# Chapter 5

# Using Qualitative Analysis Software To Facilitate Qualitative Data Analysis

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Technological advances in the last twenty years have led to the development of powerful software for qualitative data analysis. Computer assisted qualitative data analysis (CAQDAS) packages facilitate managing multiple tasks in qualitative research, from organizing data sources based on relevant characteristics, segmenting and categorizing data according to themes, searching for and retrieving information, to building visual representations that more easily elicit significant patterns in the data. This chapter presents an introduction to the use of CAQDAS packages as tools that can greatly support qualitative research activities in chemistry education.

## Introduction

The answers to many relevant research questions in chemistry education, such as how students approach the drawing of Lewis structures (*1*) or how the nature of laboratory activities influence students' conversations (*2*), can be obtained through investigations that generate in-depth information about the knowledge, beliefs, reasoning, attitudes, or behaviors of study participants (*3*, *4*). This information may be gathered using different qualitative research techniques such as classroom observations, field notes, individual interviews, focus groups,

open response questionnaires, written reports, and journals; some of these and other qualitative research strategies are discussed in depth in the chapters by Cole, Becker, and Stanford (*5*), Yezierski (*6*), and Herrington and Daubenmire (*7*) in this volume. The data collected using these strategies, such as text, images, and diagrams, is not numerical in nature (qualitative data) and tends to be very lengthy, requiring intensive and repeated examination in the search for answers to research questions (*8*, *9*). This analysis can be done manually or with the help of computer software commonly known as *computer assisted qualitative data analysis* (CAQDAS) packages that simplify the tasks of organizing, exploring, integrating, and reflecting on the information (*10–12*). The central goal of this chapter is to provide an overview of useful strategies to take advantage of these types of technological resources to support and facilitate qualitative research in chemistry education. The chapter is directed to researchers who have not yet used qualitative data analysis software to support their work.

## CAQDAS

Advances in analytical software in the last twenty years have led to the development of powerful tools for qualitative data management. These types of resources facilitate the implementation of core tasks in most common qualitative research designs, from case studies to discourse analysis to grounded theory (*3–9*). Commercially available CAQDAS packages such as ATLAS.ti (*13*), Dedoose (*14*), MAXQDA (*15*), and NVivo (*16*) allow users to import different types of data (e.g., text, images, audio, and video) and categorize them according to user-defined attributes or descriptors (e.g., gender, educational level, or course grade of study participants). These data can then be segmented and organized into categories using codes created by the user either before or during the analysis. Most CAQDAS packages also include tools for selective retrieval of text or coded data, powerful systems for writing and reviewing comments and memos linked to documents, audio or video files, text segments, or specific codes, as well as diverse avenues for data representation that facilitate the identification of conceptual themes or patterns (*10*, *11*).

The use of qualitative software for data analysis has several advantages. First, it frees researchers from tedious managing tasks, allowing them to focus on the data and their reactions to it. It provides dynamic and simultaneous access to different components of the data analysis, from excerpts to codes to annotations to demographic data. Additionally, it more quickly directs researchers' attention to themes and relationships emerging from the analysis. In many ways, the software allows users to get closer to the data and further explore its intricacies. Nevertheless, CAQDAS packages do not carry out core qualitative analysis tasks for the researcher. Common qualitative software does not, for example, transcribe audio or video files, define relevant attributes for data sources, identify meaningful segments in a text, or build and apply codes in an independent and automatic fashion. Nor do these types of resources independently detect patterns in the data or identify overarching themes. Researchers have full control, and responsibility, over the analytical and interpretative processes. Thus, the quality

of the results generated by using qualitative software is only as good as that of the research design and methods of data analysis. As is the case with packages for quantitative analysis (e.g., SPSS), the quality of the output strongly depends on the choices made by the researcher about what data to collect, how to collect the data, and what strategies to apply to analyze the data.

Differences among common CAQDAS packages are subtle and likely to become less explicit as the underlying technology advances in upcoming years. Commercially available products tend to offer the same core tools and functions, and decisions about what package to use may thus be difficult, particularly for novice users. Researchers should look for the resource that best fits their research goals and methodological approaches. Detailed comparative analysis involving the most widely used CAQDAS packages can be found in the literature (*10*, *11*). In this chapter, I will illustrate the application of core strategies in computer assisted qualitative analysis using the on-line software Dedoose when presenting specific examples. This choice is somewhat arbitrary and does not imply a personal endorsement or recommendation of any particular type of software. Dedoose is a web-based application that is easily accessible via the Internet and includes the major analytical tools present in modern CAQDAS packages. It has a simple user interface and has been designed to facilitate collaboration by geographically dispersed researchers who may work with Mac or PC systems (*14*). Comparisons between common CAQDAS packages (ATLAS.ti, Dedoose, MAXQDA, NVivo) will be presented in those areas in which differences are judged to be more substantive.

## Analyzing Qualitative Data

The analysis of qualitative data involves a variety of tasks: copying, transcribing, and organizing data; segmenting and coding transcripts, images, audio, and video; stepping back from the data, seeking to identify overarching themes and patterns; building and applying coding schemes at different levels (e.g., descriptive, interpretative); identifying quantitative patterns in coded segments across different participants (*3–6*). CAQDAS packages allow researchers to perform most of these tasks in more systematic and efficient manners. The following sections summarize fundamental strategies in the analysis of qualitative data using these types of computer applications.

### Handling and Organizing Data

Qualitative research studies generate vast amounts of textual and non-textual data of different types, from background information about the study participants to primary data collected in the field to supporting or secondary data that may be relevant for the analysis. CAQDAS packages allow researchers to import all of these different resources, integrate them into a single project, and build links or cross-references between them. Common applications will directly import documents in plain text (.txt), rich text format (.rtf), and Microsoft Word (.doc or .docx) formats, and include tools to edit such texts within the software. In most

cases, such documents may contain tables, embedded images, and rich objects, but format specifications may vary among different CAQDAS packages (*10*, *11*). Most of these applications also allow audio and video files to be directly incorporated into the software project. However, existing software packages do not have the capability to transcribe these files into written documents.

One of the key elements of CAQDAS packages is that data sources can be organized according to known characteristics. This enables researchers to easily search for, identify, and narrow their focus on subsets of data, which facilitates comparisons. More importantly, this organization lays the foundation on which the dataset can be analyzed in search of themes, patterns, and relationships across data sources. Existing CAQDAS packages organize known data characteristics differently, and use various terms to refer to them, such as families (ATLAS.ti), attributes (MAXQDA, NVivo), or descriptors (Dedoose). All of these applications allow researchers to assign these characteristics within the software or upload spreadsheets that contain such information. A critical step in the data analysis process is to carefully reflect on the attributes or descriptors that are relevant in a study. These decisions should be based on the questions researchers want to ask, the ideas they want to test, and the parts of the data set that they want to isolate for comparative purposes. These ideas will be illustrated with a concrete example.

Recently, we completed a study focused on the characterization of the ideas (assumptions) and reasoning strategies (heuristics) used by college general chemistry students when asked to judge the relative thermodynamic likelihood of different chemical processes (*17*). This research project was based on data collected using individual interviews in which participants were asked to think out loud when solving five different problems. Verbatim transcripts of the recorded interviews were our primary data and, for purposes of analysis, we decided to build different text files containing the answer of a single student to a single question. This decision stemmed from our interest in eventually comparing not only the assumptions and heuristics used by different students, but also the assumptions and heuristics applied across different questions. As shown in Figure 1, when the different text files were uploaded into the Dedoose CAQDAS package, each of the files was assigned a descriptor that indicated the student to which the file belonged (e.g., S1, S2, …) and the question to which it corresponded (e.g., Q1, Q2, …). Additionally, we built descriptors to indicate the gender of each participant and their final grade in the general chemistry class in which they were enrolled at the time of the interview. These descriptors were introduced because we were also interested in exploring the association between the types of assumptions and heuristics that students applied and these individual attributes.

In most software applications, attributes can be applied to individual documents or to sets of documents. Although it is easier and more efficient to organize data sources using attributes or descriptors early in the analytical process, CAQDAS packages allow researchers to assign known characteristics at any stage during the analysis.

| | Selected | Linked Media | Memos | Student ▲ | Question | Gender | Final Grade |
|---|---|---|---|---|---|---|---|
| | ☐ | 1 | 0 | S1 | Q1 | Male | C |
| | ☐ | 1 | 0 | S1 | Q2 | Male | C |
| | ☐ | 1 | 0 | S1 | Q3 | Male | C |
| | ☐ | 1 | 0 | S1 | Q4 | Male | C |
| | ☐ | 1 | 0 | S1 | Q5 | Male | C |
| | ☐ | 1 | 0 | S10 | Q2 | Female | B |
| | ☐ | 1 | 0 | S10 | Q1 | Female | B |
| | ☐ | 1 | 0 | S10 | Q5 | Female | B |
| | ☐ | 1 | 0 | S10 | Q3 | Female | B |
| | ☐ | 1 | 0 | S10 | Q4 | Female | B |
| | ☐ | 1 | 0 | S11 | Q4 | Female | B |
| | ☐ | 1 | 0 | S11 | Q1 | Female | B |
| | ☐ | 1 | 0 | S11 | Q2 | Female | B |

*Figure 1. Dedoose screen capture showing the set of descriptors (student, question, gender, final grade) linked to different data sources (media) in our research project about students' assumptions and heuristics. Copyright 2013 Dedoose Version 4.5, web application for managing, analyzing, and presenting qualitative and mixed method research data (2013). Los Angeles, CA: SocioCultural Research Consultants, LLC (www.dedoose.com).*

## Coding of Data

Several qualitative research approaches or designs rely on coding to conceptually organize data (*3–9*). During this process, relevant segments of the available data are identified and classified as instances or exemplars of major ideas or themes. Codes define conceptual categories that are expected to run both within and across different data sources, and may help provide meaningful responses to research questions. These codes could be predefined, arising from the theoretical framework or research questions, or they can emerge from the data during the analysis. Most coding involves the combination of these deductive and inductive approaches. In general, coding is an iterative process in which the researcher moves back and forth between careful reading of the data and critical reflection of its meaning. As a researcher dives in and steps back from the data, codes can be generated at different levels. Initially, codes may be very specific, describing significant ideas, events, or actions detected in the data. As the analysis progresses, descriptive codes may be organized or collapsed into higher order categories that are more interpretative in nature (*8, 9*).

CAQDAS packages facilitate the coding process at many levels. These applications allow the researcher to easily build a coding system either from the outset or in an ongoing manner during data analysis. Labels and descriptions of individual codes can be modified, and codes can be expanded, deleted, or rearranged when needed. Segments of text, audio, or video in any given file can be identified and highlighted to create excerpts, or audio and video fragments, that can be linked to one or multiple codes by simple dragging and dropping

movements. Consider the example presented in Figure 2, where a segment (called an excerpt within the Dedoose software) in an interview transcript in our Assumptions and Heuristics project has been highlighted, and linked to two relevant codes in our study (labeled "One-Reason Decision Making" and "Easiness"). This figure also shows the hierarchy of codes built and applied to categorize different assumptions and heuristics that emerged from our data analysis.

Chemistry educators engaged in qualitative research often use CAQDAS packages to facilitate the coding of interview transcripts or written responses to open questions. The use of this type of software can help chemistry education researchers more easily identify trends in students' alternative conceptions (*18*), explore teachers' instructional goals and strategies (*19, 20*), collect exploratory data to guide the development of quantitative research instruments (*21*), identify educational approaches that support learning (*22*), or elicit students' beliefs and perspective about diverse educational issues (*23*).



*Figure 2. Dedoose screen capture showing a highlighted excerpt in an interview transcript and the two codes associated to this excerpt. The overall coding scheme used in this analysis is shown in the lower right panel. Copyright 2013 Dedoose Version 4.5, web application for managing, analyzing, and presenting qualitative and mixed method research data (2013). Los Angeles, CA: SocioCultural Research Consultants, LLC (www.dedoose.com).*

The default structure of the coding scheme in common CAQDAS packages tends to be hierarchical (except in ATLAS.ti). This facilitates the creation of embedded sets of subcodes that can be used to categorize segments or excerpts at different levels. For example, in the case illustrated in Figure 2, the major code "Assumptions" was subdivided into the subcodes "Intuitive" and Spurious," which in turn included various subcategories. These software programs provide the user with the freedom to use as much or as little hierarchy as needed in the organization of the coding scheme. Some software packages, such as MAXQDA

and Dedoose, use different colors to more clearly indicate the status of a code within a hierarchy. Most applications allow the easy reshuffling of codes in and out of different categories. Codes can be easily renamed, grouped, merged, or reallocated within different classes. The fluid and flexible manipulation of the coding scheme within these CAQDAS packages greatly facilitates qualitative data analysis since any change automatically propagates throughout all coded segments in every document within the software project. In general, changes that involve code reorganization, merging, and streamlining are easier to implement than changes that require separating data originally linked to a single code into two or more new categories. This task demands recoding of excerpts by the researcher who needs to make decisions about how the data should be reassigned.

### Retrieval of Coded Data

When performing qualitative data analysis, it is important to step back, review the progress made, reflect on results, group similar data, identify gaps or inconsistencies, and re-strategize if needed. The ability to easily search for and retrieve coded data is thus critical and constitutes another great advantage of using CAQDAS packages. In general, these applications facilitate the completion of the following tasks:

- View all codes linked to different segments in a given document;
- Retrieve all coded data associated with an individual code or a set of codes (see Figure 3);
- Recode retrieved segments;
- Dynamically view different code frequencies as the analysis proceeds;
- Export and retrieve information in the form of reports that can be printed or saved in common formats (e.g., MS Excel or Word).

Although commercially available software packages offer these different functionalities, they differ greatly in the steps that users must follow to implement them. Some packages, such as ATLAS.ti and MAXQDA, include interactive margin views that visually display all codes linked to different segments in a single text. In other cases, such as Dedoose, these codes are displayed in a separate panel when selecting a segment (see Figure 3). In most cases, access to all coded segments linked to a given code across data sources is provided through a code index or a code panel. Different strategies may need to be applied to filter data in order to view all segments that are simultaneously linked to two or more codes. Despite these differences, common CAQDAS packages allow researchers to analyze their data in multiple manners and generate diverse reports that more easily uncover meaningful trends. For example, the analysis of excerpts linked to both the code "Easiness" and the code "One-Reason Decision Making" in our Assumptions and Heuristics project (Figure 3) revealed the existence of a potential relationship between these two types of reasoning. Reports may also serve to identify potential problems in the analysis. Reviewing all of the segments coded under a certain category can help researchers decide whether a code actually captures a targeted theme or whether all segments belong to the

same group. The software will not automatically resolve any potential issues, but will allow researchers to systematically create opportunities to pause, reflect, and make decisions to improve data analysis.
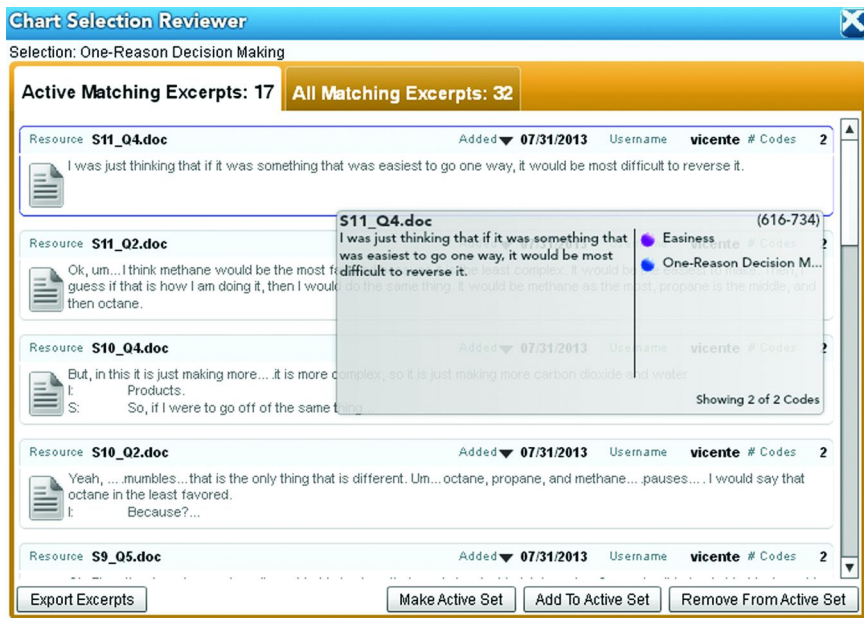


*Figure 3. Screen capture of the code window in Dedoose. Selection of a code, such as "Easiness," shows all excerpts coded in that category. By making these set active, subsets of excerpts linked to a second code, such as "One-Reason Decision Making," can be identified. Copyright 2013 Dedoose Version 4.5, web application for managing, analyzing, and presenting qualitative and mixed method research data (2013). Los Angeles, CA: SocioCultural Research Consultants, LLC (www.dedoose.com).*

### Annotating Data

Qualitative data analysis demands researchers to constantly discuss their ideas and reflect on their actions and interpretations. Researchers must ensure that they record their thoughts, insights, questions, and concerns as they delve into the data. When done manually, this writing process may become messy and inconsistent as researchers deal with different data sources and analytical components, and use a variety of annotating strategies and procedures. CAQDAS packages facilitate these tasks by providing tools that researchers can use to build notes, comments, memos, or entire research journals that can be linked to one or more pieces of the software project, from single documents, to segments within a document, to individual codes in the coding scheme. These writing elements can be built purposely as research journals or spontaneously as researchers interact

with the data; they can be managed in systematic ways, searched and retrieved when needed, and exported to be printed or saved as external documents.

Using a laptop or tablet computer, qualitative software can be used to directly write observational logs or field notes to be integrated as data sources into the research project. CAQDAS packages can also be useful in keeping research diaries or journals that record day-to-day project activities. Commercially available applications have been designed to facilitate the spontaneous construction of analytic memos to aid during the coding and interpretative processes. These memos can be used for multiple purposes, such as making comments on specific aspects of the data, posing questions for further reflection, recording tentative interpretations, or sharing thoughts with other researchers who may have access to the data. The ability to link these memos to other objects (documents, data segments, codes) allows researchers to integrate their thoughts with other components of the project.

## Visualizing Data

CAQDAS packages can also be used to create visual representations such as maps, diagrams, and graphs that aid analysis by more readily revealing trends and relationships, and helping researchers in the development of interpretations. These visual representations are usually linked to the underlying data used in their construction, allowing researchers to easily move back and forth between the data and the graphic model.

Software applications such as ATLAS.ti, MAXQDA, and NVivo include a variety of mapping tools to build networks (ATLAS.ti), maps (MAXQDA), or models (NVivo). These tools include: icons to represent codes, memos, documents, or theoretical concepts; connectors to link these objects; and linking labels to define the nature of the connections. These resources can be used to build visual constructs that resemble interactive concept maps that elicit relevant themes and relationships emerging from the data analysis. A good example of the use of these visual and conceptual aids in chemistry education research can be found in the study by Del Carlo and Bodner on students' perceptions of academic dishonesty (*24*). As shown in this work, these types of representations are very useful in creating visual structures of complex systems and phenomena. Nevertheless, it is important to keep in mind that these maps are built with input from the researcher and should thus be interpreted with caution.

The on-line software Dedoose does not include mapping functionalities but is designed to support the graphic visualization of data. For example, the application can be used to visualize code frequencies as a function of selected descriptors, or the degree of co-occurrence of two or more codes in defined sets of data (other CAQDAS packages also include this latter functionality). The resulting graphs are interactive and the associated qualitative data can be explored by clicking on different portions of a graph. All these results can be exported to external documents or printed if needed. Figure 4 illustrates some of the graphical representations that provided insights into trends and relationships in our Assumptions and Heuristics project. These graphs revealed, for example, the overreliance of our study participants on the assumption of "Easiness" in

making predictions about the thermodynamic likelihood of chemical reactions (*17*). Similarly, they helped us identify the correlation between the application of this assumption and the use of a "One-Reason Decision Making" heuristic. The software also allowed us to explore how these patterns of reasoning were affected by the nature of the question posed, the gender of the participants, and their final grade in the general chemistry course.
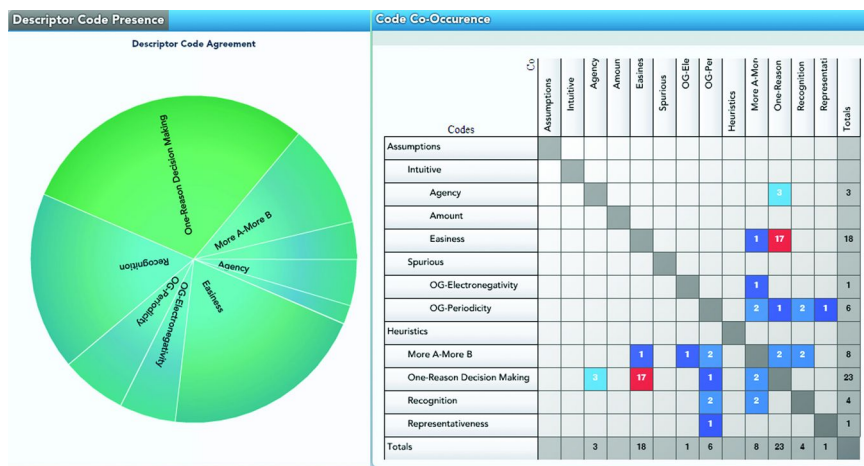


*Figure 4. Examples of the types of graphic representations generated by Dedoose based on code frequencies. The pie chart on the left shows the relative frequency of all codes; the graph to the right displays the degree of co-occurrence of different codes. Copyright 2013 Dedoose Version 4.5, web application for managing, analyzing, and presenting qualitative and mixed method research data (2013). Los Angeles, CA: SocioCultural Research Consultants, LLC (www.dedoose.com).*

## Other Functionalities

Common CAQDAS packages include other tools and functionalities not described in previous sections that can greatly facilitate data management and analysis. For example, these applications have basic editing tools that allow researchers to color, underline, embolden, or italicize words or phrases to make them more salient. Most of these computer programs also incorporate search engines that can be used to track specific words or run word frequency checks. Additionally, many systems allow the creation of hyperlinks between different points in the dataset, which can be used to link specific parts of different documents to track a line of reasoning, compare and contrast approaches to solve a given problem, or associate consistent ideas. All of these tools are particularly useful when performing text or discourse analysis (*8*, *9*). Nevertheless, researchers should be cautious when using search tools to avoid building coding systems that are based on the mere frequency of specific words.

More recent innovations in CAQDAS packages include tools to capture data from web pages, social media, and tweets that can be directly incorporated into the software projects. The number of different text, audio, and video formats that can be directly imported into the applications is steadily increasing. Systems like Dedoose, which is an on-line application, allow multiple researchers in different locations to simultaneously work and collaborate on the same project. Traditional stand-alone software packages, such as NVivo, are quickly incorporating similar capabilities, allowing multiple users to access the same files when working with the same computer or with a set of interlinked devices. Access to the same data pool by several researchers facilitates the comparison of coding done by multiple users, and the calculation of inter-rater reliability coefficients (*25*) within the CAQDAS package. For example, ATLAS.ti includes functionalities for calculating Cohen's kappa and Krippendorff's alpha, while Dedoose facilitates the calculation of percentage of agreement between multiple researchers. Easy access to a software project by multiple people creates unique opportunities to not only carry out collaborative research, but to interactively train researchers in the use of qualitative methods of data analysis.

## Final Considerations

The use of software to support qualitative data analysis is often associated with certain "myths" that it is important to dispel (*26*). On the one hand, some people envision CAQDAS packages as all-powerful tools capable of completing data analysis without much input from the researcher. On the other hand, others judge that the use of these applications will constrain researchers' ability to control the direction and approach to the analysis of the data. As shown in this chapter, none of these scenarios is real. CAQDAS packages are very useful tools for data analysis that allow researchers to keep full control of the analytical process, greatly facilitate multiple managing tasks, but do not independently and automatically decide how to segment, code, or interpret the data. The quality of analysis will not be determined by the sophistication of the software used, but rather by the thoughtfulness and rigor of the analytical procedures employed by the researcher.

Given the multiple tasks that CAQDAS packages can carry out, learning how to use and take advantage of all of their different tools may seem daunting to the beginner. Nevertheless, commercially available applications tend to have intuitive interfaces and multiple resources to support their users (e.g., help manuals and videos). The structure of these software applications allows for open exploration. Thus, I would suggest approaching the initial use of the package in a flexible and fluid manner. One should recognize that not every available functionality needs to be used in each project, and that the ability to easily import, manage, and interact with multiple documents may lead some researchers to over-saturate and overanalyze their data pool. In general, mistakes can be easily corrected by undoing tasks or re-uploading documents and major issues may be controlled and reduced by constantly stepping back from the data to critically reflect on existing results and analytical strategies.

The constant incorporation of technological advances into CAQDAS packages certainly increases their analytical power, but also carries new

challenges. For example, accessing and retaining rich multimedia data may raise ethical issues in terms of ownership, privacy, anonymity, and confidentiality. Participation of multiple individuals who can easily access and exchange research data will demand careful research design and monitoring. Researchers should thus carefully reflect on the specific practical, legal, and ethical issues that may emerge from the use of qualitative software. As discussed in Bauer's chapter in this volume (*27*), we, as researchers, are ultimately responsible for ensuring the proper collection, management, and disposal of any data incorporated into our research projects.

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