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# CHARACTERISTICS OF COLLABORATIVE RESEARCH PROJECTS USING CLOUD STORAGE: CROSS-DISCIPLINARY ANALYSIS

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## **ABSTRACT**

Cloud storage platforms are widely used among researchers for their collaborative projects. However, a study that comprehensively examined the characteristics of these projects has been missing. In addition, we lack an understanding of how the characteristics are similar or different across academic disciplines. This study investigated the characteristics of collaborative research projects that use cloud storage by conducting an online survey with 534 researchers across disciplines (sciences, social sciences, arts & humanities). More specifically, this study examined the average number of collaborators in a research team using cloud storage, the duration of the collaborative research projects, primary cloud storage platforms used for the projects, the number of files in cloud storage, frequency of accessing files in cloud storage, and the size of the cloud storage for the collaborative research projects. Then, the disciplinary differences were analyzed. The findings revealed different characteristics and indicated that the characteristics of researchers' collaborative projects using cloud storage were quite different across the three disciplines. Statistically significant differences were found in the number of collaborators, duration of the project, primary cloud storage platform, and the size of the cloud storage. Particularly, collaborative research projects in sciences

had different characteristics when compared to the other two disciplines. This study enhances our understanding of the nature of collaborative research projects using cloud storage and disciplinary differences by conducting a large-scale study with researchers across disciplines. It also informs the design of tools that better support collaborative research projects using cloud storage for researchers in different disciplines.

Keywords: Personal information management, File management, Collaboration, Collaborative research, Cloud storage

## **INTRODUCTION AND BACKGROUND**

In the past few decades, collaborative research across academic disciplines has increased rapidly (Leahey, 2016; Wuchty et al., 2007). Kimiloglu, Ozturan, and Erdem (2012) who studied collaborative research from the academics' perspectives characterized collaborative research as teamwork, knowledge and experience sharing, continuous and direct communication, and common scope and goals (p. 1141). With the prevalence and increasing number of collaborative research, many researchers investigated the benefits and advantages of collaborative research projects. These

studies reported that the benefits of collaborative research include increased productivity (Abramo et al., 2014; Katsouyanni, 2008; Leahey, 2016; Lee and Bozeman, 2005; Wuchty et al., 2007), visibility (Kimiloglu et al., 2012), confidence (Menon and Owens, 1994), access to resources (Katsouyanni, 2008; Kimiloglu et al., 2012) and the sharing of specialized knowledge and skills (Cummings and Kiesler, 2007; Leahey, 2016). Although relatively fewer in number when compared to the studies on the advantages of collaborative research, there also have been studies that examined the disadvantages and the costs of collaborative research. These include additional time (Barnett and Frede, 2001), managerial effort (Adler et al., 2009; Brocke and Lippe, 2015), and communication and coordination costs (Barnett and Frede, 2001; Leahey, 2016, Winter et al., 2006).

While working on collaborative research projects, researchers often create, use, and manage a large collection of files that are added throughout the research process (Al-Omar and Cox, 2016; Antonijević and Cahoy, 2014; Bussert et al., 2011; Chaudhry & Alajmi, 2022). There are two different ways of managing these files for collaborative research projects. These files can be saved on researchers' own computers and shared with other collaborators via email attachments, or they can be saved and shared via cloud storage such as Google Drive or Dropbox (Antonijević and Cahoy, 2014; Bergman et al., 2014). Among these two methods, the former is a traditional way of working with and sharing files, and the latter is a relatively newer way of sharing files. Using cloud storage for collaborative research projects makes it possible for multiple collaborators to access or work on the same file simultaneously and allows accessing project files anywhere at any time with any device with internet access

and sharing large files (Bergman et al., 2014, 2019, 2020; Chang and Kang, 2016; Gawadekar and Gaurum, 2019; Park and Ryoo, 2013). These are critical advantages when using and managing files for collaborative research projects, and unsurprisingly, the use of cloud storage for collaborative research projects has now become popular (Bergman et al., 2019, 2020; Branco et al., 2017; Massey et al., 2014; Voids et al., 2013). However, some new challenges in using cloud storage for collaborative work have also been reported. These challenges include the complexity of co-organizing files (Berman et al., 2019; Massey et al., 2014; Rader, 2009), reluctance to delete shared files (Khan et al. 2018; Rader, 2009; Ramokapane et al., 2017), difficulty in retrieving shared files in the cloud storages (Bergman et al., 2014, 2019, 2020; Oh, 2022), and different understandings among collaborators of how cloud storage works (Capra et al., 2014; Marshall and Tang, 2012; Ramokapane et al., 2017; Tang et al., 2013). A number of studies also reported privacy and security concerns (Alsmadi & Prybutok, 2018; Capra et al., 2015; Khan et al., 2018; Lee, 2019; Li et al., 2020; Ramokapane et al., 2017; Widjaja et al., 2019).

In order to support researchers' use of cloud storage for their collaborative research projects, it is important to understand the characteristics of such projects. However, despite the popularity of using cloud storage for collaborative research projects, we still know little about the characteristics of collaborative research projects using cloud storage. In addition, whether these characteristics are similar or different among the academic disciplines has not been fully explored. Knowing the similarities and differences across disciplines can help us to have a deeper understanding of the characteristics of collaborative research projects using cloud storage, provide useful information in conducting interdisciplinary research

projects using cloud storage, and inform the development and design of the applications and tools for specific academic disciplines. Thus, this study investigated the characteristics of collaborative research projects using cloud storage and analyzed the disciplinary differences in their characteristics.

This study aims to answer the following research questions:

RQ1: What are the main characteristics of researchers' collaborative projects using cloud storage?

RQ2: What are the similarities and differences across disciplines (i.e., sciences, social sciences, arts & humanities)?

## METHODOLOGY

### Participants and Procedure

Participants were 534 researchers who work in doctoral universities as defined by the Carnegie Classification of Institutions

(Carnegie Classification of Institutions, 2018a) in the United States. In particular, researchers who have an ongoing collaborative research project that uses cloud storage were recruited.

Among the participants, there were more female participants (61.3%) than male participants (35.2%). In terms of age group, a majority of the participants were in their 20s (41.9%) or 30s (29.7%). In the case of ethnicity, White/Caucasian was the largest group (69.4%), followed by Asian (16.6%) and Latino/Hispanic (6.5%). In the case of discipline, there were participants from all three academic disciplines including social sciences (41.8%), sciences (36.1%), and arts & humanities (21.5%). In terms of their role in the collaborative project, 44.1% were Principal Investigators (PI) or Co-Principal Investigators (Co-PIs), and 30.5% were Research Assistants (RA). Table 1 displays detailed information about the participants.

*Table 1 – Participants information*

| Demographics        |                        | <i>n</i> | %    |
|---------------------|------------------------|----------|------|
| Gender              | Female                 | 313      | 61.3 |
|                     | Male                   | 180      | 35.2 |
|                     | Prefer not to answer   | 18       | 3.5  |
| Age                 | 20s                    | 214      | 41.9 |
|                     | 30s                    | 152      | 29.7 |
|                     | 40s                    | 77       | 15.1 |
|                     | 50s                    | 47       | 9.2  |
|                     | 60s or older           | 21       | 4.1  |
| Ethnicity           | Asian                  | 84       | 16.6 |
|                     | Black/African American | 15       | 3.0  |
|                     | Latino/Hispanic        | 33       | 6.5  |
|                     | White/Caucasian        | 351      | 69.4 |
|                     | Other                  | 23       | 4.6  |
| Academic discipline | Arts & Humanities      | 110      | 21.5 |
|                     | Sciences               | 185      | 36.1 |
|                     | Social Sciences        | 214      | 41.8 |
|                     | Other                  | 3        | 0.6  |
| Role in the project | PIs/Co-PIs             | 226      | 44.1 |

|  |                        |     |      |
|--|------------------------|-----|------|
|  | RAs                    | 156 | 30.5 |
|  | Researchers and others | 130 | 25.4 |

### Data collection and analysis

Data were collected by distributing an online survey to 360 doctoral universities that were randomly selected from the list of doctoral universities in the United States (Carnegie Classification of Institutions, 2018b). More specifically, administrative representatives at each of the 360 universities were asked to distribute an email to their department's listservs. The email included a survey link and invited researchers with an ongoing collaborative research project that uses shared cloud storage to volunteer to take the survey.

Data were analyzed by using statistical analyses including descriptive and inferential statistics. A series of Kolmogorov-Smirnov tests showed that all the continuous variables are not normally distributed. Thus, nonparametric statistics were used for all inferential statistical analyses. When comparing three disciplines (i.e., arts & humanities, sciences, social sciences), responses that did not belong to one of the three disciplines (i.e., other,  $n = 3$ ) were excluded from the analysis to avoid having a group with a small number of cases when comparing groups.

### Measurement instruments

The characteristics of researchers' collaborative projects using cloud storage were measured by using multiple-choice questions except for *the number of collaborators in the research team* for which participants were asked to report the exact number, and *the frequency of accessing files in the cloud storage*, which was measured by using a 7-point Likert scale question.

## RESULTS

### Number of collaborators in a research team using cloud storage

The average number of collaborators working on the research project using cloud storage was 6.95. In particular, the average size of the research teams in sciences ( $M = 8.21$ ) was bigger than that of research teams in social sciences ( $M = 6.29$ ) and arts & humanities ( $M = 6.28$ ), whose average sizes of the research teams were almost the same.

The results of the Kruskal-Wallis test indicated that there were statistically significant differences across disciplines,  $\chi^2(2, N = 509) = 13.31, p < .01, \eta^2 = .03$ . Follow-up tests which were conducted via a set of Mann-Whitney  $U$  tests to evaluate pair-wise differences, controlling for Type I errors across tests by using Bonferroni correction method, showed that the average size of the research teams in sciences (M rank = 222.06,  $n = 185$ ) was bigger than in social sciences (M rank = 180.93,  $n = 214$ ).

### Duration of the collaborative research project

The results showed that 28.8% ( $n = 152$ ) of the collaborative research projects using cloud storage were 1–2-year projects, 24.3% were 2–3-year projects ( $n = 128$ ), 17.6% were 5+ year projects ( $n = 93$ ), 16.7% were less than one-year projects ( $n = 88$ ), and 12.5% were 3–4-year projects ( $n = 66$ ). This result indicated that over half of the collaborative projects using cloud storage were 1–3-year projects. Figure 1 presents the duration of the collaborative research project using cloud storage.

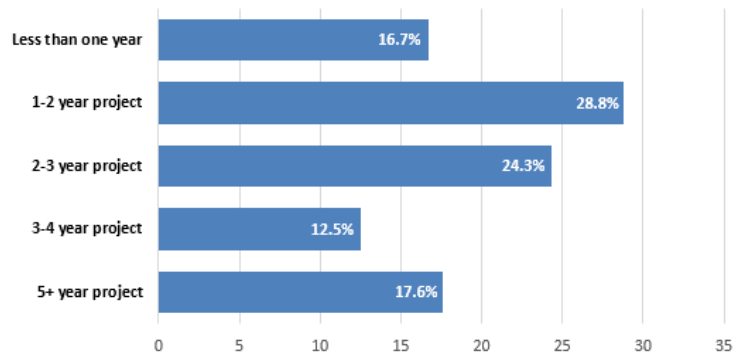


Figure 1 – Duration of the collaborative research project using cloud storage (N=527)

The two-way contingency table analysis showed that there were statistically significant differences among the three disciplines,  $\chi^2(8, N = 508) = 20.74, p < .01, V = .14$ . In the case of science research projects, the highest percentage of the projects were 2–3-year projects (25.4%,  $n = 47$ ). However, it was 1–2-year projects for both social science projects (30.8%,  $n = 66$ ) and arts & humanities projects (30.3%,  $n = 33$ ). In addition, the percentage of collaborative research projects that were longer than 5 years was higher for sciences (23.8%,  $n = 44$ ) than

for arts & humanities (15.6%,  $n = 17$ ) or social sciences (13.6%,  $n = 29$ ). Similarly, the percentage of collaborative projects that were less than one year was lower for science (12.4%,  $n = 23$ ) compared to social science (15.4%,  $n = 33$ ) or arts & sciences (26.6%,  $n = 29$ ). Thus, the duration of the science research projects tended to be longer than projects in other disciplines, while arts & humanities research projects tended to be shorter than research projects in other disciplines. Table 2 displays the duration of the collaborative research project by discipline.

Table 2 – Duration of the collaborative research project using cloud storage by discipline (N = 508)

|                    | Arts & Humanities<br>( $n = 109$ ) | Sciences<br>( $n = 185$ ) | Social Sciences<br>( $n = 214$ ) |
|--------------------|------------------------------------|---------------------------|----------------------------------|
| Less than one year | 26.6%                              | 12.4%                     | 15.4%                            |
| 1–2-year project   | 30.3%                              | 24.3%                     | 30.8%                            |
| 2–3-year project   | 16.5%                              | 25.4%                     | 27.6%                            |
| 3–4-year project   | 11.0%                              | 14.1%                     | 12.6%                            |
| 5+ year project    | 15.6%                              | 23.8%                     | 13.6%                            |

$\chi^2(8, N = 508) = 20.74, p < .01$

### Primary cloud storage platforms used for the project

When asked which shared cloud storage the participants primarily use with their collaborators for the research project, the most popular platform was Google Drive

(44.0%,  $n = 233$ ), followed by Dropbox (23.4%,  $n = 124$ ), OneDrive (14.2%,  $n = 75$ ), Box (11.9%,  $n = 63$ ), and other platforms (6.4%,  $n = 34$ ) including GitHub and Microsoft Teams. The results indicated that Google Drive is the most

popular platform among researchers for their collaborative research projects. Figure 2 displays the primary cloud storage platforms used for collaborative research projects

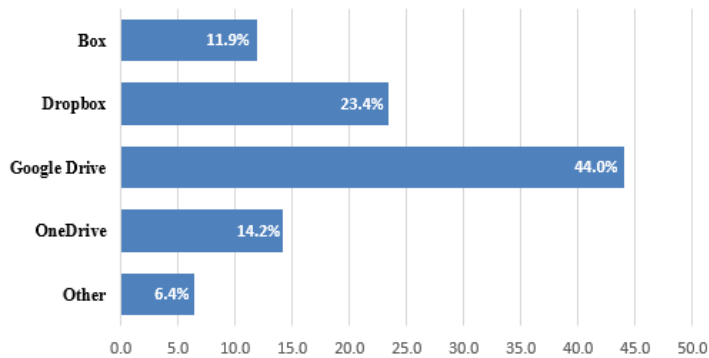


Figure 2 – Primary cloud storage platforms used for the collaborative research projects (N=529)

The two-way contingency table analysis showed that there were statistically significant differences among the three disciplines,  $\chi^2(8, N = 509) = 27.79, p < .01, V = .17$ . Google Drive was the most widely used for all three disciplines; however, it was more popular with arts & humanities researchers (50.9%,  $n = 56$ ) than science researchers (47.0%,  $n = 87$ ) or social science researchers (38.3%,  $n = 82$ ). Dropbox was used more by social science researchers (31.3%,  $n = 67$ ) than arts & humanities researchers (22.7%,  $n = 25$ ) or

science researchers (12.4%,  $n = 23$ ). OneDrive was used more by science researchers (16.8%,  $n = 31$ ) than arts & humanities researchers (14.5%,  $n = 16$ ) or social science researchers (12.1%,  $n = 26$ ). Box was also used more by science researchers (14.6%,  $n = 27$ ) than social science researchers (13.6%,  $n = 29$ ). It was not a popular choice for arts & humanities researchers (6.4%,  $n = 7$ ). These results aligned with the preliminary findings that examined the choice of repository platform (Oh, 2023). Table 3 presents these results.

Table 3 – Primary cloud storage platforms used for the collaborative research project by discipline (N = 509)

|              | Arts & Humanities<br>( $n = 110$ ) | Sciences<br>( $n = 185$ ) | Social Sciences<br>( $n = 214$ ) |
|--------------|------------------------------------|---------------------------|----------------------------------|
| Box          | 6.4%                               | 14.6%                     | 13.6%                            |
| Dropbox      | 22.7%                              | 12.4%                     | 31.3%                            |
| Google Drive | 50.9%                              | 47.0%                     | 38.3%                            |
| OneDrive     | 14.5%                              | 16.8%                     | 12.1%                            |
| Other        | 5.5%                               | 9.2%                      | 4.7%                             |

$\chi^2(8, N = 509) = 27.79, p < .01$

### Number of files in cloud storage for the project

When asked about the approximate number of files researchers currently have in their shared cloud storage for the collaborative research project, 53.0% reported 10–99 files ( $n = 278$ ), 32.8% reported that they have about 100–999 files ( $n = 172$ ), 11.0% said 1000–9999

files ( $n = 58$ ), and 3.2% answered 10000+ files ( $n = 17$ ). These results showed that over half of the participants' research teams had fewer than 100 files in their cloud storage. Figure 3 shows the number of files in cloud storage for the collaborative research project. There were no statistically significant differences in the number of files across disciplines

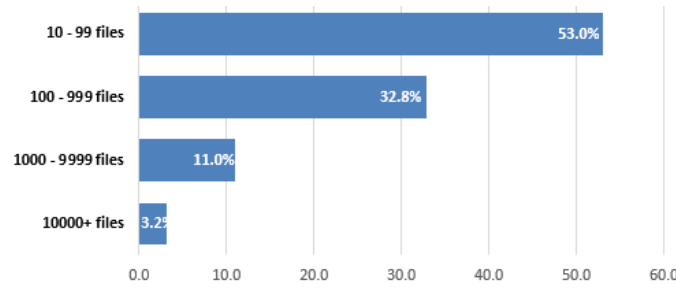


Figure 3 – Number of files in cloud storage for the collaborative research project ( $N=525$ )

### Frequency of accessing files in cloud storage

When measured using a 7-point Likert scale, ranging from 1 (never) to 7 (always), the average frequency of accessing files in cloud storage was 5.38, indicating that participants frequently or very frequently access files in shared cloud storage. There were no statistically significant differences across disciplines.

When asked about the approximate storage size of cloud storage needed for the collaborative research project, 36.5% reported 1GB–5GB ( $n = 144$ ), 17.5% of participants responded 10GB–50GB ( $n = 69$ ), and 16.7% of participants answered that they need 6GB–10 GB ( $n = 66$ ). These results indicate that over half of the project teams needed less than 10GB of storage. Figure 4 presents the size of the cloud storage needed for the collaborative research project

### Size of the cloud storage needed for the project

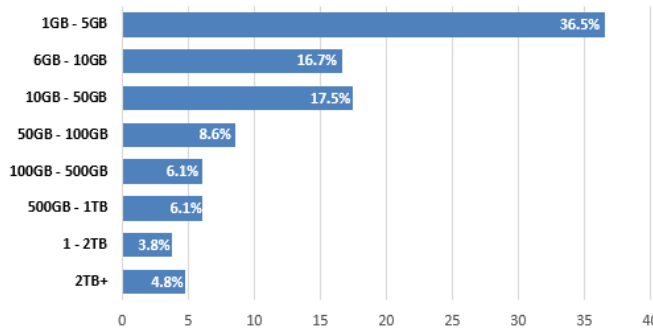


Figure 4 – Size of the cloud storage needed for the collaborative research project ( $N=395$ )



The two-way contingency table analysis showed that there were statistically significant differences among the three disciplines,  $\chi^2(14, N = 381) = 31.10, p < .01, V = .20$ . On the one hand, while 1GB–5GB was selected the most by all three disciplines, the percentages were different. It was selected by 47.4% of social science researchers ( $n = 73$ ), 38.0% of arts & humanities researchers ( $n=30$ ), and 25.0% of science researchers ( $n = 37$ ). On the other hand, 8.1% of science researchers ( $n$

= 12) responded that they need over 2TB of cloud storage for the collaborative research project, while only 3.8% of arts & humanities researchers ( $n = 3$ ), and 1.3% of social science researchers ( $n = 2$ ) needed this storage size. These results suggest that science researchers tend to need more cloud storage than researchers in other disciplines. Table 4 presents the approximate cloud storage size needed for the collaborative research project by discipline.

Table 4 – Cloud storage size needed for the collaborative research project by discipline ( $N = 381$ )

|             | Arts & Humanities<br>( $n = 79$ ) | Sciences<br>( $n = 148$ ) | Social Sciences<br>( $n = 154$ ) |
|-------------|-----------------------------------|---------------------------|----------------------------------|
| 1GB–5GB     | 38.0%                             | 25.0%                     | 47.4%                            |
| 6GB–10GB    | 17.7%                             | 15.5%                     | 16.9%                            |
| 10GB–50GB   | 17.7%                             | 20.9%                     | 14.3%                            |
| 50GB–100GB  | 12.7%                             | 7.4%                      | 6.5%                             |
| 100GB–500GB | 2.5%                              | 8.8%                      | 5.8%                             |
| 500GB–1TB   | 6.3%                              | 8.1%                      | 4.5%                             |
| 1TB–2TB     | 1.3%                              | 6.1%                      | 3.2%                             |
| 2TB+        | 3.8%                              | 8.1%                      | 1.3%                             |

$\chi^2(14, N = 381) = 31.10, p < .01$

## DISCUSSION

### Characteristics of collaborative research projects that use cloud storage

Overall, there were on average 6.95 collaborators in the research team. The average number of collaborators in science research teams was the highest, which was 8.21. Wuchty et al. (2007) who analyzed 19.9 million research papers over five decades reported that the number of collaborators in science research teams constantly has grown each year, from 1.9 to 3.5 over 45 years (i.e., from 1955 to 2000). Although the scope of this study was limited to collaborative research teams using cloud storage for their projects, this study confirmed this trend by showing that the size of the collaborative research team has grown even more in the

past 20 years. In the case of the duration of the project, over half of the projects were 1 to 3-year projects. This result provides some general idea regarding how long the researchers would use the cloud storage for collaborative projects.

In terms of the primary cloud storage platforms used for collaborative projects, the finding that over 40% of researchers used Google Drive as their cloud storage platform showed that it was a popular choice among researchers in the United States. Dropbox was another popular platform, followed by OneDrive. The author (Oh, 2023) analyzed the choice of cloud storage platform for collaborative research projects and reported that the primary reasons for choice were familiarity, functionality, and institutional

choice which provides possible reasons for these platforms' popularity.

In the case of the number of files in cloud storage, the finding that over half of the researchers currently have fewer than 100 files in their cloud storage indicates that often not too many files are saved in the cloud storage for the collaborative research project. However, it is worth noting that this study specifically asked participants to select one of their collaborative projects using cloud storage and respond to the survey questions. This means that while over half of the participants have fewer than 100 files in the cloud storage for their collaborative research, they may have more files saved in their cloud storage for other collaborative projects or their individual projects.

In the case of the frequency of accessing files, the results showed that researchers accessed files in cloud storage for their collaborative projects quite frequently. In the case of the size of the cloud storage needed for the project, over half of the researchers reported that their project team needed less than 10GB of storage. These results showed the approximate size researchers would need for the collaborative research project using cloud storage. However, again, there is a possibility that the researchers would need a bigger size to save files for other projects.

### **Variables with disciplinary differences**

A series of inferential statistical analyses showed that four out of six variables had disciplinary differences, indicating that the characteristics of researchers' collaborative projects using cloud storage were quite different across the three disciplines. In particular, there were statistically significant differences in the average number of collaborators in the research team, the duration of the collaborative project using cloud storage, the primary cloud storage platform used

for the collaborative project, and the size of the cloud storage for collaborative research projects.

Among the three academic disciplines, collaborative research projects in sciences had some different characteristics when compared to the other two disciplines. More specifically, science project teams tended to have more collaborators than social science project teams. Science projects also lasted longer and required relatively larger storage sizes, while arts & humanities projects were shorter and required relatively smaller storage sizes. In the case of primary cloud storage platforms, researchers in three disciplines had somewhat different preferences. More specifically, Dropbox was not one of the top three choices for science researchers, but it was the second most popular platform for both social science and arts & humanities researchers. Similarly, OneDrive was not one of the top three choices for social science researchers unlike researchers in the other two disciplines, and Box was not one of the top three choices for arts & humanities researchers which was different from researchers in the other two disciplines. These results regarding differences in the top primary cloud platforms used by researchers in different disciplines could suggest a potential barrier to interdisciplinary projects.

There were no statistically significant differences in the approximate number of files in cloud storage for the collaborative research project and the frequency of accessing files in cloud storage for the project. Table 5 displays variables with statistically significant disciplinary differences (marked "O") and with no disciplinary differences (marked "X").

*Table 5 – Variables with disciplinary differences*

| Variables                                     | Disciplinary Differences |
|---|--------------------------|
| Number of collaborators                       | O                        |
| Duration of the project                       | O                        |
| Primary cloud storage platform                | O                        |
| Number of files in cloud storage              | X                        |
| Frequency of accessing files in cloud storage | X                        |
| Size of the cloud storage                     | O                        |

## **CONCLUSION**

This study investigated the characteristics of collaborative research projects that use cloud storage and analyzed disciplinary differences. By conducting a large-scale study with researchers across disciplines, this study enhances our knowledge of the nature of collaborative research projects using cloud storage. The results also contribute to the literature on project management, personal information management, and collaborative information behavior. In addition, this study revealed disciplinary differences in the characteristics of collaborative research projects using cloud storage, which provides helpful information in conducting interdisciplinary research projects using cloud storage and supports smoother collaboration. For instance, this study revealed that researchers in different disciplines had different preferences for cloud storage platforms so there were platforms that were widely used in one discipline but not in another discipline. This preference could be considered when selecting a cloud storage platform for interdisciplinary projects. The results of

this study also inform the development and the design of applications and tools that better support researchers' use of cloud storage for collaborative projects including tools designed to be used in specific academic disciplines. For example, the results showed that researchers in science would require bigger cloud storage that can support a longer project with a larger research team size than the other two disciplines.

The participants of this study were recruited from the United States to limit the scope of the study. In the future, it will be interesting to expand the study and comparatively analyze the characteristics of collaborative research projects using cloud storage in different countries. This study provides a holistic and comprehensive understanding of the characteristics of collaborative research projects using cloud storage. However, this study couldn't delve into researchers' collaboration practices using cloud storage that would provide further insights into researchers' collaborative projects using cloud storage. This study was part of a larger project that examined researchers' collaboration practices, shared file management practices, challenges, and strategies by conducting an online survey and in-depth interviews. Analyzing all these data will provide a fuller understanding of researchers' collaborative projects using cloud storage.

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