION VARIABLES

Collaboration variables are a key concept in CoFra. They allow stakeholders to validate which ICT tools are appropriate for particular project activities based on a simple checklist of relevant properties for these tools.

When selecting any ICT tool(s) it is very important to know the environment and requirements of the project or organization [9] because selection is influenced by a wide variety of reasons of different natures. Tool-related and user-specific variables allow us to validate which ICT tools are suitable to the project or organization depending on its size, limitations etc. Table 1 shows a set collaboration variables belonging to both categories. Literature review in addition with workshops, interviews within multidisciplinary teams as well as our own experience, are the basis for identifying the set of collaboration variables that we believe are mostly considered while selecting ICT tools.

Each tool-related variable has a set of values. Table 1 shows the tool-related variables and their respective values. For example, the 'Type of Tool' variable has two potential values *opensource*, and *commercial*. For each ICT tool the relevant variables should get the appropriate value. These values can then later be used by applications that instantiate CoFra, such as those described in this paper. User-specific variables 'ease of use' and 'most used tool' are quantified based on direct or indirect input (e.g. surveys, field trips) from stakeholders. A large scale survey was conducted to investigate usage of ICT tools for coordination, communication and collaboration [14]. We only have survey results for two user-specific variables (ease of use, most used tool) and we want to use real data in our user study (section 6.1) therefore we only focus on them. However it will be interesting to include other user-specific variables (i.e. ease of learning). Regarding tool-related

Table 1: Collaboration Variables

Tool-Related Variables		User-Specific Variables
Variables	Values	
Type of tool	Commercial	Ease of use
	Open source	Most used tool
Budget	Freeware	
	Pay Pay and free trial	
Language support	Multi-language	
	Native language	
Mobile support	Not required	
	Yes, needed	
Interoperability	Not required	
	Yes, needed	
Notification	RSS	
	E-mail	
	Discussion forum	
User interface	WYSIWYG	
	Command	
	Wizard	

variables, we focus on a limited but important set of variables. A limited set of variables adds more comprehension. It ensures that stakeholders focus on the most important variables rather than giving in to the temptation of focusing on less important variables because they may stand out more.

In the remainder of this section we highlight the tool-related variables we introduce and discuss some of their characteristics that can be found in literature.

Stakeholders perform the effective measurement of ICT cost and benefits, as this measurement is important in decision making regarding ICT tool selection [21]. Everyday people use their mobile, hand held devices to coordinate their collaboration with one another [4]. Guerrero et al [12] agree that mobile support is essential for collaboration tools. Mobile devices are low cost, small size, and most of all provide portability. These advantages makes stakeholders to consider mobile support as important criterion in selection of ICT tools. Notification is an important feature in ICT tools, it provides the overview of the events that occurred and make information easily accessible to stakeholders [24, 1] and should be considered when selecting ICT tools. Learning a new tool is time consuming and it involves cost. The user ratings, i.e. ease of use and most use ICT tool provides insight in experiences of users, the stakeholders can used them while making appropriate selection of ICT tools[15]. Similarly, the type of tool [3], user interface [6]and support for multiple languages [13] are important variables that need to be evaluated.

5. APPLICATIONS BASED ON COFRA

We built two proof-of-concept applications based on the insights of CoFra. The first application, ITS (Selection of ICT Tools), is used to select ICT tools for activities (in interdisciplinary multi-organization research projects) based on collaboration variables (see section 6.1) and the second one, SBP (Sharing Best Practices), combines workflow with wiki's to allow flexible sharing of work practices (see section 7.1). The choice of these applications was motivated by the fact that they emphasize two important parts of CoFra which are enabling structured selection of ICT tools using collaboration variables and sharing knowledge through workflow descriptions and informal text.

To evaluate these applications, we decided to perform two user studies. We opted for an empirical approach because empirical studies have proved to be an optimal way of getting results [16]. We opted to do a user study because it is hard to do a comparative experiment mainly due to two reasons: 1) we are not aware of any tools using a similar approach and 2) completing the applications to a degree in which they could be used in a real project would require an excessive effort.

The user studies were carried out with the same participants in a closed setting over two sessions with approximately one week in between. Both user studies consisted of pre-test questionnaires, an introduction to the task, task itself, post-test questionnaires, and finally a concluding discussion regarding execution. The user studies did not take longer than 20 minutes. Before the user studies, an email was sent to all participants where each user study was shortly presented and a motivation for participation was given. All participants were in the 21-35 age range. Due to our interest in multidisciplinary teams, the participants were from different educational backgrounds - Business Development (1), Social Science (1), Engineering (2), and Information Technology (9).

Before each session, the participants were given a pre-test questionnaire to get input for sampling. The five point scale (*very little, little, some, much, very much*) was used in pre-test (both user studies) to get input from participants. None of the participants used *very little* and *very much* options. The scale used in a pre-test questionnaires measures the knowledge and previous experiences of the participants (relevant to user studies).

After completion of the tasks (in both user studies), the participants were asked to fill out a post-test questionnaire. We used the five point likert scale (strongly disagree, disagree, neutral, agree, strongly agree), and two point scale (yes, no) in post-test questionnaires (both user studies). The scale

used in post-test questionnaires help us in collecting the opinions regarding participants experiences with applications and user study design. The post-test questionnaire results are mentioned in section 6.3 and section 7.3. The results and analysis is based on the descriptive statistics.

6. ITS: SELECTION OF ICT TOOLS

The goal of this application, ITS, is to analyze CoFra to evaluate the impact of collaboration variables on the selection of appropriate ICT tools in a scientific context (PhD students and researchers from multidisciplinary background) using CoFra for single/multiple project activities.

6.1. CoFra For ICT Tool Selection

ITS is a prototype of a web based application for the selection of ICT tools that are appropriate within the context of a multi-disciplinary, distributed project in which several organizations are involved.

Figure 2 shows a screenshot of the main page of ITS. The values for activity, sub-activity, work packages, partners and collaboration variables can be selected from a set of predefined values. Note that the user first has to pick an activity (step 1) and one or more sub-activities (step 2a). Based on this information an appropriate set of variables (step 3) will be shown in the bottom-part of the screen. The user can then select appropriate values for some or all of these variables, which will result in a list of recommended ICT tools for selected project activity. Note that for this prototype, the users could only select their preferences based upon the tool-related collaboration variables shown in table 1. This choice was made so that we could concentrate our evaluation on the variables we defined. As an optional step, users of the application can also select partner organizations of whom they want to know preferences or rules regarding the usage of ICT tools. Partners can be selected based on their involvement in specific parts of the project, called work package (figure 2 (step 2b))¹.

The application database contains several possible ICT tools, project activities, collaboration variables and partners. Currently we use activities and partners as criteria to select appropriate tools but activities can be combined with work packages etc. The sample of project activities, sub-activities, work package and stakeholders in this study was based on other results of the CoCoNut project [14]. Most participants in the study were familiar with the specific terms used in the application, eliminating the need for specific instructions. The inventory of ICT tools, and their corresponding tool-related variables and values (Table 1)

¹ A work package is a subset of a project that is assigned to a party and contains a plan to create a specific result.

Figure 2: Steps Involved In Selection Of Appropriate ICT Tools.

are listed. User-specific variables (ease of use, most used tool) values are taken from the surveys conducted during CoCoNuT [14]. Only the stakeholders' preferences used in the study were fictive. When the user has completed the previously mentioned steps the recommended tools are presented. The recommended ICT tools are presented in a table that also contains specific information about the tool, such as the matched tool-specific variables and user-related variables. More generic information about e.g. the preferences of the relevant stakeholders regarding the recommended ICT-tools are also shown.

6.2. Evaluation Approach And Execution

13 participants were involved in this user study (7 females, 6 males). The objective of the pre-test questionnaire was to investigate how well the participants were acquainted with ICT tools and multidisciplinary teams. This study concerned the following research objectives.

Research Objective 1 *ITS is an optimal way of selecting appropriate ICT tools.*

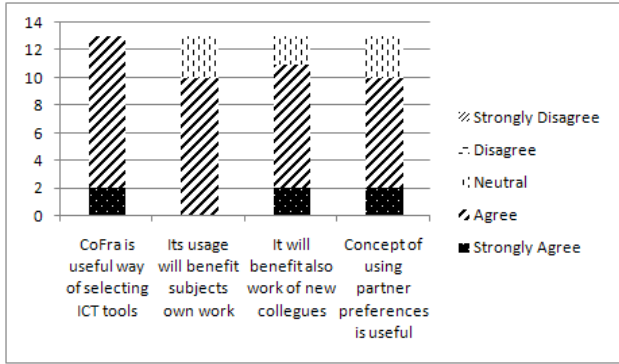


Figure 3: Answers Related To Research Objective 1

Research Objective 2 Collaboration variables used in CoFra are relevant and useful for ICT tool selection.

The participants received the task to find ICT tools supporting some project activities using ITS. In the pre-test questionnaire, 11 out of 13 participants indicated that they know *much* about ICT tools. Furthermore, 6 participants have *much*, and 5 have *some* experience in working within multidisciplinary teams. The post-test questionnaire included the questions regarding collaboration variables, stakeholders' preferences etc.

6.3. Results And Analysis

This section presents some of the results of the user study. First, the two research objectives are discussed, and then some other results are described.

Research objective 1 Among the 13 participants, 10 believe that the tested application provides a useful way of selecting ICT tools. 10 participants believe that it will benefit their work and 11 participants mentioned that CoFra will be useful for new colleagues if their organization/company implemented a tool similar to this one (see Figure 3). CoFra facilitates users not only to select tools based on their own preferences but also to consider the preferences of their partners involved in a project. 10 out of 13 participants agree that concept of using partner preferences is useful, it allows them to match their preferences and the preferences of their colleagues for better collaboration (see Figure 3). Selecting a partner's preference was optional in the test application. However, 8 participants state that it will be more beneficial if the partner preferences could be integrated with their preferences. Furthermore, 12 participants answered in the post-test questionnaire that it is nice to get the list of tools that only match their preferences. This empirical study confirms our insights based on our understanding and a literature survey: ITS is a novel way of

selecting ICT tools. 9 out of 13 participants answered that they have not used any application that allows them to select the tools based on their preferences and preferences of their colleagues .

One subject mentioned earlier use of an application for ICT tools selection, but with a limited scope compared to ITS. And 11 participants show interest in using such an application that allows them to select correct ICT tools that match their preferences.

Research objective 2 All 13 participants confirm that the concept of using tool-related variables for selection of ICT tools is useful. 12 participants believe that user-specific variables (ease of use, most used tool) will further add value in selection of appropriate ICT tools. 12 participants mentioned that it is useful that they only get the list of tools that most match the collaboration variables (see Figure 4). Post-test results shows that participants consider both tool-related and user-specific variables equally important in selection of ICT tools. The positive results in the post-test questionnaire clearly indicate that the collaboration variables used in CoFra are relevant.

The participants were asked to check what collaboration variables are not important to their opinion in the process of selection of ICT tools. 5 out of 13 participants answered that all the collaboration variables are important. The remaining 8 participants answered that few collaboration variables are not important for their selection (Table 2). But not more than 2 participants think that 3 variables are not important. The results shown in Table 2 are mutually inclusive. The display of tool-related variables depends on the ICT tools. This dependency implies that even though a given variable can be less significant for the selection, it should be considered and is not allowed to be ignored. As shown in Table 2, 'notification support' and 'most used tool' are least considered to be not important. One could derive that they are thus the most important.

Table 2: Number Of Participants That Rated Collaboration Variables As Not Important

Collaboration Variables	Rated not important
Notification support	0
Most use tool	0
Budget	1
Interoperability	1
Type of tool	2
User Interface	2
Ease of use	2
Language support	3
Mobile support	3

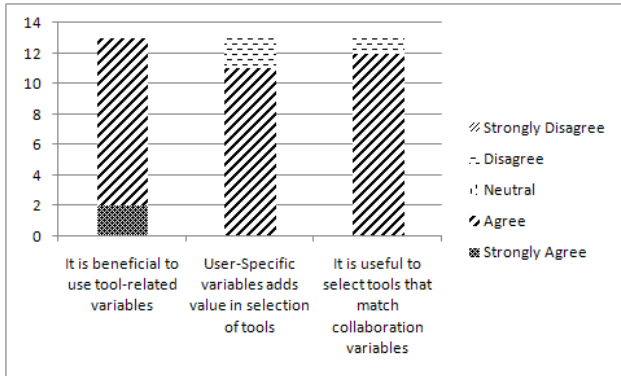


Figure 4: Answers Related To Research Objective 2

Other Results It is important that ITS is easy to use and supports a simple tool selection process. In the post-test questionnaire, 12 participants answered that the tool selection process was clear to them. The guidelines and scenario explained before the pre-test questionnaire were useful and helped them in developing an understanding of the selection process and tool usage. Another interesting finding from the study is that participants show their interest to use the application and they believe it is a useful way to select ICT tools. They are however not interested in adding new ICT tools to the collection. Only 5 participants show a motivation to contribute to the collection of information on ICT tools.

Furthermore, 6 out of 13 participants agreed that it would be nice if the list of collaboration variables could be increased. We can combine the list of current variables with the tool characteristics presented by Bolstad et al [2](see section 2), proposed in their taxonomy of collaboration. However, their taxonomy is limited to only three tool characteristics. We can extend the list by adding collaboration variables that we encountered during literature study i.e. platform (web-based, desktop), database (Oracle, SQL server), anti-spam, security, deployment and scalability as tool-related variables while user rating, ease of learning, customization are user-specific variables. Table 2 reflects that the list of current collaboration variables is relevant.

7. SBP: SHARING BEST PRACTICES

The goal of the SBP prototype application is to analyze instantiation of CoFra to sharing and promoting reuse of best practices through workflows.

7.1. SBP

SBP (Sharing Best Practices) is designed to improve the exchange of best practices, and to encourage knowledge

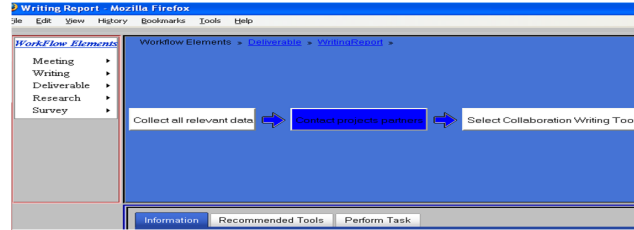


Figure 5: SBP, Top Part Of Screen

sharing among stakeholders, i.e they should be able to do their work as easily, efficiently and effectively as possible.

Figure 5 gives an overview of the different parts of the application. The database used in the application contains possible values i.e activities, sub-activities etc used in workflow. The navigation menu on the left is used to navigate through the best practices available in the database. The organization of the application's menu is based on a taxonomy developed in the same project as our collaboration framework. Data obtained during field trips and surveys [14] as well as card sorting exercises with researchers from multiple disciplines were used to create the taxonomy. This approach was chosen because stakeholders with different backgrounds have different views and more often find it difficult to identify ambiguous term [10]. The center depicts a workflow, in this case on how to collaboratively write a report. This graphical depiction should allow each stakeholder to quickly identify all necessary steps to perform this activity and allows to navigate quickly through all related knowledge and to even start execution of a specific step.

When a step in the workflow is selected, all relevant information is shown in the lower part of the screen. It is spread over a maximum of three tabs: *information*, *recommended tools* and *perform task*. The *information* tab contains detailed information about this step in the workflow. The information is presented using a wiki, as this approach not only allows stakeholders to access content but also to contribute and change the content [5]. This is important to allow information to be updated to reflect best practices in different disciplines and stakeholders. The *recommended tools* tab is a shortcut to a variant of the ICT tool selection application discussed in the previous section, while the *perform task* tab allows to directly execute a step, whenever it is possible to do so. While in the current prototype the functionality in the *perform task* tab is not related to the information in the *recommended tools* tab, it is our belief that this should be the case.

Automating some activities, using the workflow specification was not a goal of this application and would be a major challenge. Supporting an inter-organizational processes

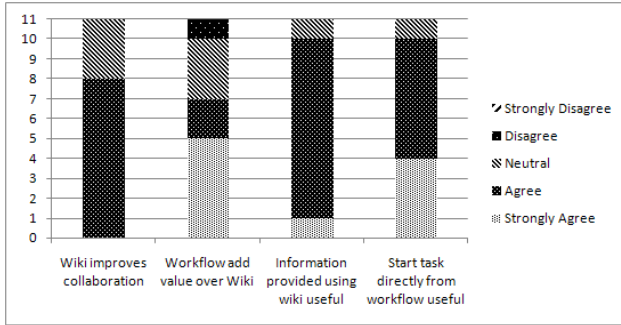


Figure 6: Answers Related To Research Objective 3

across research groups is a challenging task in workflow management [25] due to many technical and social issues. Therefore our application enables the execution of single steps in the workflow.

7.2. Evaluation Approach And Execution

One female participant with Information Technology background and a male subject from Business Development who participated in the first user study were not available for the second study. This means that 11 participants took part in the study (6 females, 5 males). The objective with the pre-test questionnaire was to investigate how familiar the participants were with the workflow concept and wiki applications. 8 out of the 11 participants have *little* knowledge regarding workflow and none of them have *much* experience with workflow applications. 3 participants have *much* and 6 have *some* experience of using wiki. Here, we aim to investigate following research objective.

Research Objective 3 *A workflow depiction improves knowledge sharing practices over traditional wiki.*

In this user study, the participants used SBP (see section 7.1). The participants were given a scenario in which they were asked to consider themselves as a new employee that wanted to know more about writing deliverables. This choice was motivated by the fact that the taxonomy used in application (see section 7.1) should be clear to new researchers with different backgrounds and that the topic would otherwise be considered trivial. While performing the tasks the participants were encouraged to try out all functionality related to the steps of the workflow for “writing a deliverable”. In the post-test questionnaire the participants answered questions related to workflow, wiki etc.

7.3. Results And Analysis

Ten participants indicated that the concept of using wiki to provide information (guidelines, best practices, other useful information i.e. web-links, videos etc) is useful (see

Figure 6). Furthermore, 8 out of 11 participants agree that a wiki could be used to improve collaboration. This can be explained by the fact that a wiki facilitates users to contribute and share knowledge. 7 participants mention that a graphical description of the workflow adds value over a wiki-only description of best practices (see Figure 6). This can be explained by the fact that the graphical representation (used in the test) provides a better overview about steps that need to be performed to complete activity. When consulted during the execution of the activity, it helps in identifying which tasks are completed and what still needs to be done. Performing a task within workflow is another feature that adds value over a traditional wiki as 10 out of 11 participants agree that starting a task directly from the workflow is useful (see Figure 6). Based on the post-test questionnaire results we infer that participants prefer CoFra’s workflow depiction over traditional wiki.

Other Results 8 out of 11 participants believe that the workflow application will benefit their new colleagues, while only 4 participants answered that it will benefit their own work. We believe that the information provided in a scenario could be a possible reason that participants believe that the workflow application benefit their new colleagues rather than their own work. On the contrary, 10 participants stated that they would use this kind of application for their work. The workflow application is equally useful to experienced researchers. They can contribute and add more knowledge based on their experiences, literature and other useful information using the wiki. The workflow generated is static and predefined, all 11 participants believe that it will be nice if they can customize the workflow, based on their preferences. We agree that there is a need to customize the workflow. This could be achieved by letting users customize their profile to personalize the interaction. We will examine the possibility to add personalization in the workflow application in future.

10 out of 11 participants agreed that it is useful to start external applications from within this kind of application. The participants also provided positive feedback regarding integration of ICT tools, all 11 participants believed that the concept of integrating ICT tool selection in the workflow adds more value than using it as a separate application. The empirical evidence strengthens our believe that the application described in section 7.1 is a suitable tool to share best practices and to promote their application through the integrated capabilities to start using the proposed tools. It thus also could help to improve collaboration.

8. DISCUSSION

Selection of the right ICT tool and sharing/promotion of best practices are very important activities in collabora-

tive multidisciplinary projects because they lay the foundation for effective communication and collaboration between stakeholders. However, since these activities require detailed knowledge about the stakeholders and estimation skills in order to be successful, it is difficult to carry them out perfectly. The inability to estimate implementation effort and a lack of framework and tool support may be one of the reasons why organizations use ad-hoc methods when selecting ICT tools.

We proposed CoFra that acknowledges the importance of appropriate selection of ICT tools and methods by placing these activities at the same level as the actual usage of these methods. Despite the fact that we devoted much attention to two applications that focus on the sharing and selection of appropriate tools and methods, we believe that the framework can be useful even without these or other specific new tools by indicating important points of attention. The primary purpose of the discussed applications is to illustrate potential software support for usage of CoFra (in multi-disciplinary research projects). Two user studies using these applications were conducted to evaluate the instantiations of a collaboration framework as a technique for selecting ICT tools and sharing best practices. Although these user studies do not give us a basis to draw definitive conclusions in real world settings, we believe they give some indications of pitfalls and potential to introduce this kind of tool support in multi-organization multidisciplinary research projects.

The results of the first user study (see section 6.1) do not contradict that using a simple set of variables can be useful to select appropriate tools and that the additional collaboration variables we provide can be useful in selecting ICT tools. The results also give an indication of what is considered important when working in teams: notification support (i.e. support for awareness) and most frequently used tools (i.e. do other people use this tool?) are closely followed by the variables budget (can we afford this?) and interoperability (can we easily reuse the output of the tool). What this shows regarding CoFra is that the *user-specific* variables (potentially) are as important as the other considerations. Using a specific tool, such as ITS, to support the selection process would probably be difficult due to the fact that only a small number of people are inclined to enter the necessary data. This finding is similar to what is seen at large scale collaborative efforts such as wikipedia.

The results of the second user study, regarding SBP (see section 7.1), indicate that graphical workflow depiction of even informal activities can be useful in distributed projects. Most people would like to adapt these workflows, which is logical since many activities are rather informal and might involve no or very limited steps that are really re-

quired to be performed in a specific way. The potential for adoption is however relatively uncertain as only a minority answered that such a tool would benefit their work but a majority indicated that it would benefit new colleagues. Most participants in the user study indicated nonetheless they would use such a tool. Considering that many parts of activities in multi-organization, multidisciplinary research projects are unpredictable in both time and space, this latter statement is hopeful since Grudin [11] indicated workflows as the best collaboration tool for this category of collaborative work. Further investigation of user-adaptable lightweight workflow systems is thus encouraged.

9. CONCLUSIONS AND FUTURE WORK

This paper reports on a study about supporting ICT tool selection and use in multi-disciplinary collaborative projects. We presented a conceptual collaboration framework (CoFra). CoFra has four main components (Stakeholder, ICT Tools, Collaboration Variable and Activity) as well as two additional components (Workflow and Best Practice). Based on the discussion in this paper, CoFra can be considered as a novel way to improve collaboration in multidisciplinary teams. It helps in selecting the appropriate ICT tools for project activities, covers a comprehensive set of collaboration variables, generate workflow, examines the best practices (e.g. knowledge sharing, integration with external applications, stakeholder's preferences in selection of ICT tools). We thus conclude that CoFra is a state-of-the-art technique in multidisciplinary collaborative projects.

We conducted two user studies to validate instantiations of CoFra. Based on the results from both studies, one can conclude that (1) CoFra provides a suitable way to select appropriate ICT tools for multiple project activities, (2) the collaboration variables used in CoFra are relevant and (3) CoFra's workflow element improves sharing of best practices over traditional wiki. The results presented in this paper indicate that our framework has a lot of potential. A future, more extensive, study is however required to make definite recommendations regarding the use of the framework in real world settings. Based on the experiences with these user studies, we believe there is a need to add personalization to improve the applications tested in this paper. It is, however, our believe that this would not result in changes to CoFra. The results of the second user study also learned us that there is a desire to adapt the workflow. An easy way to update a workflow specification or create variations of it, while ensuring correctness of the related information and ICT tools, is another area of future work.

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