Formative assessment of the effectiveness of collaboration in GCB

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Abstract: With the rapid emergence of new communication software and hardware tools and the improvement of telecommunication infrastructures, a new collaboration paradigm is on the horizon that allows researchers around the globe to expand their loop of collaborators to cross geographical and cultural boundaries. However, much needs to be learned from the user experiences not only to improve the quality of the collaboration facilities, but also to develop new social protocols for distributed human interactions. In this paper, we try to analyze the usage of cyberinfrastructure in remote collaboration among researchers. For that, we draw on survey data and interviews with members from different collaborative projects, and we analyze how our current communication tools meet the needs of collaborative research activities. Then, we articulate a series of key challenges and requirements that contemporary teams are facing. In the end, we present ideas on what sorts of collaborative tools need to be built in order to fulfil the distributed and interdisciplinary collaboration projects. Our findings shed light on the factors that drive the use of cyberinfrastructure and the effectiveness in the success of cross-national and interdisciplinary research collaboration and distance learning, and suggest further research topics.

Keywords: e-Science, formative assessment, group collaboration, distributed collaboration, distance learning.

1 INTRODUCTION

A majority of scientific researchers currently do not perceive the relevance of cyberinfrastructure (CI) for their own research [1,4]. Realization of such applicability often requires an in-depth understanding of both their scientific domain as well as the promise of CI. The Global CyberBridges (GCB) project [3] is designed to address this problem of inadequate adoption and use of cyberinfrastructure. GCB is a model global collaboration infrastructure for e-Science [2] between USA and international partners. The project is a multinational effort which aims at fully integrating cyberinfrastructure into the whole educational, professional, and creative process of diverse disciplines, bridging the divide between the information technology communities and the disciplines and creating a global community of scientists and researchers capable of collaborating with their counterparts through the integrated cyberinfrastructure.

Currently the project spans five research institutions spread over three regions: USA, China and Hong Kong, including faculty members and graduate students. Graduate students, 10 participants from USA and China, form four distributed teams of two to three individuals, with at least one person at each site in a specific team. Team members are playing the role of either CI researchers or disciplinary researchers. Disciplinary researchers are selected from academic areas such as biology, chemistry, meteorology and others. The CI researchers with a Computer Science or Information Technology background work with the disciplinary researchers in an attempt to satisfy their needs by making the best use of the cyberinfrastructure. Members of the four distributed teams have been working collaboratively for the past six months on the following projects: *Computational Modeling & Simulation of Biodegradable Starch-Based Polymer Composites, Grid Enablement of Hurricane Simulation Application, On-Demand Weather Forecast Visualization via Efficient Resource Utilization in Grid Computing,* and *Collaborative Platforms*.

Our team, which is composed of two graduate students one from USA and one from China and two faculty advisors from USA, is built to work on the last project mentioned above[1]. We believe that the success of building research collaborations across national boundaries depends very strongly on the quality of the collaborative platforms available for use by the participants and their effectiveness in using them. Therefore, our goal in this project is to provide a more convenient and efficient collaborative platform for our researchers, making global research collaboration a more productive and enjoyable experience.

To reach this goal, we have been observing, participating and studying the distributed and interdisciplinary collaboration of all four teams (including our team). We try to articulate a series of key challenges and requirements facing contemporary teams through both our observations and analysis of the survey we have conducted. Our aim in this paper is to present our research on the practice and feasibility of our existing social and technological support in providing distributed and interdisciplinary scientific researchers with an efficient and easy-to-use collaboration environment.

In current literature, similar evaluation research works using the method of survey and interview, have been done as can be seen in [7,8,9,10]. However, these works are focused on specific applications and domains different from our scenario, thus to some extent their findings does not effectively reflect the issues that we are faced with them in Global CyberBridges, and even at some points have contradictory findings compared to ours, which will be discussed later. Our work in this paper is unique in that it is the first assessment on the success of effectiveness in scientific research collaboration conducted among cross-nation/cross-culture graduate students and their respective faculty advisors. Before the research collaboration phase,

[1] The authors of this paper are members of the Collaborative Platforms project.

these graduate students have gone through a semester of technical training on High Performance Grid Computing and Networking Research[2] together. Thus, our findings shed light on the factors that drive the use of cyberinfrastructure and the effectiveness in the success of cross-national and interdisciplinary *research* collaboration as well as *distance learning*.

The rest of the paper is organized as follows. In Section 2, we introduce the assessment activities that we chose to conduct our formative assessment. In Section 3, we discuss our findings on the current social and technological issues that have been challenging our teams. These findings are based on the result of the survey and interview as well as our observational work. In Section 4, we present detailed examination of current technologies and propose some improvements. Finally, in Section 5, we conclude our work in this paper and present the research issues needed to be addressed in the future.

2 ASSESSMENT ACTIVITIES

In traditional methods of studying the effectiveness of scientific research, publication volume is often used as the key evaluation criteria. However, in distributed collaborative scientific research such as cases like our projects, publication volume itself as the only evaluation criteria is not sufficient. Because collaboration is starting between cross-cultural strangers, it may take a while for the collaboration to mature and reach to a point where publications can be measured.

As observed in the collaboration process, the project often includes the development, integration, deployment, and testing of the technical infrastructure, as well as the coordination and building research communities needed for cross-cultural and cross-national collaboration. Collaboration activities normally include joint research projects and joint working papers. However, not all projects utilize cyberinfrastructure and collaborate in the same way.

For example, as observed in the team of *Computational Modeling & Simulation of Biodegradable Starch based polymer composites*, interaction is not much intensive since tasks are clearly divided between CI researchers and disciplinary researchers. CI researchers mainly focus on assisting disciplinary researchers in operating computer clusters and parallel computers that can meet the massive computing requirements posed by applying quantum-chemical methods to polymeric systems. In more detail, disciplinary researchers first decide which software to use in the quantum computing; Next, CI researchers install and test the software on the cluster; Then, it is again disciplinary researchers' turn to program with the software to solve disciplinary problems; Finally, CI researchers will work on how to fully utilize the cluster and improve the computation efficiency, including parallel processing, and thus enable disciplinary researchers to meet their research goals.

However, in other teams such as ours, tasks are not divided so clearly. In almost every step of this collaboration process, we had to interact with each other closely. Since our project goals was being adjusted occasionally, weekly audio meeting, together with frequent E-mails and instant message sessions, should have been well guaranteed. As a first step in this collaboration, we needed to develop a common understanding of what we would like to achieve, and how we would go about doing it. The best way we found was to exchange ideas and document notes to clarify our understanding of the project and to discuss further if something is not completely understood.

Thus, we decided to assess the effectiveness of collaboration using the following activities: attending all the distance learning sessions including both the video and audio meetings; monitoring the E-mail interactions in the project group forums and the associated mailing lists; conducting a survey one month after the distance learning course has finished and the collaborative research has started; and finally, interviewing face-to-face with the team members. In the next section, we present our findings of the problems we want to further explore.

3 OUR FINDINGS

As a whole, collaborative activities we have observed in all projects include two parts: distant class participation and distributed collaborative research work. We have worked on an interim assessment of the effectiveness of the existing collaboration in the four GCB projects. As a part of the two assessing items (the technology support and the social protocols), we conducted a survey and set up interviews with respondents respectively at the two sites (Beijing and Miami) as to how satisfied they are with the progress of their respective projects, and how and what can be done to improve the effectiveness of their distance learning and research collaboration.

3.1 Survey

In the survey, we employed the extended Task-Technology-Fitness framework [5,6,8] to define the types of tasks. The survey was composed of the following three major sections.

[2] This course was taught for a semester at Florida International University (Miami, Florida, USA) and the Chinese graduate students attended the class remotely through collaborative platform utilities including SAGE tile display wall, PolyCom video conferencing, and Skype and MSN audio and text chat systems.

- **Main activities in research**

The different teams were asked to enumerate the activities in which they spent most of their time. Among the possible answers were: Writing documents, taking decisions with other peers, installing software used for their research, developing needed tools and researching. Figure 1 shows which tasks had a greater importance for the reviewees. The graph shows the possible answers in the X axis and the percentage of individuals who chose them as principal tasks in the Y axis. We can see that the most prominent activity is research itself. Nevertheless, this is a task that is carried mostly in solitary, and doesn't gain much from collaborative tools. The next two most common tasks, writing documents and taking decisions are much better targets for collaborative technologies, since they require more direct interactions among the team members.

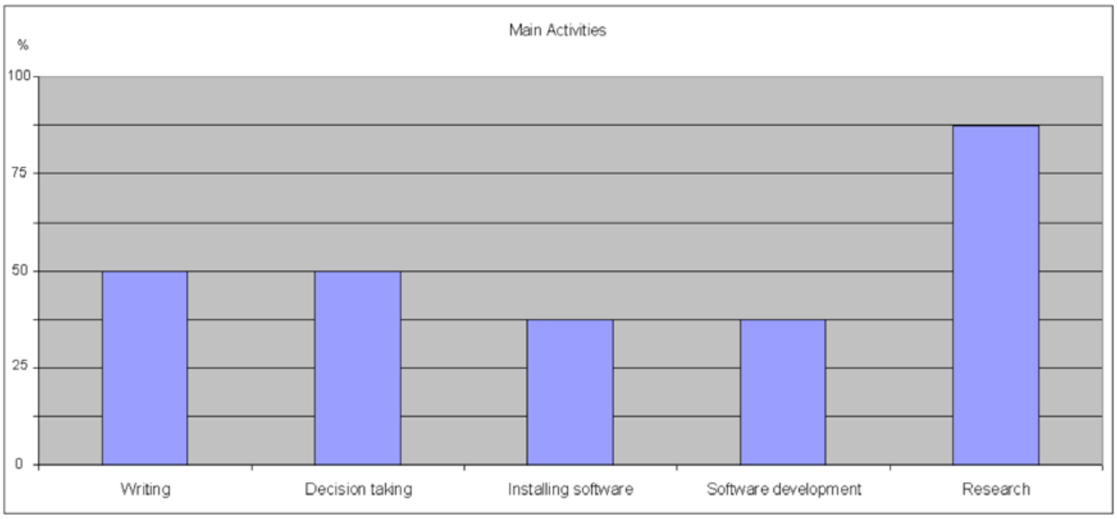

Figure 1: Main Activities in research

- **Used tools**

Another question posed in the survey was the use of the existing tools during different tasks. Figure 2 shows that the two most used tools are E-mail and Voice-over-IP (VoIP) Software. E-mail and VoIP Software are existing solutions that have been available for a long time (the latter can be considered just as an extension of the regular phone line). We believe that others, like video conferencing, were not used as much due to the difficulty of using them. For example, we have Polycom video conferencing systems in USA, China, and Hong Kong, but unfortunately they were not easily accessible and there are other social issues with video conferencing that makes the users uncomfortable as discussed later.

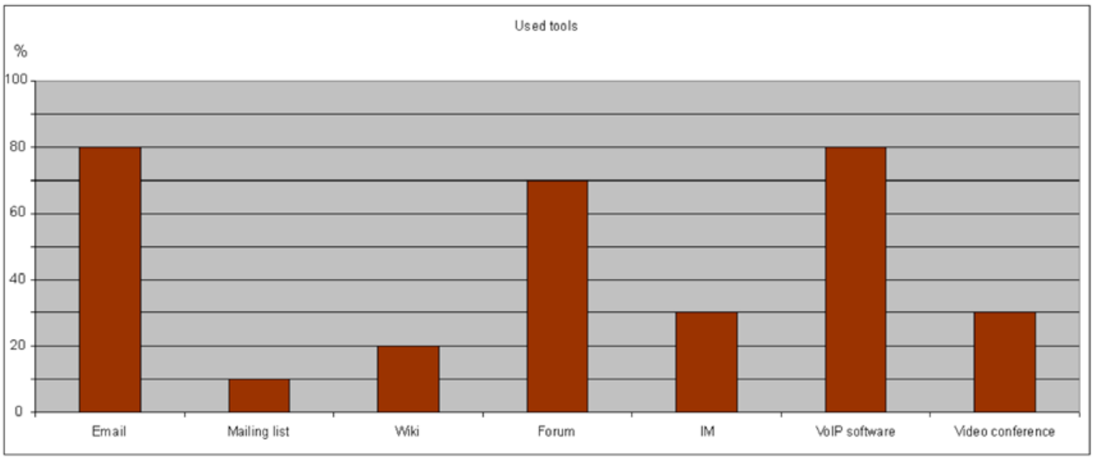

Figure 2: Tools used in the collaboration process

- **Tool effectiveness**

Finally, we asked all partners to rate the effectiveness of different types of tools for given tasks. These tool types comprise Text Systems (which includes Instant Messaging, E-mail, Wiki, Forum), Audio Systems (which includes Telephone and VoIP Conferences), Video Systems (which includes PolyCom and Skype video conferencing systems) and Face-to-Face Meetings. The low acceptance for video systems was unexpected for us, since it seems to be a more powerful tool than voice systems; providing the same service as the former plus visual appearance of partners. Our suspicion was that this characteristic of video conferencing systems, which is being seen by others, is what made some users uncomfortable with it. Many of them prefer the anonymity of text or voice systems to perform most of their tasks as can be inferred from the graph in Figure 3.

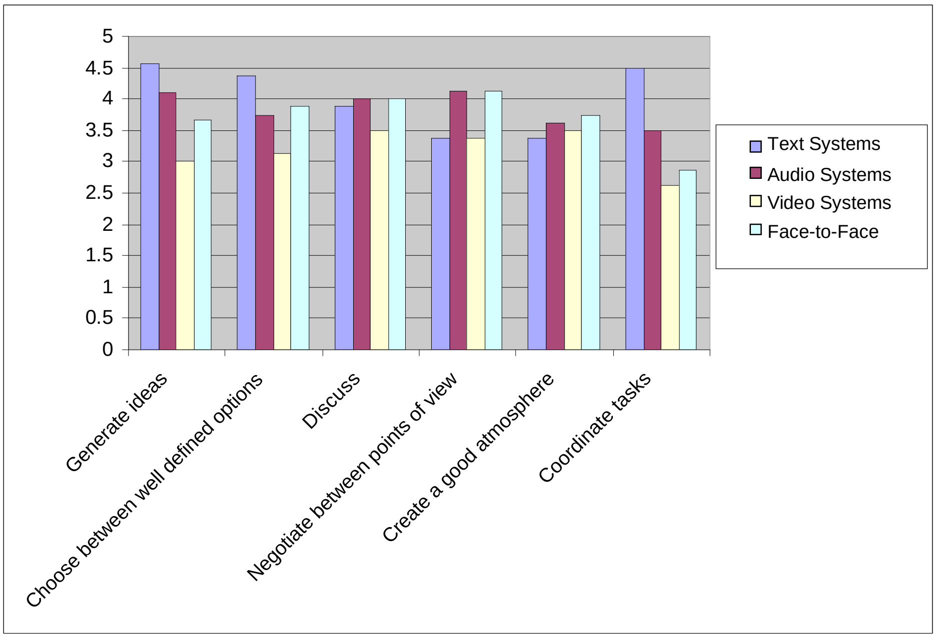

Figure 3: Tool effectiveness according to tasks

3.2 Ongoing Feedbacks and Interviews

Apart from the ongoing feedbacks and complaints that we were receiving from time to time from the partners, which were very helpful on trying quick solutions to the problems, we also set up semi-formal face-to-face interviews with the team members after analyzing the survey. We believe that there are more aspects to collaboration that cannot be demonstrated on the above histograms and ongoing feedbacks; this is where face-to-face interviews can help. We also wanted to have their ideas on some open-ended questions that could not be elaborated in our survey. Below, we will present our analysis based on informal introspection combined with more formal observational work. Our findings of current issues and problems with regards to both the technology support and the social protocols are as follows.

Discussion on the technological aspects

In this part, we present three of the technology requirements in the GCB project and discuss the respective issues and problems with regards to each of them.

- **We require effective communication technologies for distance learning.**

  Video Tele Conferencing (VTC) is used as the main means of distance learning. Although we admit that VTC is currently the best way that we can connect people regardless of their location and that video plays an important role in developing a cosy atmosphere as well as building a close affinity among cross-cultural strangers, current VTC technologies are far from perfect. We believe that the distance barrier can be broken only when distributed people are communicating just as they are talking face-to-face, which requires views from various perspectives with no distraction from the technology itself, but the widely available VTC technologies today does not yet provide such an environment. The not-so-good quality and occasional delay (jitter) of sound and video that happens every now and then are among the major problems that have greatly challenged the Chinese students and have added to the language difficulty that they already had. To mention another problem, the VTC technology that we used does not support sharing of the presentation slides. This has introduced yet another problem as the projected PowerPoint slides could not be displayed simultaneously in the two sites (USA and China) together with the image of people who were participating in the classroom, not to mention other views that only the local participants can perceive. Remote participants usually find it hard to figure out who is talking about which part of the slide.

  As we learned about such problems, we tried to address them by trying different solutions. For example, for each session of the class, a student volunteer would take the control of the PolyCom VTC and would change the focus of the camera to whoever was talking at the moment. Among other improvements we set up a chat system to go along with the VTC. This was very helpful as the teacher could clarify a point, send a URL, etc. using text messages without causing new confusions. Also, we developed a simple human-to-human protocol that would force us to pause several times during the lecture to make sure that remote participants can catch up with the teaching pace. Still, we admit that there is a lot to improve to make distance teaching more satisfactory and effective.

- **We require effective communication technologies for distributed collaborative research.**

  First of all, based on the analysis of survey and interview, we found that our users are more willing to use the simple collaborative tools that they have been familiar with such as E-mail and voice conferencing, which shows the fact that a criterion of use for a given technology is the level of familiarity that users already have with that technology. According to our study, we found out that E-Mail was the most widely used tool in communication between peers, as well as VoIP software in the case of small groups of people; the former medium is one of the most extended online tools, and the same can be said for the VoIP technologies, which can be seen as an extension to the traditional telephone systems. Users feel more comfortable if they can keep their existing habits, and this criterion is also valid for the opposite case: the use of video conferencing or wiki software, for example, was not as well rated among users, given that these technologies require new habits and skills.

  Secondly, many interviewees agreed on the point that E-mail was more effective for generating ideas and coordinating tasks, while voice conference calls were better for discussion and negotiation. Our study results also suggest that occasional video conferences are instrumental in a good atmosphere which is a crucial precursor to the effective use of distance communications technologies. However, the 12 hour time difference between Miami and Beijing has forced our team members to limit their synchronous communication (e.g., voice/video teleconferencing) to only once or at most twice a week and communicate mostly through E-mail, IM, mailing list, and group forums.

  Thirdly, contrary to the point "*Instant Messaging are not seen as efficient or well suited communication channels for collaborative tasks*" as discussed in [8], our findings reveal that IM is necessary for effective collaboration. The biggest barrier in distributed collaboration is the unreachability of distant partners. Normally partners make schedules and meet regularly to coordinate tasks and make new schedules. However, when unscheduled and exigent problems arise, they usually feel helpless either because of the unawareness of their partner's phone number, or as a result of the unwillingness to get in touch with their partners at the cost of expensive international calls, which largely decrease the effectiveness in distributed collaboration. In such cases, IM has proved to be a good solution for our team members.

  Last but not the least, we found that efficient collaboration necessitates a seamlessly integrated work platform where researchers have easy access to all collaboration tools. Currently, we have forums, wiki, E-mails, mailing list, video conference, and instant messaging at our disposal. As a direct consequence of all these different, but complementary technologies, we have to keep track of many usernames and passwords, and have to login and open several websites and/or collaboration software tools in order to be able to communicate with our collaborators. We believe that it would be very helpful to the researchers if we could free them from going through such tedious and distracting tasks by providing them with an integrated and single-sign-on system that would satisfy all their communication needs. A successful collaboration platform is one that allows researchers to focus on the flow and integration of information and not on the details of the underlying components. One such approach is underway in the Communication Virtual Machine project [11].

- **We require effective technology for visualizing complex phenomena.**

  As another result of our study, we realized that for effective scientific collaboration, the ability to visualize and share high-resolution and complex phenomena is a must. For the GCB project, we chose to use the tile display wall technology instead of expensive custom-design solutions, both because of the cost involved (using off-the-shelf equipment) and because of the ability to scale the system, if needed. A wall-mounted tile display consists of a number of regular LCD screens placed one next to the other, which forms a grid of LCD screens. In our case, we use SAGE [12], a software utility that synchronizes the output of several computers so that an image can be plotted with a very high resolution on the grid of LCDs. Although this software was originally developed to provide a solution to displaying very high resolution images, we also plan to use it as a collaborative whiteboard where distant peers can exchange ideas.

Discussion on the geographical and social aspects

Based on our observational work and the analysis of the survey and the interview, we reached to some new findings as follows.

Firstly, contrary to the common belief that it is hard for global collaboration to attain the same effectiveness as local collaboration does because of the poor technological support and incomplete social protocols, we have an interesting and exciting finding that shows this global work pattern can become even more efficient than local collaboration as a direct result of the time zone difference. Let us consider coordination, which is a common task in collaboration, as an example. Assume that the workload related to a task assigned to two remote team members is one day for each of the members and one member has to wait until the other one is done before the other one can start his/her part. As the global partners in our project have 12 hours time zone difference, when it is the beginning of the day for one person, his/her partner at the other side of the world has just finished a whole day of work and is ready to go to bed. Therefore, it actually takes this distributed team only one full day to finish the whole task (24 instead of 48 hours)!

Secondly, in order to maintain such a success in the effectiveness of distributed collaboration, we realized that maintaining a strong commitment to different tasks is absolutely necessary to its success. Keeping communication and interaction, especially quick response and having each other updated about the latest status in collaboration, is also very important when distant strangers try to build a collaborative research relationship. Interaction should include not only technical discussion but also chatting about day-to-day matters. Feedback should be provided as soon as possible to correct problems if things are not working properly. We believe that in a collaborative research work, feeling like being a part of the team is the ultimate key to success of the team and any effort in this regard cannot be overestimated.

Finally, we fount out that technology reliability has a strong affect on the building of trust and social relationships. For example, the group forums used in the collaboration did not work well for some time at the beginning. The expectation from the forum software was to send an E-mail to all the group members for each new posting to the forum. However, as the forum software was updated and the new version requires explicit mention of such setting, there was no E-mail sent to the group members (by default) to notify them of the new postings. Misunderstandings and disappointments arose in this condition and harmed the willingness to collaborate with each other for the period in which the problem persisted.

Based on the discussions presented in this section, we identified several methods that are useful and should be adopted in a distributed collaboration activity. First, you need to make sure that people at remote sites understand each other, and more importantly, are in synch with each other. For example, during a distant learning session, it may be useful to develop a protocol to signal or interrupt an ongoing conversation for more clarifications on the subject matter. In addition, according to our experience, we found out that sending the presentation slides and the other shared material in advance to all the involved parties is very helpful in light of the technological deficiencies of the current VTC technology, as well as making sure redundancy in the system if a channel fails – SAGE Tile Display Wall, Polycom, Chat, or Moodle [13].

4 POTENTIAL IMPROVEMENTS TO THE EXISTING TECHNOLOGY

The initial set of tools selected for enabling collaboration in different GCB projects were based on well known communication software tools. Since the project was not starting from any prior study of communication tools effectiveness, the choice was guided by the familiarity and availability of the tools, rather than by their effectiveness in distant collaboration. Among the basic technologies used were E-mail, instant messaging using MSN Messenger, a Web-based forum using Moodle, Wiki pages of LA Grid, video conferencing using Polycom and VoIP voice conference using Skype. A wall-mounted tile display running SAGE software for visualization was also available. These technologies proved to be enough to allow distant researchers to communicate, follow a lecture across geographical boundaries, and carry on with different research projects, but many improvements can still be done to facilitate users' experiences. Below, we first classify communication tools and then provide some improvement suggestions to the design of future communication tools.

4.1 A Classification of Communication Technologies

There are other existing technologies which were not used in the different GCB projects and we believe that they can help researchers to collaborate more effectively. Below, we introduce a classification of the available tools that we developed to better understand our options and to be able to recommend possible replacements to the currently selected tools for the future GCB projects. The categories that we came up with are the following.

- **Synchronous Communication Software**
  - Telephone and VoIP, Instant Messaging, Video Conferencing, etc.
- **Asynchronous Messaging Tools**
  - E-mail, Mailing Lists, Forum Software, etc.
- **Collaborative Editors**
  - Wiki Pages, Synchronous Word Processors (Google Docs), etc.
- **Workspace Sharing Applications**
  - Whiteboards, Desktop Sharing Software, etc.
- **Integrated Environments**
  - Some tend to be focused to a given area, like Basecamp or Novell's GroupWise, and some tend to be more general with ways to customize the communication such as CVM. These environments sometimes encompass existing technologies like video conferencing, E-mail, etc.

Although some tools can fall into more than one category, each of these categories presents some strong points and also some deficiencies. We found that *synchronous tools* for communication, like telephone, instant messaging and video conference systems are needed less frequently (e.g., once or twice a week) in order to discuss ideas, take decisions and create a consistent collaborative ambient. Nevertheless, they make necessary the presence of both interlocutors at the same time, and in the case of telephone and video conferencing systems participating peers have a higher personal exposure, which in some cases proved to be counter productive in the early stages of the projects.

Asynchronous messaging tools like E-mail, mailing list, and Web-based forum software are more suitable when researchers are situated in different time zones and cannot be present at the same time. A drawback of these tools, however, is the difficulty to maintain prolonged conversations, since responses are not necessarily immediate.

Collaborative editors are used as an important technology to accumulate knowledge. Wiki software allows partners to collaborate by putting ideas together and discussing them, although not as effectively as with other synchronous tools like phone systems or instant messaging. On the other hand, synchronous editors like Google Docs [14] allow a more immediate feedback to changes, letting peers to exchange ideas as they propose them.

Workspace sharing applications are similar to collaborative editors, but they usually allow participants to express ideas in a visual fashion. These tools are synchronous in many cases and provide the best alternative for sketching ideas, initiating discussions and showing concepts from different points of view.

Finally, *integrated environments* integrate different tools in a single package, making it easier to use them effectively. Nevertheless, these technologies are developed for specific groups of users, and bring problems when adapting them to the collectives for which they weren't addressed primarily. Although, there are some attempts to address this issue [11], there is no widely used integrated communication environment that can be adopted immediately for the GCB projects. Additionally, such environments typically require a high learning effort, which is not desirable and in most cases not practical.

4.2 Suggested Improvements to the Design of Future Communication Tools

There are many improvements that can be applied to the exiting communication tools, which were used in the GCB projects, and there are a number of new technologies that can make collaboration among researchers more efficient. There are also some features that make one communication utility more useful than others, and such features have to be considered when choosing a tool. For example, as discussed in Section 3, we found that a criterion of use for a given technology is the level of users' familiarity with the tool. This fact shows that a potentially useful communication utility is normally disregarded or falls into disuse when it conflicts with the users' daily habits or when it brings a burden associated with its high learning curve. This point indicates that new tools have to be similar to existing and established ones and new features should not require dramatic changes in the use of the existing tools.

Another improvement to the existing technology is the detachment of the software from the typical input and output devices. Bigger screens, tactile input and new interaction metaphors can enhance collaboration experiences and bridge the gap among distance and cultural frontiers. The drawbacks of such technologies, however, are primarily their cost, their low adoption rate and immaturity. In our particular case, the wall-mounted tile display running SAGE software, although being a powerful tool, has a slow adoption phase. We associate this deficiency to different factors such as the technology being in its early stages, the difficulty of deploying it, and the lack of user preparedness from our team members. SAGE is a software utility that enables high definition image and video representation, but so far proved to be inefficient for other uses such as videoconferencing or real time collaboration for our projects. We plan to address the inefficiency of SAGE in our future work.

5 CONCLUSION AND FUTURE WORK

This paper provides a formative assessment of the effectiveness of the collaboration in the GCB projects. We started from an analysis of the survey and interview about collaborative tools used by the project participants, their functionality, and their usefulness and effectiveness regarding different task types. Our assessment items cover both technological support and social protocols. Next, we examined current communication tools supporting collaborative work and in combination with the GCB communication requirements, we proposed our future work based on a currently inchoate collaborative tool, called *SAGE* .

Our work in this paper is based on both informal introspection and formal observational work combined with analysis of survey data and interview. This *Formative Assessment* is instrumental in that it not only helps the GCB team members make required, mid-project changes and corrections to the communication/collaboration styles and technology tools, but it also helps us identify needs for additional tools and social protocols, which should either be acquired or developed, and sheds light on future development work on our Collaborative Platforms project. In addition, as the primary aim of GCB is to foster collaboration between early-career scientists from USA and its international partners, this early feedback should increase the chances of success of GCB. We believe that continuous monitoring and refinement of the GCB collaborative projects will reveal even more issues related to cross-culture, cross-nation exchange of ideas that would require new improvements to the collaboration tools and would need new coordination, communication, and management techniques and solutions to be explored in the future.

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