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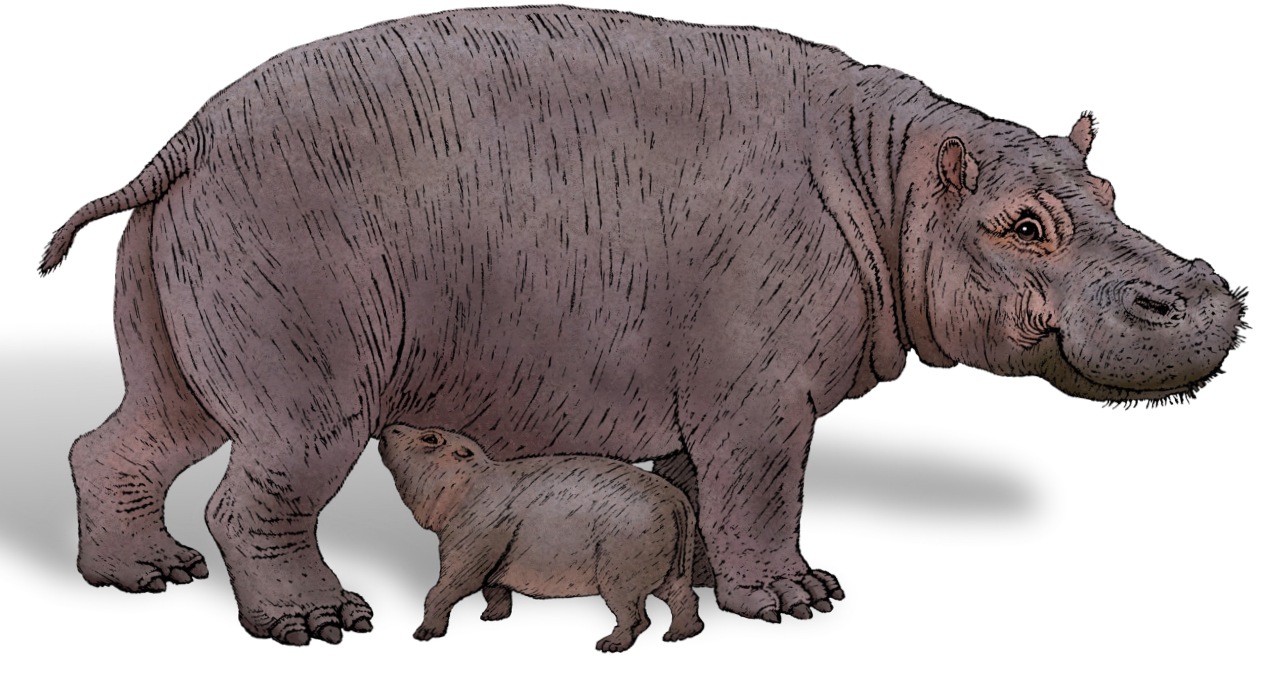
Learning Microsoft Power BI

Transforming Data into Insights



Jeremey Arnold

O'REILLY®

Learning Microsoft Power BI

Microsoft Power BI is a data analytics and visualization tool powerful enough for the most demanding data scientists, but accessible enough for everyday use for anyone who needs to get more from data. The market has many books designed to train and equip professional data analysts to use Power BI, but few of them make this tool accessible to anyone who wants to get up to speed on their own.

This streamlined intro to Power BI covers all the foundational aspects and features you need to go from "zero to hero" with data and visualizations. Whether you work with large, complex datasets or work in Microsoft Excel, author Jeremey Arnold shows you how to teach yourself Power BI and use it confidently as a regular data analysis and reporting tool.

You'll learn how to:

- Import, manipulate, visualize, and investigate data in Power BI
- Approach solutions for both self-service and enterprise BI
- Use Power BI in your organization's business intelligence strategy
- Produce effective reports and dashboards
- Create environments for sharing reports and managing data access with your team
- Determine the right solution for using Power BI offerings based on size, security, and computational needs

Jeremey Arnold is senior analytics architect at Onebridge, a large data analytics consulting firm in Indianapolis, Indiana. Jeremey has worked in data analytics for over a decade and has been a Microsoft Power BI user since its release in 2013. His experience covers multiple industries including healthcare, finance, manufacturing, and the public sector, all with a focus on transforming data into insights and enabling truly data-driven environments.

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by Jeremey Arnold

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[LSI]

I dedicate this book to my wife, Katherine, and my children, Elainamia and Makayla. They are my constant source of encouragement and joy.

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Preface

I was a senior at Ball State University when one of my professors, Dr. James McClure, and I were discussing classic challenges to the perfectly competitive market model. We were having a back-and-forth, and throughout our entire discussion, I kept bringing all the critiques back to a single problem: asymmetric information. *Asymmetric information* is the condition in which one party knows more about the topic at hand than the other party, to the point where they can use that for some sort of advantage.

We live in a world in which Google, Facebook, Amazon, Netflix, and others know so much about you that they can try to figure out what you want before you know you even want it. However, you have access to that same information. In the information age, we don't have an asymmetric information problem as much as we have an asymmetric *comprehension* problem. What we historically haven't had is the ability to process data in the same way. Or at least, we didn't until recently.

Tools that would allow you to aggregate information at scale were historically tools of organizations that could afford complicated investments into data platforms that the ordinary person could neither comprehend nor afford. However, today there exists a piece of software that puts one of, if not *the* most powerful analytics engines ever made into your hands with an initial investment cost of zero dollars and zero cents. We have never been more awash in data, and that data is more available to people like you and me than it ever has been in human history.

Microsoft's Power BI platform gives users a tool to aggregate incredibly large amounts of data to discover insights that can give you just as much, if not more, information than those around you. Whether you are using it for personal reasons or as an organization looking to get a competitive edge in the marketplace by making data more meaningful within your company, there has never been a lower-cost entry to data processing with the ease of use of Power BI Desktop.

Microsoft has spent years working with companies all over the world on a technology for complicated data analytics. Power BI is built on that technology, and Microsoft is literally putting all that know-how into your hands. Data is the great equalizer. It's not just about having more or less of it. It's about using the data you do have effectively.

Organizations all over the world collect more data than you and I could ever comprehend in a lifetime, and yet they do nothing with it because they have no idea how to use it, and they find themselves losing market share to smaller competitors who are using the data they have effectively. Nonprofits are using Power BI to do data analysis that makes the world a better place to live, on issues from conservation to climate change to healthcare access. Citizen data analysts are using publicly available datasets to uncover financial misbehavior and to double-check results from data provided by organizations and governments around the world. If the ability to process and make data meaningful is truly the great equalizer of the information age, then Power BI is a tool that gives you the ability to sit at a table and look giants in the eye.

You might be an accountant looking to automate complicated data cleaning processes for regulatory purposes and want a tool to quickly visualize profit and loss statements. You might be a citizen data analyst looking for a tool to help crunch millions of records of data for a personal project. You could be a data scientist looking for a tool to accelerate adoption of your work by end users. If you are a person who works with data in any capacity and want to get more out of that data than you ever have, then Power BI is an ecosystem that you should have exposure to.

I wrote this book because, first, I'm super passionate about data being used effectively and I truly believe that everyone in the 21st century can interact with data in some way to improve, either professionally or personally. Second, Power BI has been a vehicle for me to better understand all sorts of important data concepts, and I think those ideas are important to accomplishing that first goal. How do we put data from different sources together? How do we deal with tables that are too large for Microsoft Excel? How do we target specific groups or slices of a group for analysis effectively? How do we visualize those results to make them comprehensible to our audience? My early career was spent deep in the bowels of corporate finance, and if I had Power BI then, I would have saved so much time and heartache in manually manipulating data and doing simple groupings and pivot tables.

Our 21st-century data requires a 21st-century tool to unlock it. I believe Power BI is the best tool to do that. It can store the data. It can analyze the data. It has the reach to be available to anyone who uses Windows. No other data visualization or exploration tool can make that claim, and that's why I'm excited you're picking up this book. And I hope you find your data journey as fulfilling as mine has been and continues to be.

Navigating This Book

This book is organized roughly as follows:

- Chapter 1, "Intro to Power BI", provides a brief history of Microsoft's previous business intelligence efforts and how those products have evolved into the Power BI we know today. Alongside that, it goes into detail about how Power BI works under the hood, in terms of how it stores and queries that data.
- Chapter 2, "The Report and Data Views", and Chapter 3, "Importing and Modeling Our Data", introduce portions of the Power BI user interface, including how to navigate the various ribbons and how to bring your data into Power BI for analysis.
- Chapter 4, "Let's Make Some Pictures (Visualizing Data 101)", and Chapter 5, "Aggregations, Measures, and DAX", go into basic principles of visualization and utilizing data aggregations.
- Chapter 6, "Putting the Puzzle Pieces Together: From Raw Data to Report", is a walk-through using the work of the previous chapters to go from nothing in Power BI to a fully functional report page.
- Chapter 7, "Advanced Reporting Topics in Power BI", discusses some advanced analytics topics in Power BI, including AI visuals and what-if analysis.
- Chapter 8, "Introduction to the Power BI Service", and Chapter 9, "Licensing and Deployment Tips", introduce the Power BI service, the cloud-based platform for sharing reports and insights.
- Chapter 10, "Third-Party Tools", introduces useful third-party tools to accelerate or ease future development.
- Appendix A, "Commonly Used DAX Expressions", and Appendix B, "Some Favorite Custom Visuals", provide examples of DAX functions for you to take and modify for your own future data, and a valuable list of some of my favorite custom visuals and their various functionalities, respectively.

Conventions Used in This Book

The following typographical conventions are used in this book:

Italic
: Indicates new terms, URLs, email addresses, filenames, and file extensions.

`Constant width`
: Used for program listings, as well as within paragraphs to refer to program elements such as variable or function names, databases, data types, environment variables, statements, and keywords.

Using Code Examples

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CHAPTER 1
Intro to Power BI

You're a data person. You understand your data. You know how spreadsheets work. But there's so much data to process, and your spreadsheets aren't cutting it.

You need a way to visualize the data and share it with business users so that they can see the analytics, understand the data as you do, and even manipulate the visualizations with little to no training.

If that's why you're looking at this book, you made the right move. Microsoft Power BI is exactly what you need. This book will show you how to get up to speed quickly—so quickly that you'll be building and publishing reports that will wow your colleagues and make your mom proud.

Microsoft Power BI is a data analytics and visualization tool powerful enough for the most demanding data scientists but accessible enough for everyday use by anyone needing to get more from their data.

In the beginning, back when life was simpler (in 2011), Power BI was just a simple piece of desktop software. But it isn't anymore. It's an entire business intelligence ecosystem that can fit into multiple diverse technology stacks.

This chapter introduces Microsoft Power BI, discusses the entire Power BI family of products, provides an overview of how Power BI works, and looks at what distinguishes it from other similar tools. By the end of this chapter, you'll:

- Know what components fit in the Power BI ecosystem and why they're important.
- Learn the history of Microsoft's business intelligence work to learn how that got us to Power BI.
- Discover what makes Power BI different from its competitors.

What Is Power BI?

Power BI is both a piece of software and a larger ecosystem of products. Usually when people throw out the term "Power BI," it's in reference to the desktop authorship software. However, when discussing how most people will (visually) share the fruits of their work with others, it's done in the context of the Power BI service, a software-as-a-service (SaaS) solution that hosts Power BI datasets and reports that can be used by others who have access.

Even beyond these two features, a wide variety of products in the family allow you to embed reports into websites and other applications, view reports on your mobile device, and even have your own version of the SaaS solution on premises.

This book focuses on Power BI Desktop and the Power BI service since they are your most basic and valuable building blocks.

Power BI Desktop is a tool for data investigation and visualization. Analysts can take data and create interactive reports that enable end users to garner insights that were previously buried. In finance, you might use Power BI to automate the generation of profit and loss (P&L) statements or analyze costs over time. In construction, you could use Power BI to identify variances in times to complete projects based on team composition or geographical factors. In retail, you might identify which of your products are the most successful, while pinpointing which ones might be on the cusp of taking off if given a bit more of a push via a what-if analysis.

According to Microsoft at the 2021 Business Applications Summit, 97% of the Fortune 500 uses Power BI in some capacity. That means it's a technology you can trust putting your time and effort into, especially if you're looking for the kind of insight that transforms your enterprise. Or in my case, it's the excuse to build a Pokédex for my daughter. Sometimes you just really want to be the best, like no one ever was.

Power BI Components

Power BI today consists of a wide variety of products that allow users to create and consume reports from your data. According to Microsoft (at the time of publishing), here are all the components that make up the Power BI family of products:

- Power BI Desktop
- Power BI service
- Power BI Mobile
- Power BI Report Builder
- Power BI Report Server on premises
- Power BI Embedded

There is much to unpack in these products, but the main focus of this book is on the first two components. We'll spend most of our time learning Power BI Desktop because that's the foundation you need; it's what the whole ecosystem is built around. Then we'll discuss the Power BI service in more detail toward the end because you're

going to need that knowledge to publish (and then share) your amazing work that'll make you the envy of your department.

With that in mind, a quick overview of these components will be useful in the future, so here they are:

Power BI Desktop
: A free application you install on a local computer that you can use to connect to, transform, and visualize data. This is the building block for all the other portions of the Power BI ecosystem.

Power BI service
: An online SaaS solution that lets end users share reports created in Power BI Desktop or Power BI Report Builder with users across an organization. (In case you're wondering, the "s" in "service" is lowercase on purpose; that's just how Microsoft named it.)

Power BI Mobile
: A set of applications for Windows, iOS, and Android that allows end users to view reports in the Power BI service from their mobile devices without having to use a web browser.

Power BI Report Builder
: A free application you install on a local computer that you use to generate pixel-perfect paginated reports in the same form as SQL Server Reporting Services. For example, if you want to build something to automate invoice generation or create long lists of data for distribution, you could do that here.

Power BI Report Server on premises
: If, for security reasons, you cannot publish reports to the Power BI service, your IT team may put a version of that software on an internal server behind the company firewall using on-premises computing resources, as opposed to cloud resources. Power BI Report Server is not always in feature parity with the Power BI service. That's because Report Server is updated only three times a year (January, May, and September). It's also worth noting that if you are going to deploy reports to Report Server on prem, you will need to use a special version of Power BI Desktop that is in alignment with the version of Report Server installed.

Power BI Embedded
: Allows you to integrate Power BI reports and visuals into applications or websites. This has its own pricing and licensing structure.

Now that the whole family has been introduced, we'll shift focus to the two components pertinent to this book, Power BI Desktop and Power BI service.

Power BI Desktop

Power BI Desktop is software that allows you to connect, transform, and visualize data. Let's dig into some details. Power BI Desktop comprises its own components. The two that are most important to a Power BI beginner are the Power BI canvas and Power Query, so those are the two we're going to focus on. Essentially, this is where you'll spend the most time in your Power BI Desktop work.

The *Power BI canvas* is the place where you build visualizations. Think of the canvas as a PowerPoint slide for your data. Here you'll use drag-and-drop functionality to pull information into different visualizations to explore your data and garner insights. This is also where you'll apply formatting to visuals, add images and text boxes, and more.

Power Query is used to import and manipulate data, essentially shaping it. In Power BI, unlike Excel, for example, you do not edit *cells* of data; you manipulate *columns* of data by using its functions, wizards, and formulas. Power Query provides options for creating custom columns based on rules you design. It lets you combine multiple tables of data or add values from one table to another.

Everything in Power Query first begins with getting data from your sources, and Power Query supports a huge number of data sources. You want to connect to a database? SQL? Oracle? Teradata? Power Query has you covered. You want to connect to an Excel workbook to get a table? No problem. Comma-separated values (CSV)? Easy. Cloud sources? Also not a problem.

Microsoft has gone out of its way to create new connectors to data sources to show that Power BI is not just to be used with other Microsoft products but wherever your data lives. If you become sufficiently talented at M (the programming language of Power Query), you can even, in theory, create your own custom data connectors to data sources that aren't officially supported. Just note that this book isn't going to discuss M or advanced Data Analysis Expressions (DAX) topics or actual programming. We're here to help you as a Power BI beginner, and you'll do just fine without those.

The Power BI Service

Now we get to the good stuff that's going to move you from an ordinary person who just produces reports to a celebrity whose reports draw people from far and wide. The Power BI service, the online SaaS solution, allows users to share their reports from Power BI Desktop with other users in their organization.

Everyone has access to their own personal workspace for free. You get one personal workspace that is pregenerated when you log in for the first time, and it's like a private development space in the larger Power BI service environment. You technically can share things from this personal workspace, but it's not a best practice to do so, and anyone you share it with would still need the appropriate licensing to view it.

The right way to share reports with other users is to create a new workspace and invite them to that workspace. To be eligible to be invited to a workspace, a user must have a Power BI Pro license, or your organization must be using Power BI Premium dedicated capacity to share reports with users who do not have Power BI Pro licenses.

The Power BI service lets other end users explore reports you've created to get insights from your work. This exploration can take the form of dashboards of curated visuals you put together. Or it can be access to a report you've created with all its pages. Or it can even be the ability to ask natural language questions using the Q&A feature to get insights from the data.

The Power BI service also includes several other features, such as the ability to create special objects known as *dataflows*. These dataflows can be used to get information in the Power BI service outside of a database, while allowing end users to access that data and combine it with other data inside a Power BI Desktop model.

Developers can manage deployment pipelines for workspaces in the Power BI service, which lets you create and manage the development, test, and production workspaces. Deployment pipelines enable ongoing development work on Power BI projects, without impacting the user experience for items already being used by end users.

A new feature in the Power BI service gives users the ability to create goals. The goals are tracked using data in the Power BI service. Information on the goals can then be shared with appropriate users for quick, actionable insight.

In sum, the Power BI service is the critical glue that makes Power BI different from, say, simply sharing an Excel workbook around the office. It creates a shared space enabling people to see the same insights securely, while inviting them to explore shared data elements that can be curated for meeting the specific needs of each end user.

The Power Platform

Now let's take a step back and look at the big picture: what are the "Power" products within the Microsoft family? The Power Platform is a larger compilation of low- or no-code products that support one another, with Power BI as just one component. While we won't train you on these other items, it's good to know what else is out there in case you develop a need to integrate one of the products into your Power BI reports in the future:

Power Apps
: A low- or no-code development environment where you can develop your own applications to solve different business challenges

Power Automate
: A framework that allows end users to create "flows" that automate organizational processes

Power Virtual Agents
: A no-code tool that lets you build chatbots to engage with customers and employees

Each of the components can be used by Power BI to create insights to help push your work forward. Let's go through some examples of how each piece could work with Power BI.

In Power Apps, for instance, you could have an application that would allow a site inspector to take notes and upload that data to a SQL Server database. A Power BI report could also be connected to that SQL Server database, download that information that was uploaded by the Power App, and update the report based on the new data being added by the numerous inspectors in the field using Power Apps.

Let's say your boss, for whatever reason, wants to see a static version of a report every day. Well, you could manually go into the Power BI service and create an export, download it, write up an email, and click Send. Instead, a more efficient option would be to use Power Automate to create a flow that would automate the task for you, ensuring that at 8 a.m. sharp every day there's a nice PDF in your boss's inbox with the most up-to-date version of your Power BI report. If that doesn't get you points, I don't know *what* will.

When it comes to virtual agents (software that provides customer service to humans, mimicking a customer service representative), a large amount of data is collected in the process whenever end users interact with your chatbots. All that data is collected and stored, which means Power BI can generate reports about it. This creates an end-to-end reporting solution that allows your organization to get textual insights into what your consumers are really looking for from your organization. The end users can work with and see the actual data.

How Did We Get to Power BI?

Microsoft's history in business intelligence is long and storied. In many ways, Power BI is the most recent (and maybe final) chapter, representing the culmination of business intelligence capabilities developed in a series of components Microsoft built throughout the years. For you to get the most out of this product, it's worth discussing how Microsoft's business intelligence stack got to Power BI and what that journey means for you as an end user.

This section will provide you with valuable context: why was Power BI developed, why is it important, and what products are interrelated? Knowing this up front will

help you the same way it helps when you do research about a company before you walk into a job interview. The clarity you gain will serve you well in the future.

SQL Server: Microsoft's Relational Database

In 1989, Microsoft released its first relational database in the form of SQL Server for OS/2. A *database* is a piece of software that contains and organizes large portions of data for different uses. While SQL Server was the first step (and a necessary one) for Microsoft to move into business intelligence, a database alone isn't sufficient to provide business intelligence.

SQL Server Analysis Services Multidimensional: One Small Step into BI

As processing power grew, new methods to process data became popular—for example, data cubes. In 1998, Microsoft released its first online analytical processing (OLAP) engine and called it OLAP Services, which would eventually become SQL Server Analysis Services. *OLAP Services* is a fancy way to say a cube-based way to interact with data for analysis. The cube approach dominated many enterprise BI environments for well over a decade.

SQL Server Reporting Services: Pixel-Perfect Reporting, Automated Reports, and More

Microsoft eventually needed to add a pixel-perfect reporting option to SQL Server. This was required because, as data use cases grew, the need to create reusable assets to an exact specification grew as well. For example, you want to make sure that every invoice you print is in exactly the same format every time.

In 2004, Microsoft released SQL Server Reporting Services as an add-on to SQL Server 2000, with its second version being released alongside SQL Server 2005. SQL Server Reporting Services had several features that were useful in an enterprise deployment, including pixel-perfect report generation, automated report distribution, and, in many deployments, the ability for end users to generate queries to the backend SQL Server database through a user interface.

Excel: A Self-Service BI Tool

Every piece of software mentioned so far is what we would define as *enterprise business intelligence* tools. These expensive tools required large teams to manage and deploy them.

If enterprise business intelligence is defined by its large deployments and high levels of investment, *self-service business intelligence* is the ability to use and manipulate data in such a way that you empower the end user to explore and analyze the data they have.

Microsoft's history in self-service business intelligence comes down to one core product that almost everyone has seen or touched once: Microsoft Excel. The first version of Excel came out for the Macintosh in 1985. At its core, Excel is a product that allows you to take data, pull it into a "flat" extract, and manipulate it or make impromptu calculations on it as needed. Excel empowered end users to take their data and get insights out of it. That's the premise of self-service business intelligence.

Power Pivot

In 2010 Microsoft released PowerPivot. PowerPivot was later renamed to add a space so it was two words, thereby matching the other product names in this new Power BI suite of tools. Originally an add-on for Excel, Power Pivot let end users get information from a myriad of sources and store that information in a relational OLAP (ROLAP) model inside the workbook. Power Pivot also shipped with Power Query. Power Query is an in-engine extract, transform, and load (ETL) tool that allows for data manipulation using the M language.

Important New Functionality That Leads to Power BI

Around this time, we began to see enterprise and self-service business intelligence start to flow together. In SQL Server 2012, Microsoft released a new feature with Analysis Services called the *tabular model*. Analysis Services could now support a method of data organization more like that of a classic data warehouse, as opposed to a cube structure that becomes increasingly difficult to manage over time and tends to be more confusing for end users. The difference was that to get performance gains in this tabular model, Microsoft developed its first columnar (column-based) data store technology. Eventually, this would become what we know as *VertiPaq* today, the in-memory columnar data store Analysis Services tabular model. So basically, with these improvements, performance became really fast.

Alongside this process, a new formula language called *DAX* was developed to support these tabular models that allowed for calculations across those columns of data to help make that data actionable.

The next version of Power Pivot released with Excel 2013 used this engine as the base for its work.

Power BI Desktop Is Born

On July 24, 2015, the first generally available version of Power BI Desktop was released to the world. Inside Power BI Desktop was an entire enterprise-level semantic (designed to be understood by people) modeling tool with the VertiPaq engine and the DAX formula language. It used Power Query to get information from a wide variety of sources and pull it into the engine, and it allowed for transformations that could shape that data for future analysis.

Figure 1-1 shows the timeline of the Microsoft business intelligence tracks and how they converge, highlighting some of the milestones over the last 30 years in both enterprise and self-service business intelligence.

No one will quiz you on this history, but hopefully it has given you the perspective to understand how we got here. I mean, sure…not all of us keep history books on Microsoft on our bookshelves, but not all of us have secret shrines to Satya Nadella either. It's a life choice.

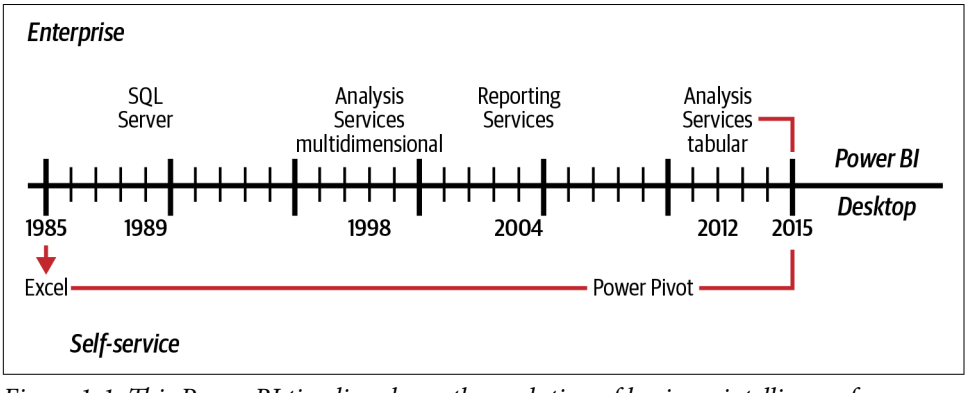


Figure 1-1. This Power BI timeline shows the evolution of business intelligence from Excel to present-day Power BI Desktop

Power BI Desktop Under the Hood

Power BI Desktop works because under the hood it has two powerful engines. These are what make the whole thing work on a technical level. There's the formula engine, which takes data requests, processes them, and generates a query plan for execution. Then there's the storage engine, which stores the data of the data model and pulls the data requested by the formula engine to satisfy a query's demand.

Another way to look at it is to think of the formula engine as the brain. It figures out the best way to approach a problem and sends the appropriate work order to the right parts of the body to get it done. The storage engine is the body that receives those commands and does the work of getting all the data together.

VertiPaq: The Storage Engine

Let's meet the storage engine of SQL Server Analysis Services tabular models, called VertiPaq. This enterprise-level semantic modeling tool is included with every copy of Power BI Desktop. When you pull data into Power BI Desktop, the VertiPaq engine reads the data source post-transformation and puts the data into a columnar structure. This division of the data allows for faster queries via selective column selection and data compression as entire columns get compressed. This compression of the

data significantly cuts the file size compared to what it would be otherwise. It then puts the entirety of the data model in local memory. This view can be refreshed from the original data sources.

Now, before you get excited and run out to celebrate, know that this data storage engine comes with a significant hurdle for users coming from, say, Excel. You cannot modify individual cells of data. As the data is converted into columns for storage and indexed and then compressed, the data inside the model becomes effectively immutable. You can add calculated columns and measures, but the underlying data doesn't change. If you want to change the data, you must either go back to the transformation step of the data (say, in Power Query) or go back to the data source and make your edits there, and then refresh your data.

DAX: The Formula Engine

Also, let's discuss the formula engine and its language, DAX. DAX is a formula language used in Analysis Services Tabular, Power BI, and Power Pivot. When you want to access the data in your data model, DAX is how it's done. This is done in the same way as someone would write SQL to get data from a database. Power BI users will most commonly use DAX to create measures and calculated columns. The wonderful thing about Power BI is that for simple drag-and-drop functionality, or when visuals get created, Power BI generates the DAX for you and passes it to the internal engine to have its query plan generated and executed.

Nothing you do in Power BI is done without DAX. You may not see it, but it's always there, playing the pivotal role of figuring out how best to get the information from your data model to satisfy your request.

What Makes Power BI Different from Its Competitors?

Honestly, there has never been a better time to be a data analyst than today. Many of the tools in the marketplace have a variety of strengths and weaknesses, and Power BI is no exception. In fact, just to see how many competitors there are in this marketplace, let's take a quick look at Figure 1-2, which shows Gartner's Magic Quadrant for Analytics and Business Intelligence Platforms for 2021.

Now, whatever you think about the position of the competitors on the analysis, the sheer number of them can be enough to make your head spin. Each competitor has a reason they're in the market today. Notice, though, that the leader's quadrant contains only three players: Qlik, Tableau, and Microsoft.

Figure 1-2. Gartner's Magic Quadrant for Analytics and Business Intelligence Platforms

The real source of differentiation between Microsoft and its competitors in this space is the ability to execute on its plan for its software. Microsoft has a more than 30-year history in business intelligence, and SQL Server is itself now over 30 years old. Microsoft has been in this game a very long time and has the highest number of supporting technologies to its business intelligence platform, as compared to the others.

All these major competitors offer products that allow you to take data and turn it into great data visualizations that help you learn something you didn't know from your data. I will forever be jealous of Tableau's capability to click and drag for groupings, for instance.

Regardless of Tableau's dazzle, Power BI offers a tool for data ingestion that is unequaled in terms of ease of use for nontechnical resources in Power Query. It also

has one of the strongest, if not *the* strongest, analysis engines on the planet today in the form of Analysis Services Tabular. These tools have accelerated the rate of data democratization inside many organizations. Power BI has created citizen data analysts around the world who use data to do transformative work. Indeed, by putting in the effort to read and digest this book, you're taking the steps necessary to join that community!

Here are some examples. The world's leading conservation organization, the World Wide Fund for Nature, uses Power BI to share impact effects with donors. Engineers at Cummins use Power BI to do advanced capacity planning to get engines out the door more quickly. Humana leverages Power BI to centralize and visualize data against more than 45 unique data sources across its enterprise, using Power BI as a consolidation platform for end users. King's College London uses Power BI's artificial intelligence (AI) visuals to identify key factors that could indicate shifts in student performance, allowing for targeted outreach to maximize the opportunities for student success. These are just some of the varied use cases happening today on this platform.

Power BI has decades of Analysis Services experience behind it, with a frontend that can now match its promise. In addition, Microsoft releases updates for Power BI Desktop every single month with new features, connectors, and visualizations. Microsoft is committed to the Power Platform, and it's safe to say Microsoft will be here for the long haul. When 97% of the Fortune 500 agree on something, there's probably a good reason.

Conclusion

Power BI at its core is more than just a desktop authorship tool. It's an entire platform that Microsoft has been working toward for the better part of three decades. It has the unique strength of having two of the most enterprise-tested analysis engines in the world, VertiPaq and DAX. It also has a great tool to allow nontechnical users to get disparate data together and begin real analysis on that data with Power Query.

Power BI Desktop is now an enterprise-level solution that is used by the world's largest companies, nonprofits, and even small businesses to help get insights from their data that would have previously been impossible.

With an understanding of what Power BI is, we are ready to finally open the software with a clear vision about what we'll do with it. That begins with the Report view, so get a soda, pet your dog, and let's dive in. This next chapter will cover the user interface and how to use it.

CHAPTER 2
The Report and Data Views

Power BI Desktop is a robust data visualization tool that allows you to take your data and create visualized insights from it in a variety of ways. In this chapter, we'll go over the basics of the Power BI Desktop interface, specifically looking at the Report and Data views.

This will be a detailed dive into the User Interface, so stay with me. Parts of this chapter might be a bit dry since I'm going to concentrate on what the UI does, not necessarily on how we'll use it.

A majority of our focus will be on the Report view because that's where you'll be working the most. Plus, the Report view has the largest number of elements to interact with. The two most important things you need to know about within the UI are the functions of the Home tab of the ribbon and the Visualizations pane, so keep that in mind as you read.

Microsoft said its goal for Power BI Desktop was to make it "PowerPoint for your data." As of the writing of this book, you can see that Power BI has adopted many design principles from other tools in the Microsoft Office family, PowerPoint included.

If you've used any other Microsoft Office product since 2010, you've seen some version of the ribbon UI in Word, Excel, PowerPoint, and other products. Having that familiarity with the interface gives you an advantage, but the Power BI user interface does have some quirks. Now and then, you'll see that Power BI will add and remove items from the ribbon based on item selection context, which can feel awkward at first.

Let's look at how Power BI integrates the ribbon and show you the first thing you'll see when you open Power BI Desktop. See Figure 2-1.

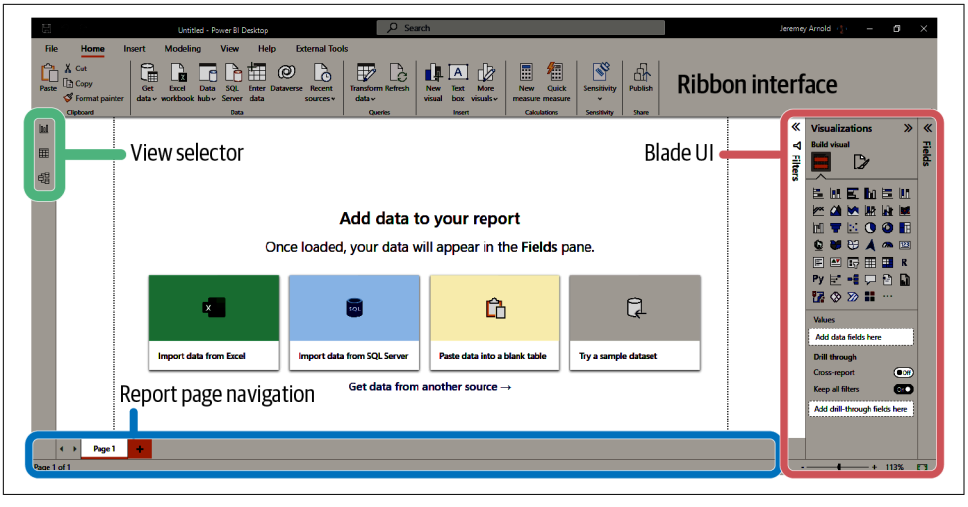


Figure 2-1. This is the first thing you see when you open Power BI Desktop

Looking at the view selector in Figure 2-1, we see three possible views: the Report view, the Data view, and the Model view.

Report View: Home Section of the Ribbon

Power BI defaults to the Report view when you open it. You can see a classic ribbon interface at the top that allows you to search for actions you might take. On the right, you'll see the pane portion of the UI. This part is very similar to what Microsoft did with the original Xbox 360 interface.

You can add different panes to see by using the View portion of the ribbon. You can also take panes that are currently visible and minimize them, as you can see with the Filters and Fields panes in Figure 2-1 where the Visualizations pane is open.

At the bottom, you'll see the Report Page Navigation options. You can click individual report pages or, if your report is large, you can use the arrows to scroll across your list of pages, very similar to how you would explore worksheets in Excel. Finally, on the left, you'll see the three icons that indicate the view selector. The views in order from top to bottom are Report, Data, and Model. The ribbon menu changes based on which view you are in.

Starting with the ribbon interface, the default view is the Home tab, as seen in Figure 2-2. The Home tab goes by a few names, including Home view, Home ribbon, and Home section. I'll refer to its parts (Home, Insert, Modeling) as *tabs* moving forward.

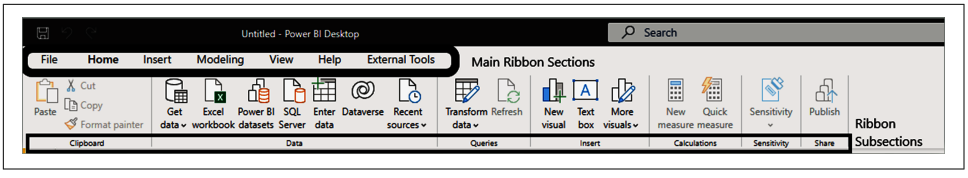


Figure 2-2. The Home tab, also called the Home ribbon, Home view, or Home section, is Power BI Desktop's default view

All of the tabs, or main ribbon sections, in Figure 2-2 are divided into *subsections* separated by a faint vertical line. The names of the subsections are on the bottom row of the ribbon. In Figure 2-2, the subsections are Clipboard, Data, Queries, Insert, Calculations, Sensitivity, and Share. So when I refer to a "subsection" of a tab moving forward, look down at that bottom row to see what I'm referring to.

(I realize that if you've been alive for the last couple of decades and used any Microsoft Office product, you already know this, but I just want to make sure we're aligned on what I mean when I refer to a "subsection" of a tab.) After I identify the tab and the subsection, I'll get into the buttons.

The Clipboard Subsection

So let's get back to the Home tab. You'll first see the Clipboard subsection with items for your standard Cut, Copy, and Paste functionalities. You can use Format Painter to apply one visual's formatting to another, just as you would if you were using format painting in Excel or PowerPoint.

The Data Subsection

In the next subsection, the Data subsection, you'll see several fast options to quickly connect to different data sources. We can see these more clearly in Figure 2-3.

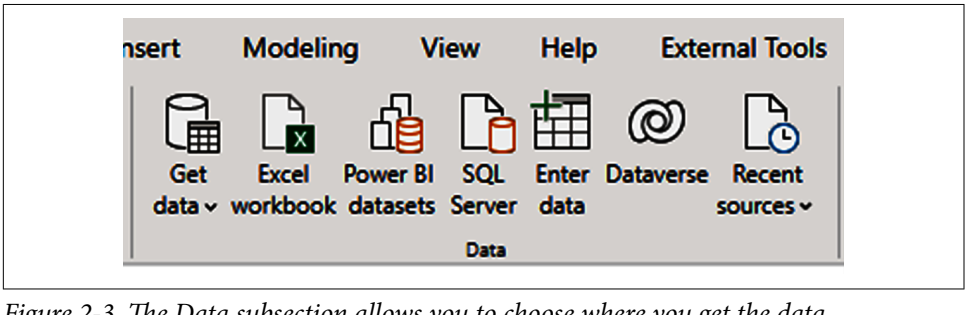


Figure 2-3. The Data subsection allows you to choose where you get the data

Starting on the left, you see the "Get data" button, which has an icon and a drop-down arrow. If you click the icon, you'll see a new menu appear with the entire list of possible data connectors in Power BI, as shown in Figure 2-4.

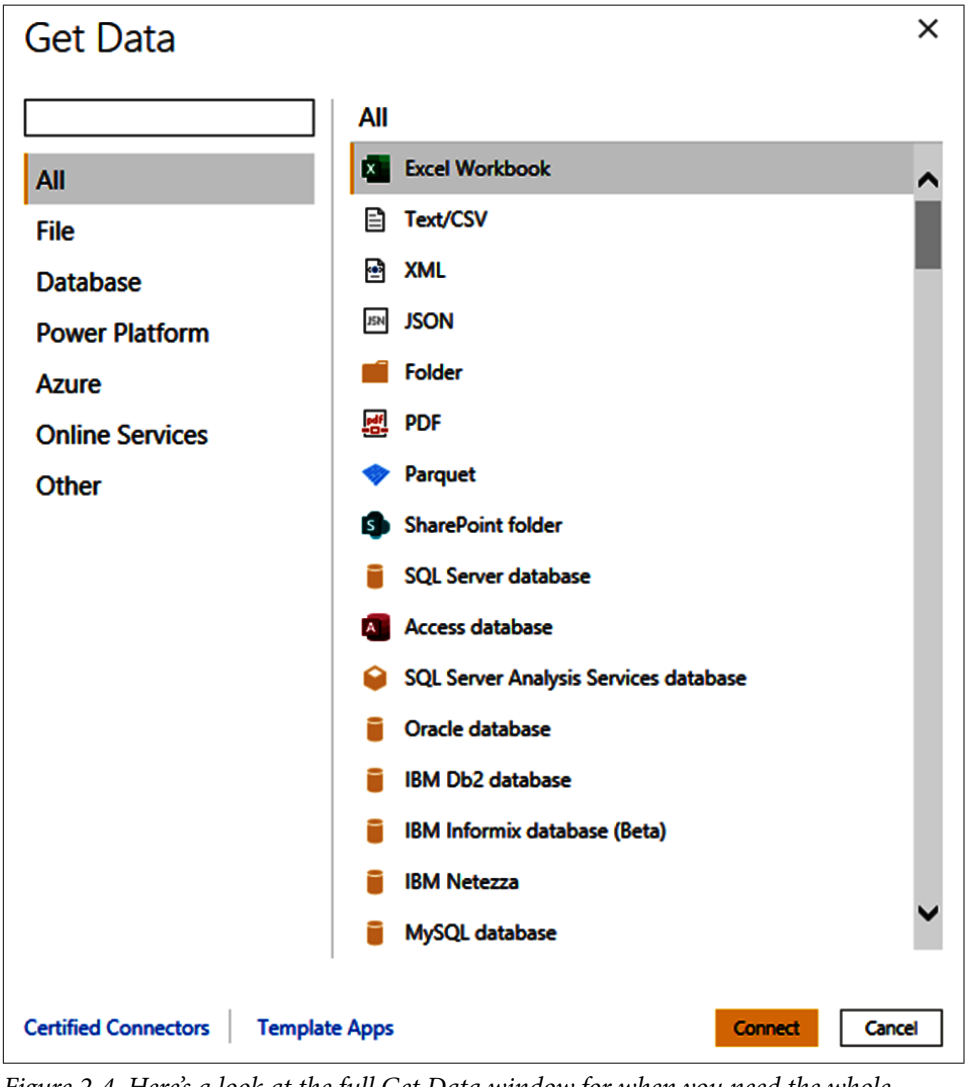


Figure 2-4. Here's a look at the full Get Data window for when you need the whole enchilada, meaning the entire list of data connectors

If you click the drop-down button, you'll see a smaller, truncated list of more commonly used data sources. This can be very convenient when you don't need to access the full list of connectors. The truncated list is shown in Figure 2-5.

Figure 2-5. The quick data selection list is a shorter list of data connectors, for when you're having a "classic" for lunch

The "Excel workbook" button will immediately open an Explorer window to navigate to your Excel file. Click the "Power BI datasets" button, and a window will appear so you can select a dataset that is already published in the Power BI service to connect to via a "live connection." For reference, see the window in the example in Figure 2-6.

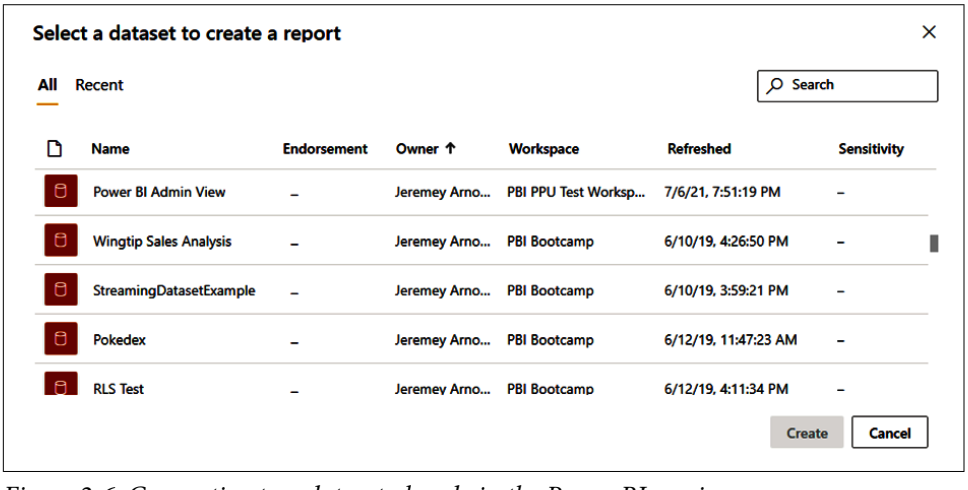


Figure 2-6. Connecting to a dataset already in the Power BI service

If you click the SQL Server button, a pop-up menu will appear for you to enter the server's name or address, along with an optional database name. The server will ask for your credentials when you try to connect.

You'll also see an option for selecting Import or DirectQuery. In Import mode, you download the data into your local data model. In DirectQuery mode, Power BI generates queries against the database and then, when that data is returned, does whatever is needed with the data. That window is shown in Figure 2-7.

There is also an "Advanced options" button you can click that will allow you to add a command timeout in minutes, pass a custom SQL statement, include relationship columns, navigate using full hierarchies, and enable SQL Server failover support.

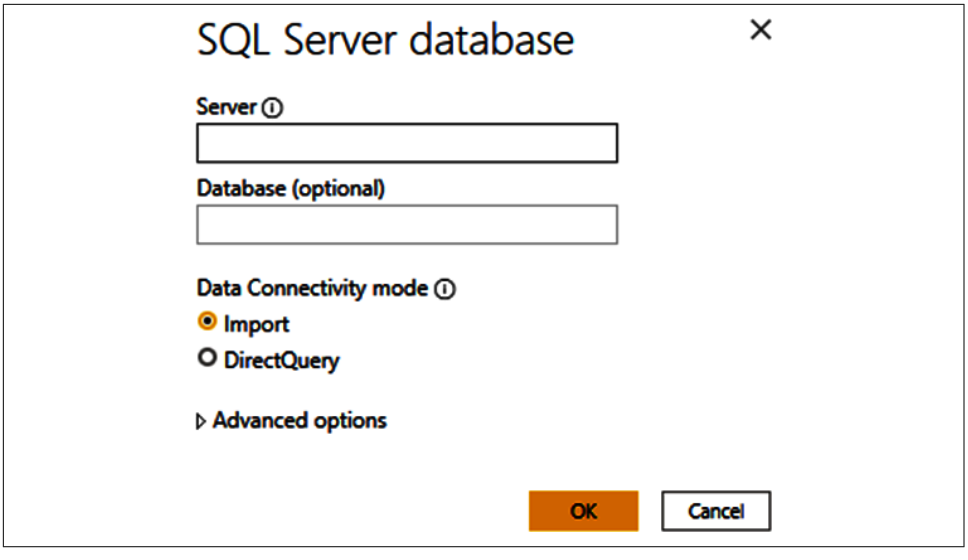


Figure 2-7. Connecting to your friendly neighborhood SQL Server

The "Enter data" button (way back in Figure 2-3) will give you a0n interface that should feel familiar if you use Excel, as it opens a table-like structure where you can add columns, name them, and put data into cells, as shown in Figure 2-8. It's important to note that this interface has no formula function. It's only for simple data entry. You can copy and paste information into this window, as well, but be careful before going copy-paste crazy.

This window can be useful for testing or if you have a lookup table that you want to generate for your model. But I recommend that you do not put large amounts of information into this type of table structure because it has to be manually managed and has a maximum capacity of 3,000 cells' worth of data.

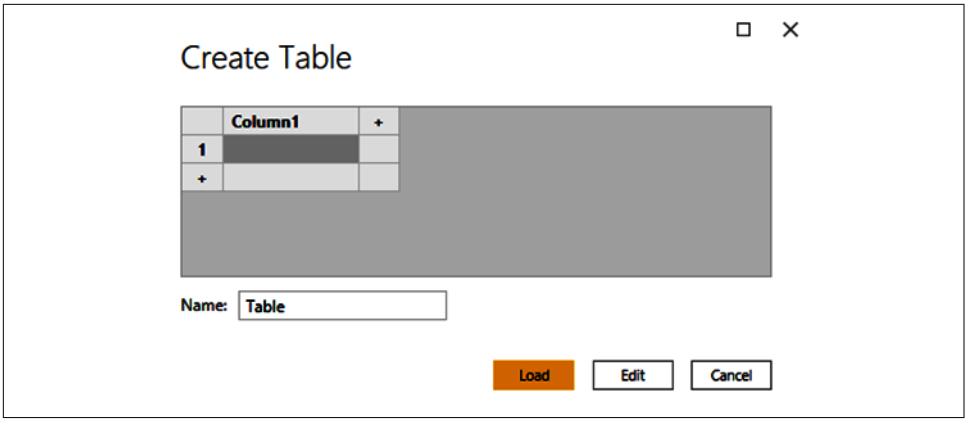


Figure 2-8. A simple data entry window, for when you need a little extra something you don't have elsewhere

The Dataverse button seen back in Figure 2-3 will generate a pop-up for entering your environment domain information alongside a prompt. If you're familiar with Microsoft Dynamics, you might have heard this referred to previously as the Common Data Model. The window for providing your Dataverse information is shown in Figure 2-9.

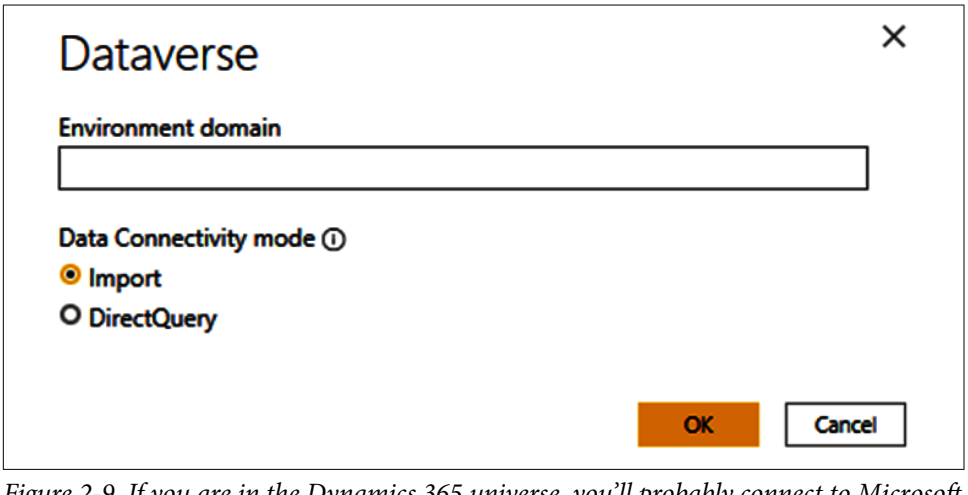


Figure 2-9. If you are in the Dynamics 365 universe, you'll probably connect to Microsoft Dataverse

The "Recent sources" button (Figure 2-3) will open a drop-down menu of your most recent sources so that if you must connect to a data source again, it's conveniently already there for you. You can click More from the drop-down to get an even longer list of recent data sources. Figure 2-10 shows some of my mos000t recent data sources in Power BI.

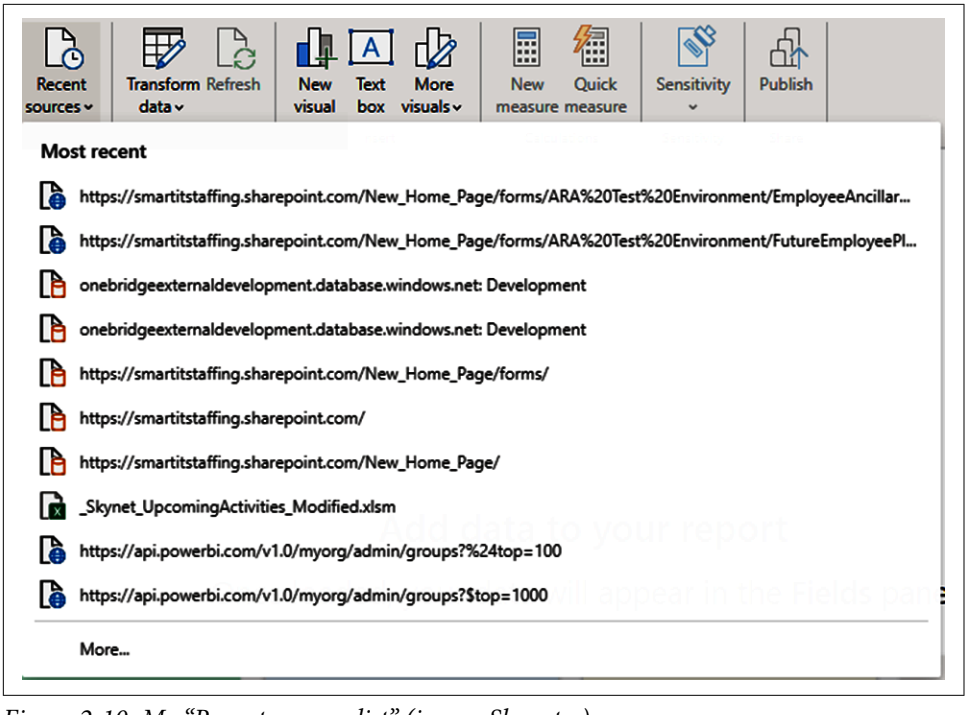


Figure 2-10. My "Recent sources list" (ignore Skynet...)

The Queries Subsection

Moving 00on to the Queries subsection, you'll see two buttons: "Transform data" and Refresh. Refresh is grayed out in Figure 2-11 because I have no data in my model to refresh. However, when that button is available and clicked, it will do a complete refresh of all data sources in your data model.

"Transform data" has two separate functions, depending on whether you click the its icon or its drop-down arrow. If you click the icon, it takes you straight to the Power Query interface, which we'll discuss in more detail in Chapter 3.

If you click the drop-down arrow, you'll get a drop-down menu with a couple of options. "Data source settings" takes you to a pop-up to modify those settings for things like credentials or locations of files and the like. If you have parameters and variables, they can be modified here as well.

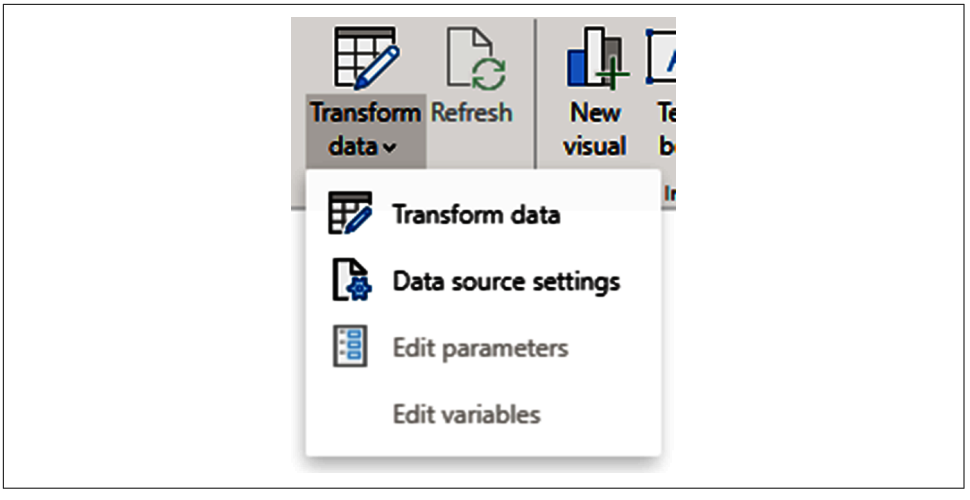


Figure 2-11. "Transform data" options

The Insert Subsection

Next is the Insert tab, which has three options. You can insert a new visual onto your report page, insert a text box, or add more visualizations to your list of visualizations in the Visualizations pane.

If you click "New visual," a visual will be put onto your canvas. The default visual that will be placed on the canvas is the stacked column chart.

The "Text box" button will put a text box onto your canvas in the same way it would appear in PowerPoint.

The "More visuals" button, when clicked, will look like Figure 2-12. If you select "From my files," you'll be directed to an Explorer window, where you can select a visual to add from a file on your local machine. These files are usually in PBVIZ format, though in recent years Microsoft has really pushed AppSource as the preferred method to get custom visuals.

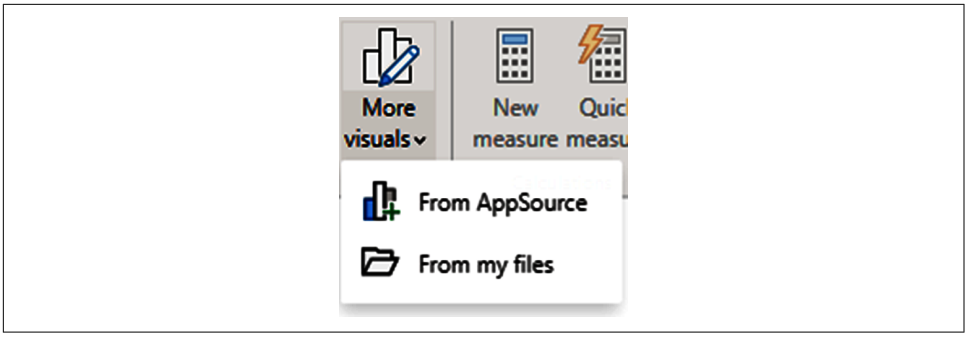


Figure 2-12. Adding visuals from two possible sources

If you select From AppSource, you'll see the window shown in Figure 2-13. Here you can select a third-party visualization to add to your list of visualizations.

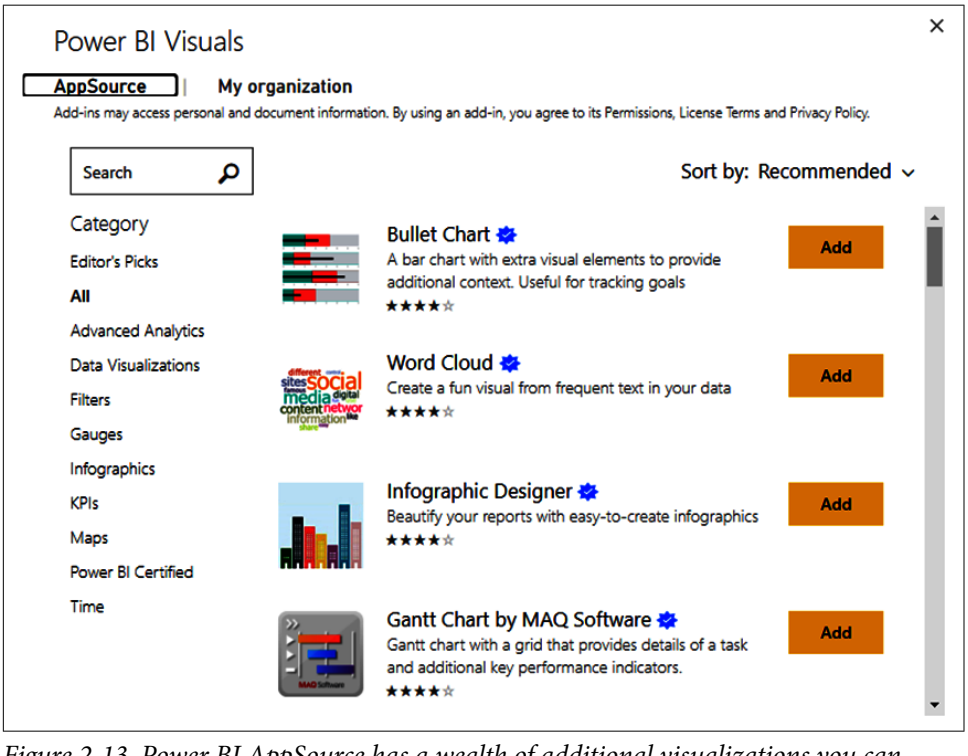


Figure 2-13. Power BI AppSource has a wealth of additional visualizations you can select for your reports

The Calculations Subsection

Under Calculations, you have" New measure" and "Quick measure" options.

Measures are calculations across your data using DAX. We will discuss measures in more detail later in this book, but for now, if you click "New measure," you'll see a formula bar appear below the ribbon, where you can put in the DAX for your measure. This is like the formula bar you might use in Excel.

Clicking the "Quick measure" button opens a pop-up box that helps you create a measure by using a wizard with several predefined calculations. You can see both the formula bar and pop-up in Figure 2-14. Here's a helpful tip: Microsoft adds new quick measures in some releases, so it's always worth going back after an update to see if new quick measures have been added.

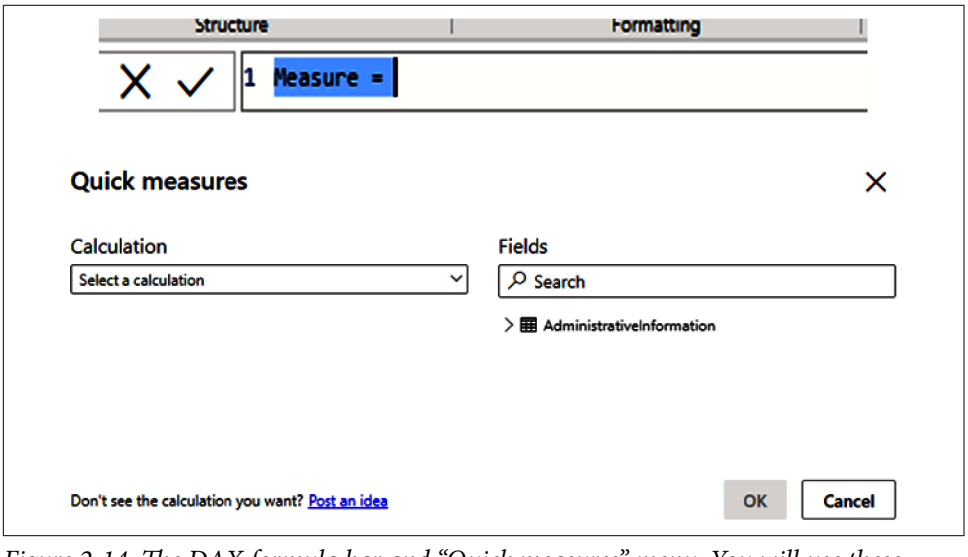


Figure 2-14. The DAX formula bar and "Quick measures" menu. You will use these, I promise.

The Final Subsections: Sensitivity and Share

The last two buttons on the Home tab deal with sensitivity labels and the capability to publish your report to the service. I'll discuss more about publishing and sharing reports in the Power BI service in Chapter 8.

Report View: The Insert Tab

Next on the ribbon under Report view, we move to the Insert tab shown in Figure 2-15.

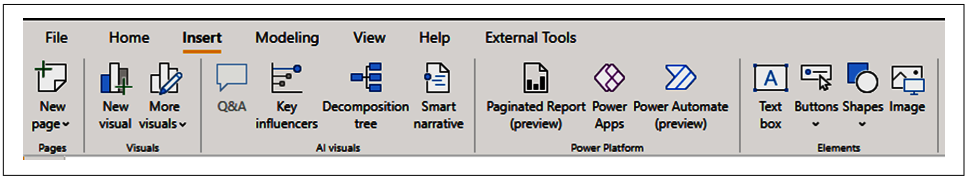


Figure 2-15. The Insert tab in the ribbon

The Pages Subsection

In the Pages subsection, the "New page" button will create a drop-down menu no matter which portion you click. That menu gives you two options: "Blank page" and "Duplicate page."

"Blank page" creates a new page in your report farthest to the right of all your other report pages. "Duplicate page" will make a copy of your current report page exactly as it is currently configured, with all visuals on the canvas, and you'll find that new copy farthest to the right of all the other pages in the report.

The Visuals Subsection

The Visuals subsection has two of the exact same buttons that we saw in the Home tab: the "New visual" and "More visuals" buttons. Their functionality is exactly the same too. They are duplicated here as a matter of convenience, so if you're looking for other specific items in this subsection of the ribbon, which revolves around putting things onto the canvas, you can also do it from here.

The AI Visuals Subsection

The next subsection in the Insert tab deals with AI visuals, shown in Figure 2-15. At the time of this writing, there are four of these AI-powered visuals in general availability. If you click any of them, that puts a blank version of that visual onto the canvas as far to the top and left-hand corner as possible. We'll discuss these visuals in more detail in Chapter 7, where we'll provide a complete rundown of all the visuals that are available in Power BI out of the box.

What's important here is that these visuals in particular offer unique functionality in terms of analytics capability. Microsoft is keen to demonstrate its AI prowess in as many Power Platform products as possible, and Power BI is no exception. I expect more AI-powered visuals to come to general availability down the road.

The Power Platform Subsection

The next subsection, Power Platform, deals with items that are technically visuals, but they are fundamentally different from every other visual in the platform.

Power Platform visuals offer the ability to interact with and engage the other portions of the Power Platform that we discussed earlier, embedding them into your Power BI report. They are very powerful and help demonstrate the Power Platform's holistic value inside an organization.

The Elements Subsection

The final subsection of the Insert tab, Elements, deals with report elements. These are items that aren't necessarily interactive like Power BI visuals, but they can help enhance your report or give it extra clarity. Elements choices include the Text box, Buttons, Shapes, and Image controls.

"Text box" in Power BI does the exact same thing it does in PowerPoint. It puts an editable text box onto the canvas, along with a basic formatting tool for your text. This tool allows you to change the font, font size, text color, bolding, italicizing, underlining, and text alignment, and to add hyperlinks to web pages outside of your report.

Other elements on the "Text box" can be edited in the "Format text box" pane that appears when a text box is selected. See an example of what that looks like on the canvas in Figure 2-16.

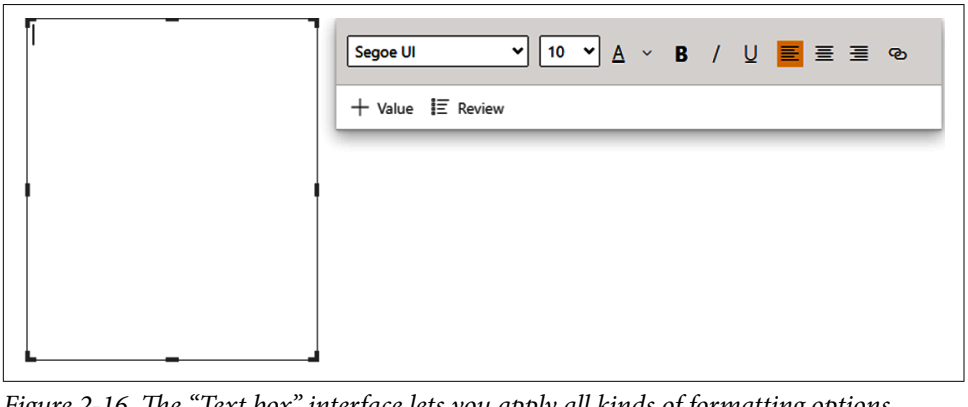


Figure 2-16. The "Text box" interface lets you apply all kinds of formatting options

Click the Buttons element to get a list of options that can help with report navigation or provide additional information. There are quite a few. Figure 2-17 shows the whole list, so you can start thinking about how you might use these in your future reports.

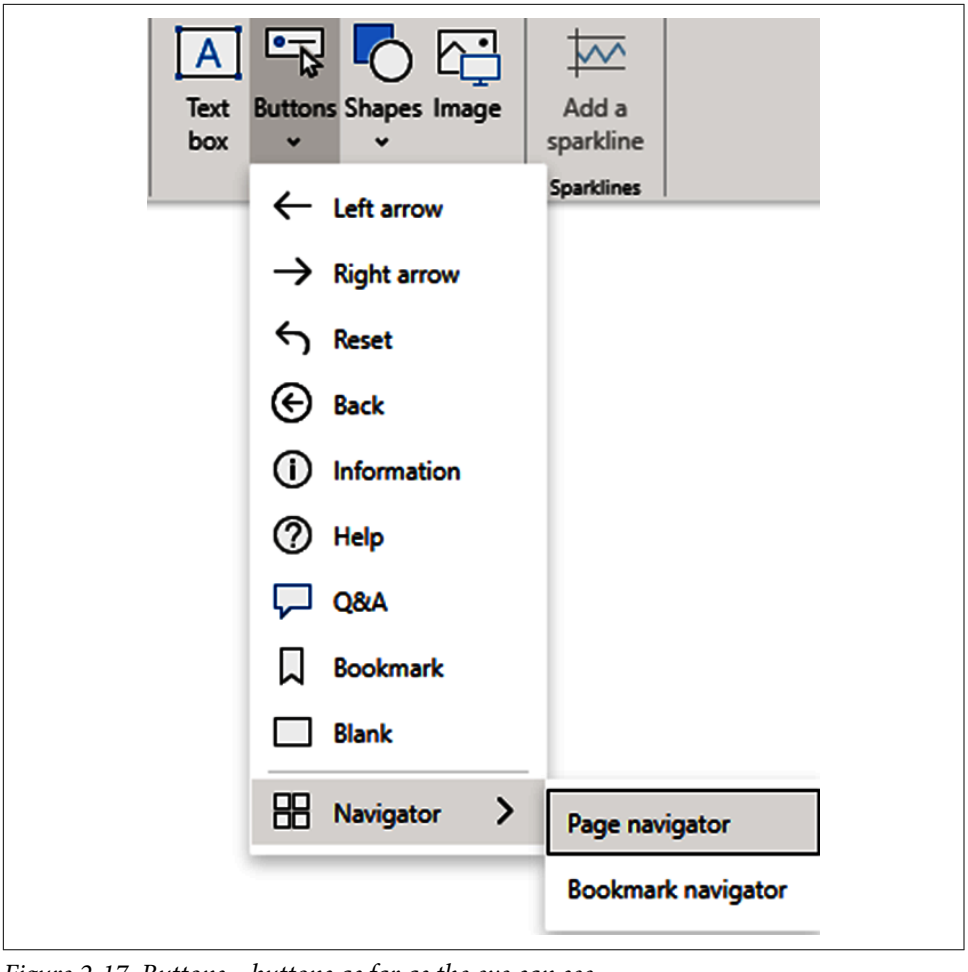


Figure 2-17. Buttons…buttons as far as the eye can see

It's important to note that for all these buttons, except Q&A, Bookmark, and the Navigator options, placing the button on your canvas doesn't do anything until you give Power BI the context for how that button should be used. When you put one of these buttons on your canvas, you'll see a "Format button" pane appear on the right, and it will contain visual formatting options, noting what action that button should do.

The Q&A and Bookmark buttons have default actions already set to the Q&A and Bookmark functions, respectively. However, you can still change these actions if you feel your report could use that button in a different context.

The Shapes button will show you a wide list of shapes that you can put into a report. The shape, when selected, will appear on your canvas already filled with a default color based on your theme. You can change it from there by manipulating the size of

the visual on the canvas. The shape can also be manipulated when selected for formatting, as shapes have their own special pane.

Finally, if you click the Image button, an Explorer window will pop up, allowing you to select an image to bring into your Power BI report. Power BI can add in pictures from several formats, as shown in Figure 2-18. (As an aside, there is a correct way to pronounce GIF…don't be on the wrong side.)

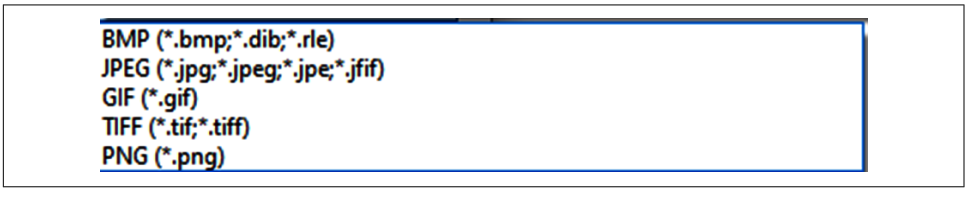


Figure 2-18. Seriously, there's an image format for just about everybody

Once your image is on your report page (as with every other item available in the Elements subsection of the ribbon), when selected, it will have its own special formatting pane appear on the right side. The shape can, like all other Power BI elements, have its size modified in the report by clicking and dragging the box to the size desired.

Report View: The Modeling Tab

The third part of the ribbon in the Report view is the Modeling tab. Here you have more data management options from the Report view. There is a lot of magic in Figure 2-19.

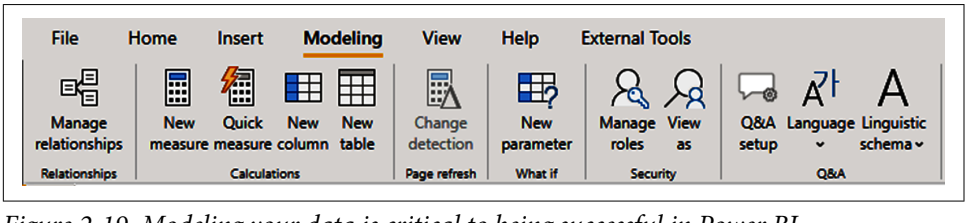


Figure 2-19. Modeling your data is critical to being successful in Power BI

The Relationships Subsection

First we see "Manage relationships." This button opens a window where you can see all the relationships in your model, and you can add or make edits to existing relationships from here.

By default, Power BI will try to autodetect relationships based on column names. This can be useful for getting an initial set of relationships together for your data model, but it might not always be the way you want the model set up. It's important to note that this button is grayed out if you have fewer than two tables in your data model.

We will go into more detail on relationships in the next chapter, when we discuss the Model view.

The Calculations Subsection

The next area involves Calculations. The "New measure" and "Quick measure" buttons function exactly as described earlier for the Home tab.

The other two items are prompts that will bring up the inline DAX editor that we showed earlier so that you can create either DAX calculated columns from the "New column" button or DAX calculated tables from the "New table" button.

Please be aware of an inconvenient quirk with the "New measure" button. If you don't have a table highlighted in the Fields pane before selecting this button, Power BI assumes that the measure is going to go into the first table that it sees in that pane. In theory, these objects can be moved by dragging and dropping them in the Fields pane to another table, but be aware of that behavior.

The Page Refresh Subsection

The "Page refresh" subsection has a "Change detection" button that is relevant only in DirectQuery scenarios, as discussed briefly earlier in the chapter. You can determine whether you want your pages to refresh when there's a detected change in the data or on a fixed refresh interval. You can simulate this function in Power BI Desktop using this feature.

The What If Subsection

"What if" simply lets you create what-if parameters. They will be discussed in further detail in Chapter 7.

The Security Subsection

The Security subsection has two buttons that are very important. The "Manage roles" and "View as" buttons are how we do row-level security (RLS) in Power BI.

RLS is a feature enabling us to control the way people see the data in our model, based on roles that are formulaically constructed using DAX. Think of this as making sure that people can see the data only in a way that's filtered for their specific context and security constraints. For instance, if we had a report published for multiple college classes, we could create simple DAX statements that describe how we want the data filtered and then, as shown in Chapter 9, assign users to those roles so the data is then filtered in the way we want for them. We can see an example of this in Figure 2-20, where I create a role for spring 2021 students with a very simple statement to define a filter condition.

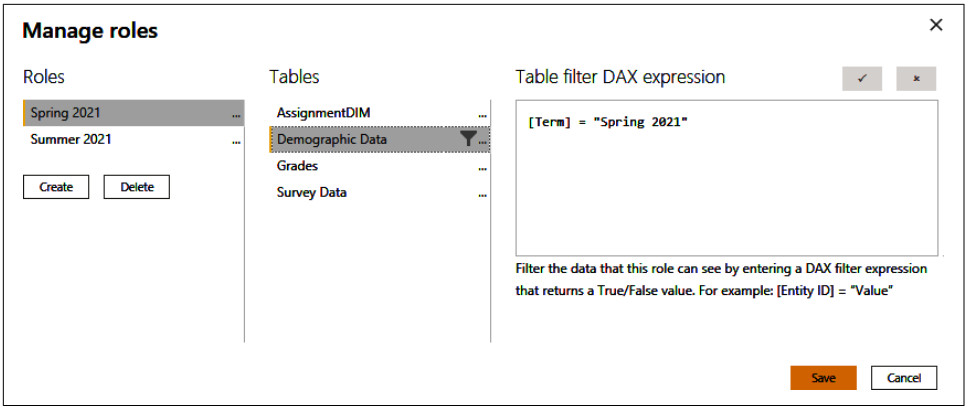


Figure 2-20. In this simple RLS example, users assigned to the Spring 2021 role would see only data for which the Term field in the Demographic Data table is equal to Spring 2021

The Q&A Subsection

Finally, we have the Q&A subsection. The "Q&A setup" button brings up a large wizard that shows how you can fine-tune the Q&A engine to adapt to more natural language around your users. See Figure 2-21. You can use this to teach the engine synonyms so that when you ask a question with a certain word, the Power BI engine knows what that word means in the context of your data model.

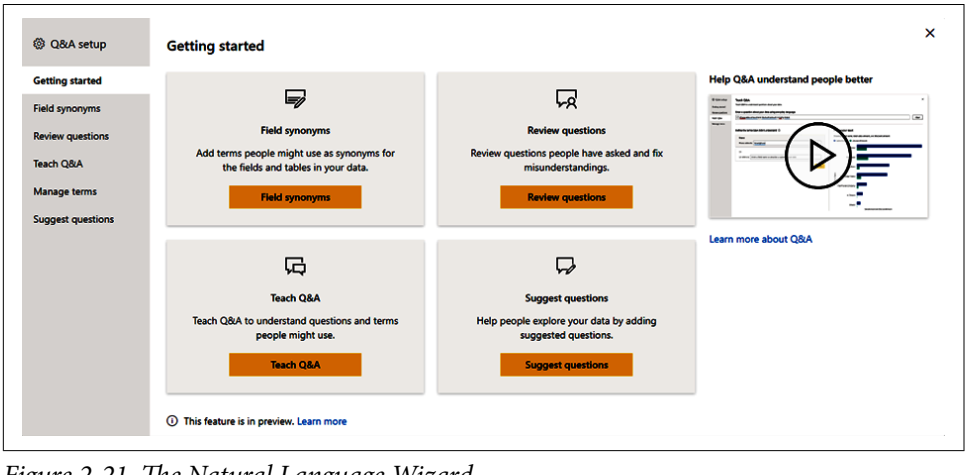


Figure 2-21. The Natural Language Wizard

Select the Language button to get a list of eligible languages for Q&A. I expect the list of languages to grow in the future.

Lastly, the "Linguistic schema" button has a drop-down that allows you to import or export a linguistic schema file. If you want to learn more about this subject, I suggest you go to "Editing Q&A Linguistic Schemas" and download the example linguistic schema file and example PBIX file.

Report View: The View Tab

The next major part of the ribbon is the View tab, shown in Figure 2-22. This tab is important because it allows you to set themes, set up different page views to see how your users might see your report, and more. Want some PowerPoint in your Power BI? This is where to make some of that happen.

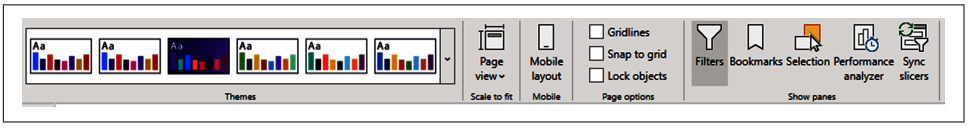


Figure 2-22. Put some PowerPoint in your Power BI by using the View tab

The Themes Subsection

The Themes subsection works the same way it does in PowerPoint. You can work from default themes, or you can click the drop-down menu on the right to get more themes to choose from, browse for other themes, see the theme gallery, or customize your current theme and save those changes. There are many themes, so feel free to experiment!

The Scale to Fit Subsection

In "Scale to fit," the "Page view" button gives you the option to your canvas to fit the page, fit to width, or show its actual size. This goes hand in hand with the Mobile subsection's "Mobile layout" button, which will change your report canvas to a size and shape suitable for reports being displayed on a mobile device.

Mobile report development is quite a bit different from standard report development in terms of what you must think about, since you have more limited real estate.

The Page Options Subsection

In the "Page options" subsection, you have three buttons to select from. You can show the gridlines, have items snap to the grid, and lock objects.

Gridlines are helpful in giving you guiding references for where your items are in respect to other items.

"Snap to grid" has a function only while in Mobile layout and will force all visuals to fit neatly into a given pixel density.

"Lock objects" prevents items on a page from being moved around.

The Show Panes Subsection

The "Show panes" subsection is the last one on the View tab. This subsection is related to the different panes you can have added or removed at any time from that portion of the UI.

We will detail these functions' UIs later in this chapter, but as a general overview, the Filters pane allows you to modify filters at a visual, page, or report level.

Bookmarks allows you to set a report page to a certain series of events and then return to that state at a later point, like a web bookmark.

The Selection pane shows you all the objects on your canvas in each report page and can allow you to quickly select a specific object. You can also use this to group objects and determine their hierarchy of importance when they might overlap.

The Performance analyzer lets you see what's impacting your report page's performance and can allow you to extract machine-generated DAX.

The "Sync slicers" pane allows you to determine which slicers, if any, should be synced across report pages, enabling a way to keep comparisons the same across different report pages.

Report View: Help Section

The Help tab on the ribbon will enable you to see which version of Power BI Desktop you're using and provide links to guided learning, training videos, documentation, and support links, as shown in Figure 2-23.

I'm going to skip to the Community subsection because the Info, Help, and Resources subsections are self-explanatory. Plus, the Community subsection is very powerful.

Under Community, you'll find links to the Power BI blog, ways to connect to the broader Power Platform community, specific documentation for developers (called "Power BI for developers"), the ability to submit an idea for Power BI Desktop, and a link to commonly used external tools.

I do want to highlight the submitting and voting on ideas because this is something that will help you. The Microsoft Power BI development team has said on multiple occasions that it listens to those ideas and pays attention to what is getting voted on. Almost every month or two, there's an update to the software, and the team discusses how popular a given idea was on Power BI Ideas. So if you have an idea, this is the right forum for it.

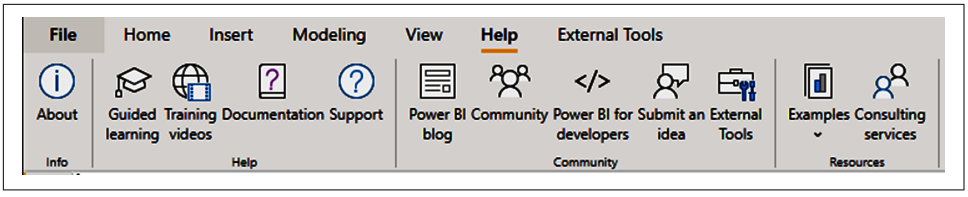


Figure 2-23. We can do with a little help from our friends, and we get this on the Help tab

Report View: External Tools Section

Lastly, there's the External Tools tab on the ribbon. There are a ton of external tools, and they're not all equal. Just to give you an example, see Figure 2-24. We'll further explore some of the most important external tools in Chapter 10, but for now, just take a look at the variety.

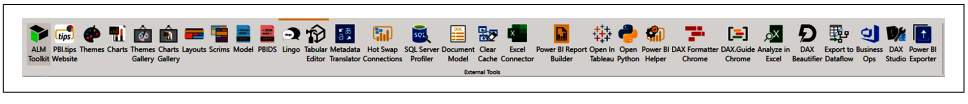


Figure 2-24. That's a lot of external tools!

The Pane Interface of the Report View

Each section of the user interface has a unique set of panes that allows for different functionality. In the report view you can access seven panes, as shown in Figure 2-25..

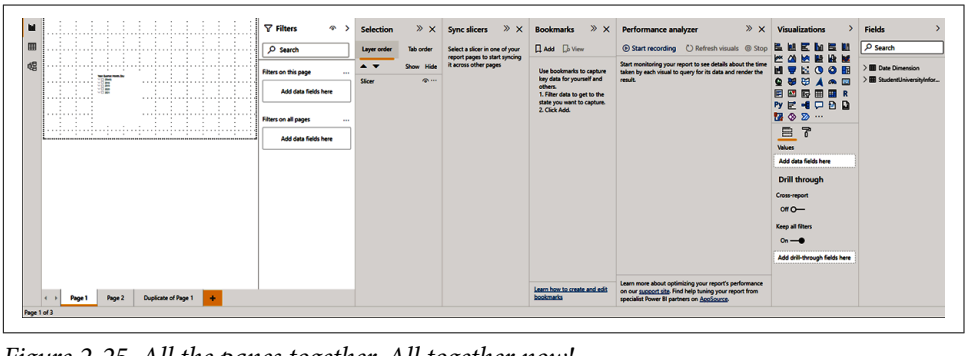


Figure 2-25. All the panes together. All together now!

As you can see, when all the panes are displayed fully, they don't leave you a lot of real estate to work with. However, only two are always visible: the Visualization and Fields panes. Further, the Filters pane is different in that it's more attached to the canvas than the other panes, since it dictates how items on the canvas behave.

Visualizations Pane

The Visualizations pane is where you choose visualizations to add to a report, add columns and measures to display in those visuals in the Values subsection, and more. Let's go through the visuals list first, and then to the next subsection. The visuals are listed in order from left to right, top to bottom:

- Stacked bar chart
- Stacked column chart
- Clustered bar chart
- Clustered column chart
- 100% stacked bar chart
- 100% stacked column chart
- Line chart
- Area chart
- Stacked area chart
- Line and stacked column chart
- Line and clustered column chart
- Ribbon chart
- Waterfall chart
- Funnel chart
- Scatter chart
- Pie chart
- Donut chart
- Treemap
- Map
- Filled map
- Shape map
- Azure map
- Gauge
- Card
- Multi-row card
- KPI
- Slicer
- Table
- Matrix
- R script visual
- Python script visual
- Key influencers
- Decomposition tree
- Q&A
- Smart narrative
- Paginated report
- ArcGIS Maps for Power BI
- Power Apps for Power BI
- Power Automate for Power BI

That's a very large number of visuals out of the box, and it can seem overwhelming. I promise it's not as bad as it looks, and some of them might be items you never use.

Be aware that if you have any custom visuals or imported visuals in your Power BI report, they will appear beneath this list, above the Fields and Format buttons that we will discuss next.

Between the visualization list and the Values subsection are two buttons. The left is for Fields, and the right is for Formatting. Each visual's subsection is going to look slightly different, as they accept different parameters. A column chart and a line chart might look similar, but a column and line chart are going to have multiple areas to put fields, for instance.

Likewise, the Format pane is also going to have different parameters based on the visual, as each visual has something unique about it to format. However, there are some constants. You'll also note that when you have a visual selected, a third option will appear in this area as well. That's the Analytics button. It's important to understand that this function works only with the visualizations built into Power BI by default, and even then, they aren't available for every visual. However, you can do things like set trend lines, constant lines, averages, etc.

What's important about this subsection is that you should feel free to explore the myriad of settings available. If you aren't sure, let Power BI do the work for you with its default settings. When you're ready to take a little more control, the Format and Analytics subsections give you the abilities you'll need.

The final area of the Visualizations pane is the "Drill through" subsection. This is a powerful feature that allows you to drill down from one subsection of your report to another, while keeping all the data elements filtered as you had them previously—enabling you to quickly develop a story with data that allows users to find specific examples that are relevant to their analysis.

Fields and Filters Panes

The Fields pane contains a list of all the tables, columns, and measures in your report. Beyond that, it will also contain any folders you might create, as well as any hierarchies or groups you may define in your data model. Adding these items to your visuals is as easy as clicking and dragging the column or measure to the appropriate area of the Visualizations pane or onto the visual itself on the canvas. You can also click the check box to have Power BI move the item into your selected visualization. Or if you don't have one, Power BI will put a visualization on the canvas for you with that chosen data element.

If you right-click a table in your model, you'll get a context list for adding a new measure, a new calculated column, a new quick measure, refreshing the data, editing the query for that table in Power Query, and more.

If you right-click a column in this area, you'll get a context list for checking it to your canvas, creating a hierarchy from that first column, adding a new measure or column,

adding the column to your filters list, or adding it to drill through. You'll also have the option to hide it from sight in case you don't want that data element used at that time.

The Filters pane has three subsections. You've likely used filters already, but a *filter* is a function that sets a condition by which the data must be true in order to be displayed. For example, if I have a filter of an age bracket and select the grouping from 12 to 18 years old, that is all the data I would see. All other data would be ignored.

On the Filters pane, when you have a specific visual selected, it will allow you to apply filters to that specific visual.

"Filters on this page" filters all visuals on that specific report page.

"Filters on all pages" sets a filter condition for the entire report.

By default, any fields that are in a visual will also show up in the Filters pane in the "Filters on this visual" subsection and can be interacted with there.

You can set three common filter types in the Filters pane, each with its own behavior. The basic filtering displays all the values for the given column and allows you to select any number of those values to be true. It's very straightforward. The advanced filtering offers you a combination of two separate and unique conditions with logic available based on the type of data the column represents:

- Contains (text)
- Does not contain (text)
- Starts with (text)
- Does not start with (text)
- Is (all)
- Is not (all)
- Is blank (all)
- Is not blank (all)
- Is empty (text)
- Is not empty (text)
- Is after (date)
- Is on or after (date)
- Is before (date)
- Is on or before (date)
- Is less than (number)
- Is less than or equal to (number)
- Is greater than (number)
- Is greater than or equal to (number)

Most of these conditions are clear-cut, but it's important to remember that you must put the value into the subsection yourself, unlike with basic filtering, which allows you to see a selection of values. You can then select the button to make an and/or condition and set a second logic set. You don't need to set a second logic condition to use advanced filtering.

The third common filter type is a Top N–type filter. Here you can set the number of top or bottom values you want to display by a certain value in your model that can be, but don't have to be, in that visual.

A classic example of this would be to see your top 10 sales clients by state, country, revenue, or volume. You set the number of values to display and whether you want the top or bottom values for that specific field in the visual. You will note that Top N is not available when filtering for an entire page or report. Top N filtering works only when used at the visual level.

Dates also have two other possible types of filters that can be utilized: relative date and relative time.

Relative time will show only if the date field has a time component as well. These filter options allow you to set specific time intervals for a visual or for the report, like the last 10 days or the next week or the last year. Relative time allows you to get into this level of detail with hours and minutes.

A Quick Rundown of the Other Panes

Four panes are not visible by default, but you can turn them on in the View tab, and they'll appear in whatever order you add them. These are the Bookmarks, Selection, Performance analyzer, and Sync slicers panes (Figure 2-26).

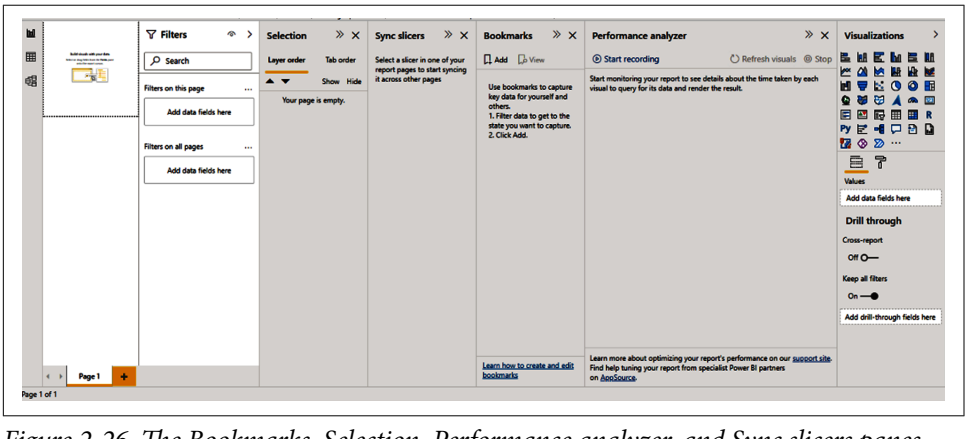


Figure 2-26. The Bookmarks, Selection, Performance analyzer, and Sync slicers panes

The Bookmarks pane allows you to save filters, drilling, and other conditions you may have set for a given report page, like a bookmark that you can return to. Let's say, for instance, we have an example of our report page that shows all the data, but we would like end users to be able to quickly change the report to a specific filtered view. We can use Bookmarks to toggle the conditions of the page from one point to another.

The Selection pane allows you to quickly manage visibility and layering order of objects in the report. Say you have a logo that you want to appear in a very specific location on the report at all times, but as you put visuals onto the canvas, the logo gets

covered up by the visual's box, even if the portion of the box that's overlapping the logo is blank. Well, to fix that, you would want to bring the logo to the front, and you can do that and manage your entire layering order from this menu. You can also group objects to be treated and moved together.

The Performance analyzer helps you, when you're ready, to troubleshoot why something in a report might be taking longer to display than you think it should or why it loads slower than it perhaps did in the past. You can use the Performance analyzer to gather information around how many milliseconds it took to generate the DAX query, visualize the results, and other items, including the DAX that Power BI generated to create the visual. While machine-generated DAX isn't always the easiest to learn from as a beginner, when you have some DAX experience under your belt, it can be useful to know all the filter and row context to see how Power BI generates the appropriate code to power the visualization. Likewise, when your report is having issues, you can test different configurations to see if your report performance improves or degrades.

The last pane to discuss is the "Sync slicers" pane. When you put slicer visuals onto a report, they function only for that page. However, with the "Sync slicers" pane, you can select a slicer and add it to other pages and sync them—so that when the slicer is changed on one page, that slicer changes on all the other pages.

This can be great for exploratory analysis, when someone is looking at the data and they find, for example, a specific company they want to home in on. If they set that filter in one portion of the report, this will carry that slicer selection to all the other pages that also have that slicer. You even have control to say it should sync on Page A, but not on Page B, for instance.

Data View

The Data view allows you to see the table-level data inside your report. It will display the columns in your report in their ordinal order instead of their alphabetical order. The *ordinal order* is the order of the columns from the data source or, in our case, the order of the columns as they appear in Power Query before being loaded into our data model. Let's take a look at my sample Date Dimension table to see what an entire table looks like in the Data view in Figure 2-27.

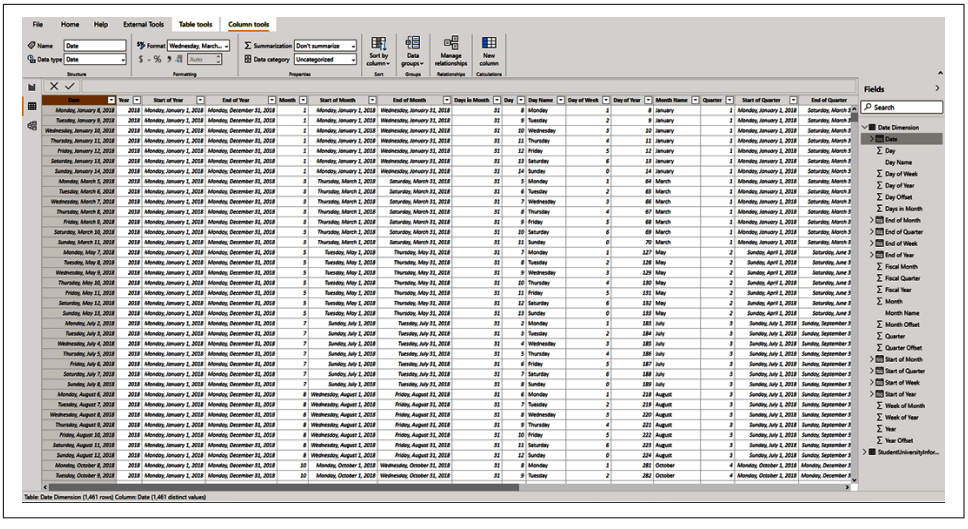


Figure 2-27. An example table in the Data view

First, you'll note two new subsections of the ribbon to interact with. The "Table tools" tab of the ribbon will show up when you have any table or column selected in the Fields pane. The "Column tools" tab will appear only when a specific column is selected. These tabs are completely contextual. Let's see that by zooming into Figure 2-28.

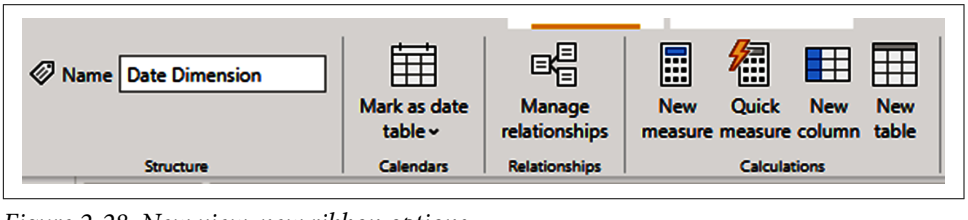


Figure 2-28. New view, new ribbon options

The Table Tools subsection allows you to change the table name or mark it as a date table, or we can look at our relationships here in the same way we did from the ribbon as discussed previously. In addition, we have our calculation options for creating measures and tables. Not too much here is new, and this view also shows up in the Report view when you have a table or column selected.

The one thing that is unique here that's worth discussing is the "Mark as date table" function. By default, behind the scenes, Power BI creates a date table for every instance of a date field in your data model that contains all the dates between the first and last date for that field. It does this so it can put together date hierarchy functionality and some other necessary functions behind the scenes.

In a small model, this isn't a big deal. However, when you start to get large models with dozens or even hundreds of hidden date tables, your model can start to grow very quickly. Power BI allows you to bypass this process by setting a date table in your model to serve that purpose for all those other dates. Since I have a Date Dimension table, I'm going to do exactly that.

When I have a column selected, I can also see the "Column tools" tab, as seen in Figure 2-29.

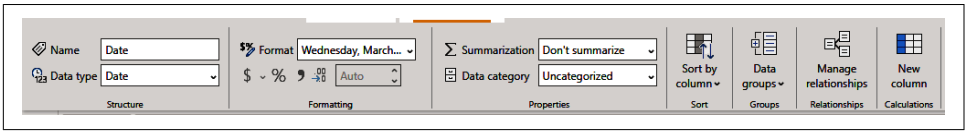


Figure 2-29. "Column tools" tab

Starting on the left, I can see the name of the column and its data type. In this case, I'm looking at the Date column, and it has the Date data type that is different from the Date/Time data type. I can select how I want the data to be formatted when it is brought into a visual. Given that it is a date, I can select a drop-down and see a variety of options.

If I have a column with numbers selected, I can choose to show the value as currency, a decimal number, whole number, percentage, or in scientific notation. The General option will default to the way the data is stored in the data model. There are grayed-out options for currency, percentage, showing commas in values, and setting the number of decimal places for a value since the selected data in Figure 2-29 is not a numeric data type.

Next, in the Properties subsection, you can set the properties of that column for its default summarization and how Power BI should categorize that data. By default, nonnumeric columns are not summarized. However, you can set a default summarization for any column or count or count (distinct). The default summarization for numerical columns is set to sum; however, this doesn't always make sense. The default summarization options are sum, average, minimum, maximum, count, and count (distinct). You can always set any column to have no default summarization by setting it to "Don't summarize."

The Data category is a description of the context for that data. By default, most columns are not assigned a data category and are left uncategorized. For numbers, there aren't very many options, unless you want to set a numerical value to be recognized as, say, a postal code or a barcode value. Dates do not have any data category options. Text, however, has a great number of options, and having these selected for appropriate columns can make working with that data in certain visualizations much easier. These options are Address, Place, City, County, State or Province, Postal code, Country, Continent, Latitude, Longitude, Web URL, Image URL, and Barcode.

The next subsection is "Sort by column." This is hidden away, but it's a jewel of a setting. This allows you to set a rule for a column in terms of how it automatically sorts itself when put into a visual. I have some example data for a fake university, Cool School University. This data is specifically for ISOM (Information Systems Management) 210 Introduction to Data Visualization. What if I want to sort one column by another value? Like sort last names by their Student ID number? That's what "Sort by column" allows you to do.

Data groups allow you to put combinations or bins of data together for quick analysis. Some obvious examples of this are age brackets or ethnographic groupings. However, you can probably come up with a ton of ways to create groups. Have a complicated product list? Group them into more manageable ones. Want to separate a certain patient condition from others as a control group? Group them specifically.

Conclusion

Hopefully, in this chapter you've gained a better understanding of the UI for the Report and Data tabs by using the ribbon and the panes in that interface. We've seen there are a ton of ways to interact with our data in the Data view that will be helpful to us later. However, we must get data into our Power BI file before we do anything else. To that end, in the next chapter we'll discuss bringing data into our model and how we use the Model view.

CHAPTER 3

Importing and Modeling Our Data

In the previous chapter, we went into detail to help you understand the UI functions of the Report and Data views. This chapter deals with the UI of Power Query and the Model view. By the end of this chapter, we'll have imported the mockup class data into a Power BI Desktop file and used that data to demonstrate some of the basic capabilities of Power Query for data manipulation and shaping.

In our discussion of the Model view, we'll demonstrate what relationships are in a data model and what they do. Finally, we'll go through the data and actively try things with it. If you're a hands-on learner, I highly recommend you take the sample data and follow along with me to try to replicate the steps and results.

Getting Our Data

For the purpose of this exercise, I'll be working from three Microsoft Excel files that can be downloaded from *https://oreil.ly/MS-power-BI-files*. We'll place ourselves in the shoes of a data visualization course instructor at Cool School University. We have files representing the information the school has given us, the information we've acquired ourselves from our pupils, and the students' grades on their assignments.

Starting from the Home tab on the ribbon in the Report view, let's use the Excel workbook shortcut and bring in our first file, called *School Supplied Data*. When we click the "Excel workbook" button, Power BI brings up an Explorer window to navigate to the Excel file. Select the file and click Open.

A Navigator window pops up that will generally look like the one in Figure 3-1. I say "generally" because when you're using a database as a data source, you'll probably see a larger number of selectable data elements based on your access level to the database. When connecting to an Excel workbook, you should see all the worksheets in the workbook. When you select a data element, in our case Sheet 1, from the drop-down menu, a preview of the data will be displayed, as shown in Figure 3-2. Notice that I clicked the square next to Sheet 1, effectively selecting it for import. Just so you know, you don't need to have the checkbox selected to see the preview.

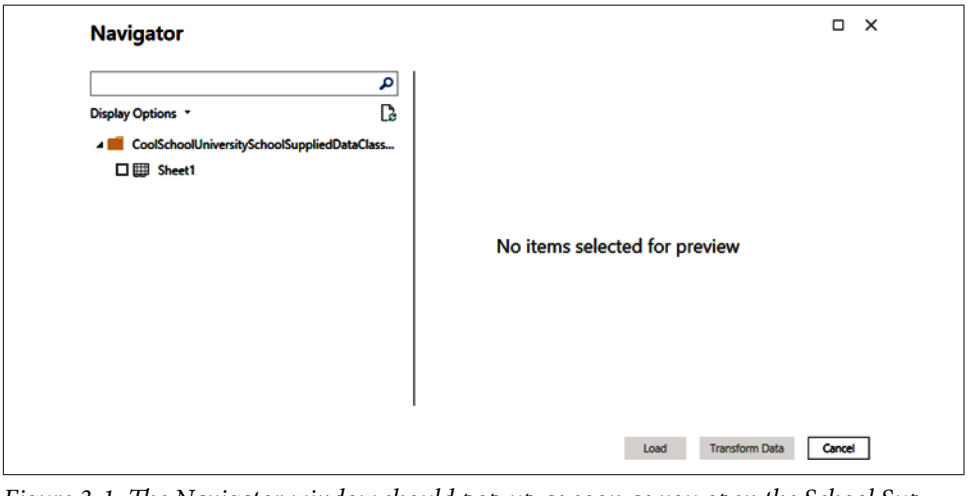
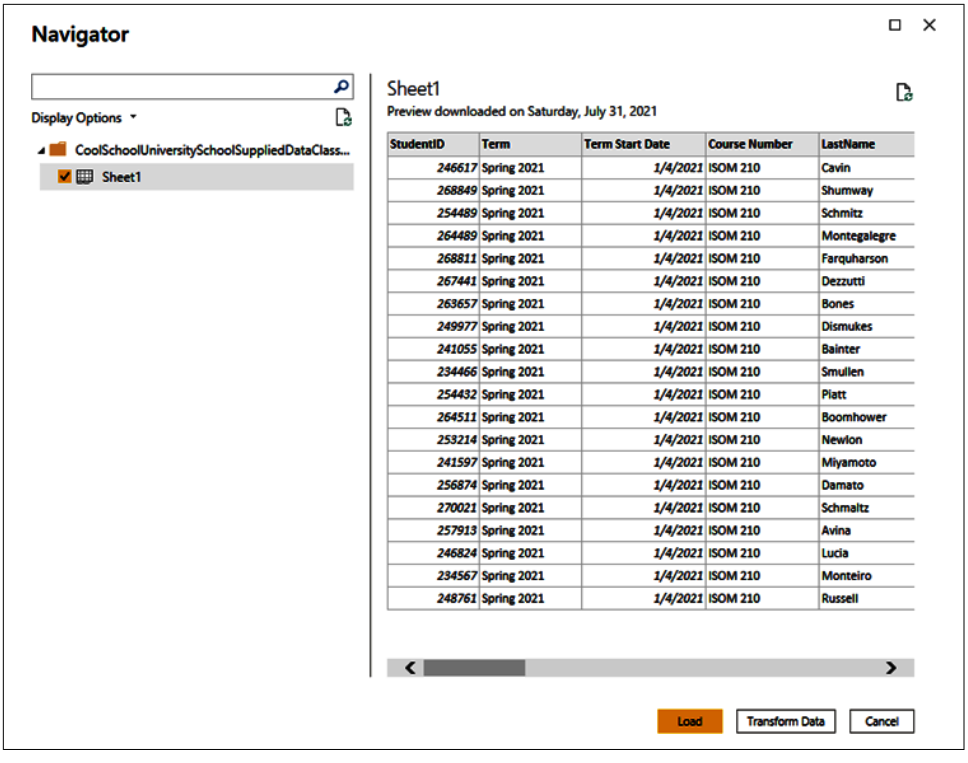


Figure 3-1. The Navigator window should pop up as soon as you open the School Supplied Data file

From here, I want to bring your attention to the bottom-right corner, where you can see that the Load and Transform Data buttons are no longer grayed out. This happens after a data element is selected by clicking the checkmark box. While this file has only one worksheet, if the file did have multiple worksheets, we could select multiple worksheets at the same time for importing. However, as I once learned from two wise bald men who conveniently live in cubes, always select Transform Data. Clicking Load will take the data exactly as the preview sees it and load it into the data model. Nothing prevents us from going back into Power Query later and manipulating the table, but once we choose Load, every other process stops for Power BI to bring in that data and put it into VertiPaq's storage.



StudentID	Term	Term Start Date	Course Number	LastName
246617	Spring 2021	1/4/2021	ISOM 210	Cavin
268849	Spring 2021	1/4/2021	ISOM 210	Shumway
254489	Spring 2021	1/4/2021	ISOM 210	Schmitz
264489	Spring 2021	1/4/2021	ISOM 210	Montegalegre
268811	Spring 2021	1/4/2021	ISOM 210	Farquharson
267441	Spring 2021	1/4/2021	ISOM 210	Dezzutti
263657	Spring 2021	1/4/2021	ISOM 210	Bones
249977	Spring 2021	1/4/2021	ISOM 210	Dismukes
241055	Spring 2021	1/4/2021	ISOM 210	Bainter
234466	Spring 2021	1/4/2021	ISOM 210	Smullen
254432	Spring 2021	1/4/2021	ISOM 210	Piatt
264511	Spring 2021	1/4/2021	ISOM 210	Boomhower
253214	Spring 2021	1/4/2021	ISOM 210	Newlon
241597	Spring 2021	1/4/2021	ISOM 210	Miyamoto
256874	Spring 2021	1/4/2021	ISOM 210	Damato
270021	Spring 2021	1/4/2021	ISOM 210	Schmaltz
257913	Spring 2021	1/4/2021	ISOM 210	Avina
246824	Spring 2021	1/4/2021	ISOM 210	Lucia
234567	Spring 2021	1/4/2021	ISOM 210	Monteiro
248761	Spring 2021	1/4/2021	ISOM 210	Russell

Figure 3-2. You'll see a data preview when you select a data element from the drop-down menu

My general rule of thumb is it never hurts to take an extra second, click Transform Data, and double-check in Power Query that the data is shaped and typed the way you intend. Let's see what happens when we click Transform Data in Figure 3-3.

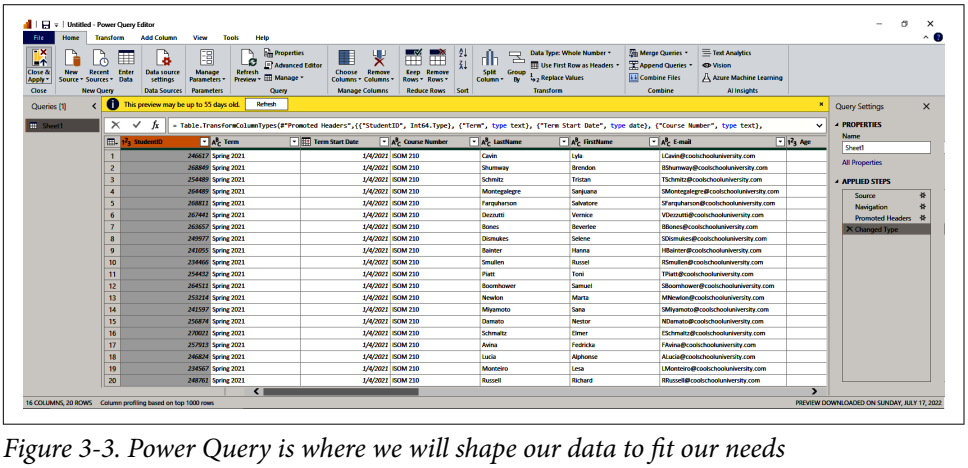


Figure 3-3. Power Query is where we will shape our data to fit our needs

A new pop-up window appears. It shows a lot of stuff: our prospective table (currently titled Sheet 1), a preview of the data, a whole ton of data transformation options, and the currently applied transformation steps to what Power BI is now calling a query. A *query* is a data element that is going to be imported into our data model.

Before we go into all the bells and whistles of Power Query, let's get our other two Excel files into Power Query and give them names that make more sense than Sheet 1 and Sheet 2. Without leaving the Power Query window, choose New Source → Excel Workbook and add *GatheredStudentInformation*. Done? Now repeat that to get our grades for the semester.

It's worth noting that when you add data sources from inside Power Query, the Navigator window will not show you the Load and Transform Data options. There's just a single yellow OK button and a Cancel button. Not to worry; when you click OK in the Navigator window from Power Query, it acts as though you chose Transform Data.

At this point, you've probably noticed that the *Grades* file is different from the first two! Sorry, I had to sneak in a bit of a curveball here. This file does, in fact, have two worksheets. We know from our earlier discussion that we can bring in both worksheets by selecting both and clicking OK.

But look at the GradeScores data preview, and you'll notice it has extra columns that are not named and are null. I intentionally messed with this file a bit so I could show you the Suggested Tables feature. In the Navigator window, you'll see a Suggested Tables drop-down. If you select it and preview the data, you'll see it looks correct without the extra null columns. Let's select the AssignmentDIM from the top and Table 1 from the bottom and bring those both in. If you can figure out what I did to mess up the Excel sheet, I'll give you 15 points. Unfortunately, much like the originally British and then American comedy show, *Whose Line Is It Anyway?*, the points are fake and don't matter.

Now, before we wrap up this section, let's rename the queries so they make sense. The AssignmentDIM kept its worksheet name, which is helpful, but we still need to rename the others. Remember the survey data came from the *GatheredStudentInformation* file and the school-supplied demographic data came from the *SchoolSuppliedDataClassStart* file. Rename those by either right-clicking the table in the Query view and selecting Rename, or adjusting the name from the properties window on the right side of Power Query with the query selected. Let's rename these "Demographic Data," "Survey Data," and "Grades."

If you did everything correctly, Power Query should look like Figure 3-4. If not, I suggest right-clicking each object, choosing Delete, and starting over to see if you can figure out where you went wrong. When you have it all together, click the Close &

Apply button to load the data. To come back to the Power Query window from the Report view, in the Home tab, click the Transform Data button. Once Close & Apply is hit, the data will get loaded and then compressed into the storage engine.

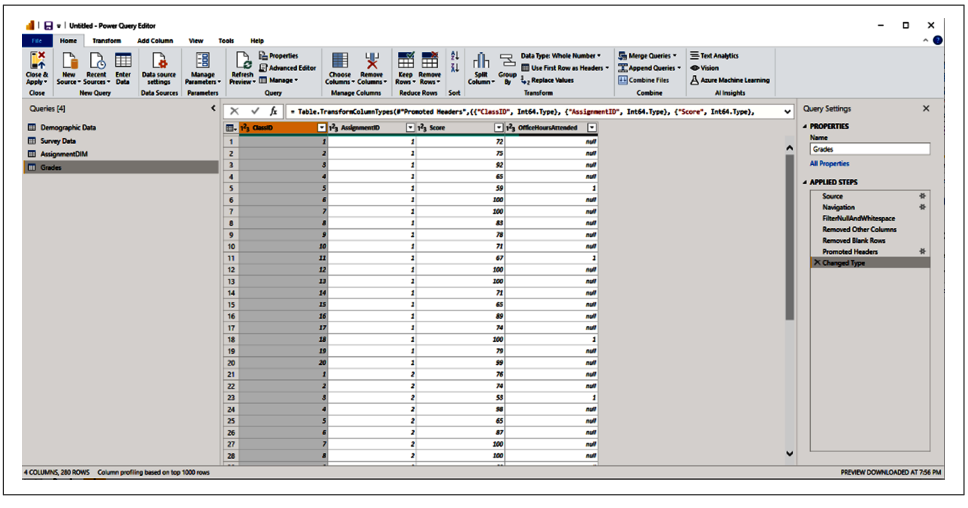


Figure 3-4. If you're following along at home, you should be here

The Power Query Ribbon

Now we've imported our data into Power Query, and just by clicking around the ribbon, you'll see there are many ways to transform your data. For this introduction, I'll be focusing on the Home, Transform, and Add Column areas of the ribbon of Power Query. If there is a data transformation you want to do, but you can't find it in the ribbon, you may be able to perform that via manual coding. That is beyond the scope of this exercise, but if you want to learn more about M, the Power Query language, you'll find Microsoft's documentation on the language at "Power Query M Formula Language".

Finally, before I move on, in the following section you'll note references to selected columns. You can select a column by clicking the column title. As you can see in Figure 3-4, I have the ClassID column selected. When you want to select multiple columns, you can select a column and hold down Shift and click to another column. This will select all the columns between those two columns. To choose columns individually, press Ctrl and click to select multiple individual columns.

The Home Tab

The Home tab in Power Query is, for the most part, straightforward. Looking at Figure 3-5, we can see all the icons in their groups, and we'll walk through them and give you some examples of their use cases.

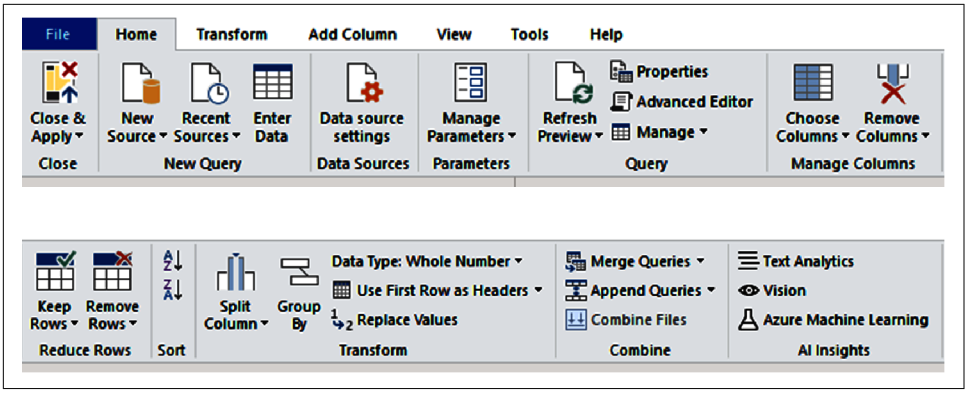


Figure 3-5. The Home tab is where the heart is…or would it be brain?

The Close & Apply button takes all the modifications you've made until that point and applies all the changes, refreshing any data elements that were impacted by the changes. If you click the drop-down arrow, you'll see a drop-down menu giving you three options: (1) Close & Apply; (2) Apply, which, as you might expect, applies changes but doesn't close Power Query; and (3) Leave, which does not apply any changes. If you choose to leave, Power BI Desktop will warn you that you have unapplied changes.

The New Query section allows us to bring in new data with the New Source button. Clicking its icon brings up the whole data source selection menu, whereas clicking the drop-down arrow generates a drop-down menu of the most common data.

The Recent Sources button allows you to quickly connect to any data source you have worked with recently, not just in your current Power BI Desktop file. This can be useful if you are doing testing and want to generate a second file and make quick connections, or if you are working on a new model and want to add onto it with something you've worked with previously.

Enter Data will bring up a rudimentary table structure where you can manually insert data and create column names. I don't recommend using Enter Data extensively, but it can be useful if you have disparate data sources to make a mapping table or a quick extra dimension that may not exist elsewhere in your data. While the interface for Enter Data may look very Excel like, it has no formula support and no data validation rules. It's just rows and columns, and the more data you put into it, the more you must manually manage. That's why I generally caution about using Enter Data if it all possible, but it's there if you need it.

The "Data source settings" button will bring up a window like the one shown in Figure 3-6. From here, you can change sources, export a PBIDS file (which you can imagine is basically a Power BI Desktop shortcut for that data source that you can open in a different Power BI file), edit permissions, and clear permissions.

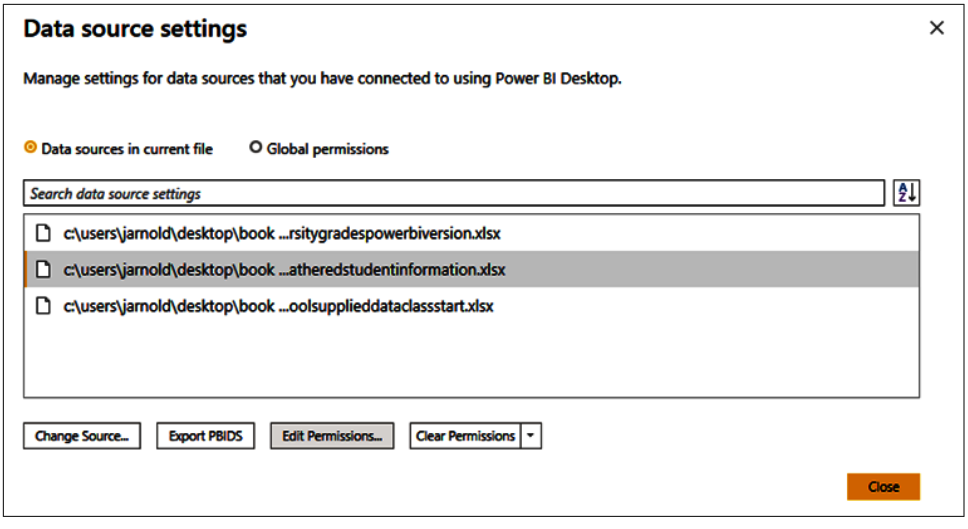


Figure 3-6. "Data source settings"—this area doesn't seem that important, until it is

Manage Parameters allows you to create, view, and edit all your existing parameters. *Parameters* in Power Query are values that can be called in specific contexts to change the way certain data is interacted with. Parameters have a multitude of applications that we will discuss later, in conjunction with what-if analyses, parameter rules in deployment pipelines, and more. For now, just recognize that there's power in parameters, and we'll return to this later.

The Query section of the Home tab allows you to refresh the preview, see the properties, open the Advanced Editor, or manage a query, the meaning of which isn't necessarily obvious.

The Refresh Preview button takes the query you currently have highlighted and gets an updated preview of the data for you to reference as you're working. This can be helpful when you have datasets that update frequently and you want to confirm that you are still getting your intended transformation behavior while that data is changing. You can also click the drop-down arrow to choose to refresh the preview of all the queries in your model currently.

The Properties button opens a dialog box that shows you the name of the query, the description of the query, and two selections to "Enable load to report" and to "Include in report refresh"; by default, these are always selected. There is nothing in the description window until it's added, so describing a query can be helpful.

When "Enable load to report" is turned off, that will treat the entire table as if it does not exist, and all visuals that rely on that table will break. Think of this sort of like a soft delete of a table from your data model. It's still here in Power Query if you want to reenable it, but otherwise Power BI treats it like it doesn't exist.

The "Include in report" refresh function is not quite as intuitive as it should be. If "Enable load" is turned off, you cannot include that table in the report's refresh. When this is disabled, it leaves the data as it currently exists in the model but does not update that query when data refreshes occur. I generally use this when a table is very large and I want to test some other changes in a data refresh without reloading the largest table. In other use cases, people will keep certain data at a point in time for auditing purposes and such.

The Advanced Editor is where you can see the actual M that is generated by every transformation you make! I personally think it's neat that there's a way to see the code generated when you make a change, particularly if you have any interest in learning the language yourself. M as a language, in my opinion, is easy to pick up but difficult to master. If you want to try modifying the M directly from the editor here, make a copy of your currently functioning code in a text file or other backup before making changes. The reason is that whatever changes you make and then click Done, that's what you'll get, whether your code is functional or not. A good rule of thumb is, as always in programming, make sure you have a backup!

Finally, the Manage button is poorly named. When you click this button, you'll see three options: Delete, Duplicate, and Reference.

Duplicating a query takes the query as it currently exists and duplicates it. This is straightforward and does, in fact, mean you are storing that data twice.

Reference does something a bit different. It makes a new query that looks at first like a duplicate, but it's not. It takes whatever query it is referencing, in whatever its final shape is, and allows you to work from there. If you should make changes to the parent query, the referenced query will change as well, and that could cause errors in that query, so be careful.

The Manage Columns area has two buttons: Choose Columns and Remove Columns. Both get you to the same place, but in different ways.

Clicking the Choose Columns icon will bring up a dialog box where you can choose which columns you want to keep in the query, discarding the others. Clicking the Choose Columns drop-down arrow allows you to go to the Choose Columns dialog box just mentioned or to go to a specific column in the query. This second feature can be useful when you have many columns in a query and aren't sure where it is in the column order.

Clicking the Remove Columns icon just removes the column. It does not give you a dialog box. It takes whatever columns are selected and throws them into the abyss. Clicking the Remove Columns drop-down arrow opens a menu offering a second option, to Remove Other Columns. This takes all the columns you don't have selected and throws them out.

The Reduce Rows section has two areas: Keep Rows and Remove Rows. Each has its own unique use cases around the top *X* number of rows or rows between numbers *X* and *Y*. One thing I do want to warn you about in this area is the ability to remove duplicates as shown in the Remove Rows section. It is important to know that it removes duplicates based on the columns you have selected. So, if you have only one column selected and remove duplicates, you might lose data that you originally intended to keep. The Sort section allows you to highlight a column and then sort in ascending or descending order. This does not work when multiple columns are selected.

Next, we get to the Transform section, which gives you some basic transformation options. Split Columns allows you to take a column you've selected and split it into multiple columns based on a delimiter of your choosing. A classic use case of this is a single-name column that has a first and last name, but you need them separated.

Group By allows you to create some sort of aggregation across your current query. This can be useful when, say, you have a large amount of data and you want to do some sort of preaggregation to reduce the number of rows. In Figure 3-7, you can see an example group using our grades data to get the average score per assignment.

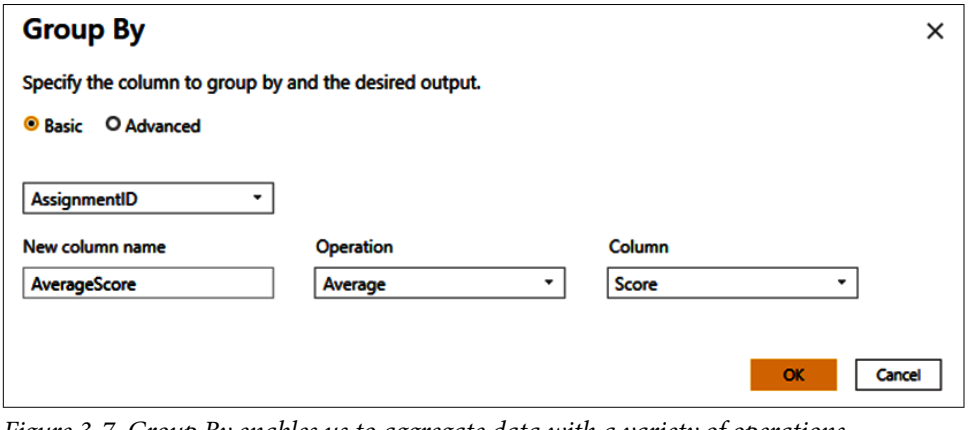


Figure 3-7. Group By enables us to aggregate data with a variety of operations

We can use the Data Type button to change the data type of a column that we have selected. There are many different data types, and Power BI will try to autodetect them when data is first brought in to Power Query. Power BI actually does a good job at detecting data types, but sometimes it's not perfect, so if you need to make a manual adjustment, you'll do that here. Coincidentally, you can see a column's data type by the icon in the column header, as well as a quick check.

Use First Row as Headers is pretty self-explanatory, and Power BI will often try to detect whether the first row comprises column headers, depending on the data

source. If you click the arrow next to the Use First Row as Headers button, you will also see an option to make your headers the first row instead, the inverse operation.

Replace Values allows you to find and replace values in a given column. A common use case here would be to either treat zeros as nulls or nulls as zeros, depending on your analysis. It's important to note that you cannot edit individual cells because cells are not a concept that is known to Power Query; it understands only columns.

The Combine section allows us to merge queries, append queries, and combine files. Merge Queries works like a SQL `JOIN` statement. Say you have Column A in Table A and Column A in Table B, and you want to add Column N from Table B to Table A. A `JOIN` statement says that where the value in Table A's Column A and Table B's Column A are equal, give me the Column N value and add it. We're doing the same thing here.

The intended use of Append Queries is to take multiple queries where the data is the same shape and format and to consolidate them into one longer query, more like a `UNION` statement from SQL.

Combine Files allows you to get ahead of the issue in Append Queries by precombining multiple files into a single view. If you should have columns that are unique to each table, this option will smash all of that together to get a single result encompassing all the columns and values between the two tables, so be careful when appending tables that you are getting your intended result.

Finally, the AI Insights section has items that your organization may use that allow you to connect to Azure AI services. Understand that these features require Power BI Premium to be used if they're going to be refreshed. It's quite probable your organization does not have these resources, so I'm not going to spend time on this except to say that they're there. Ask your Azure Administrator if the organization does use Azure Machine Learning studio or Cognitive Services to learn more.

The Transform Tab

The Transform tab contains some extra options for transforming your data beyond what we saw in the Transform section of the Home tab. However, just as we saw in the previous chapter, Microsoft does put some redundancy into the ribbon here, and I'll call out those situations specifically. But first let's take a look at Figure 3-8 to see the whole Transform tab.

First, in the Table section, we see Group By and Use First Row as Headers. These are self-explanatory.

Transpose takes your columns and makes them rows. Reverse Rows takes the order of your data by row and flips it so that the last record is first and the first record is last. Count Rows will show you how many rows you have in that query.

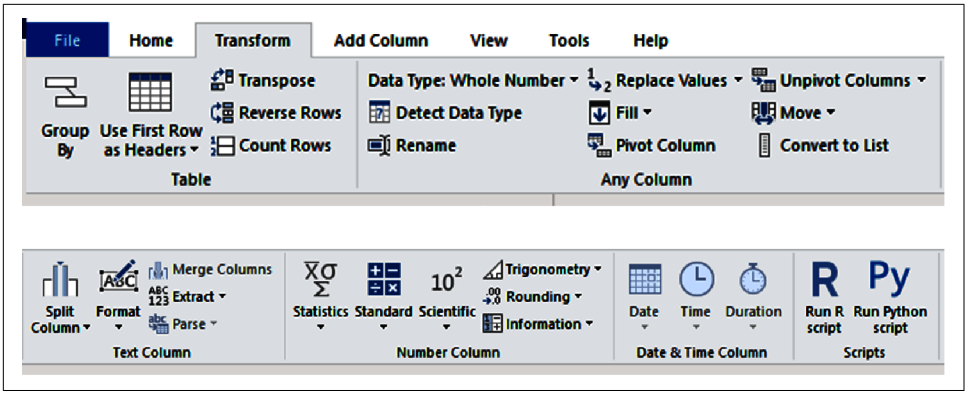


Figure 3-8. Transforming your data to more than meets the eye

The Any Column section provides the ability to edit a column's data type, as we saw previously. You can also replace values as discussed previously.

Unpivot Columns takes columns of data you select and reshapes the data into an "attributes" column and a "values" column. At times you may want to reshape your data in this way, like when you want to consolidate many columns into a smaller number of columns with a higher number of records.

The Detect Data Type button will go through each column and attempt to assign it an appropriate data type based on its preview of the data. Power BI will often do this automatically in the first pull of the data into Power Query, but you can have it do this again if you make a number of transformation changes that might change the data types of multiple columns.

The Fill button allows you to, either from the top or bottom, fill in missing values with a value based on other values in the column. I'll be completely honest, I've never once actually used this feature.

The Move button allows you to move the location of a column in a table. You can move it left, right, to the beginning, or to the end. You can do this with multiple columns selected.

Rename allows you to rename a chosen column.

Pivot Column allows you to take the values of a column, turn those values into columns, and recalculate values across the new combination. This can be useful when you have attributes in one column and values in another, and you want to see the values with the attributes as columns.

Convert to List is a unique function. It takes one column and turns it into a special type of table in Power Query called a *list*. Lists can be passed sort of like parameters to special custom functions. We're not going to worry too much about lists in this book.

The Text Column section is a bit strangely named because you can use these functions on more than just text columns. Thankfully, they are pretty straightforward for the most part.

Split Column allows you to take a column and split it into two columns based on a delimiter selection.

Format does not allow you to edit the data type. It does allow you to do things like making all the data lowercase or uppercase or adding prefixes or suffixes. Using this feature will turn that column into a text type column.

Merge Columns smashes two or more columns together, allowing you to choose a separator.

Extract allows you to modify a column or columns to keep specific characters in a column. I don't use this one very often, but when I have, I used it mostly to remove non-Unicode characters.

Parse does something different compared to everything else here. Parse takes a JSON or XML file, semistructured data, and puts it into a more classically structured format for analysis. We aren't using any JSON or XML files in our examples, but if you were working with NoSQL databases or getting results from API calls, you might need to parse that data before you could do analysis on it, and this parse function does that.

The Number Column functions can allow you to get statistics on a column as a separate value, perform standard calculations against a column to edit its values, apply scientific calculations against a column, perform trig functions against a column, round a column, or find whether a value is even or odd or its sign. With the exception of the statistics function, I recommend duplicating a column before applying any modifications to the data; then you can have both the original clean value and the modified value.

The Date & Time Column area functions in the same way as the Number Column, with numerous date and time transformations.

The final section in the Transform tab is the Scripts section, which offers the ability to run both R and Python scripts against your data. To use these functions, you must have R or Python installed, and Power BI has to know where your installation of those language libraries are. If you're more comfortable working with data frames in R or Python and would rather perform transformations there and use that as a single step, you can. You can also do pre-prep of the work in Power Query, apply a script task, and then make further modifications in Power Query. You can mix and match these functions, and if you wanted to use both, you could. Learning R and Python is beyond the scope of this book, but if you are going to pursue a career in data analytics, both of these languages could prove very useful to you.

The Add Column Tab

The first thing to note in the Add Column tab is that except for the General section, we have seen all the other functions in other places in the ribbon to this point. However, the General section contains so much that it still merits a section of its own. Looking at Figure 3-9 will make it a little clearer.

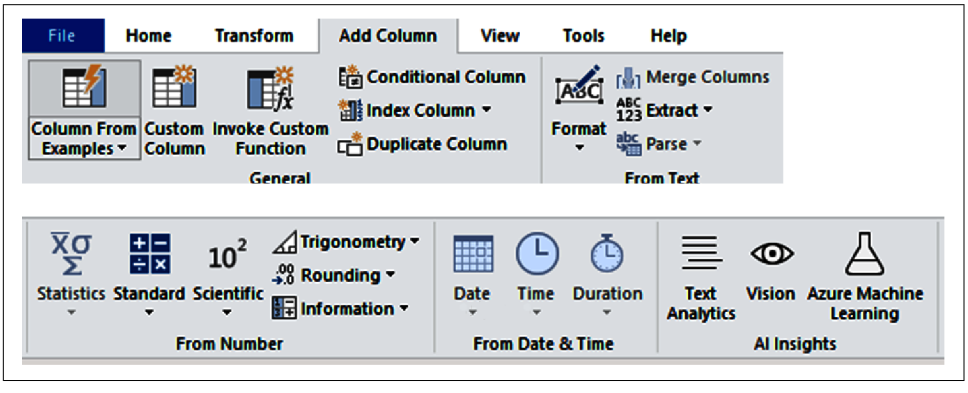
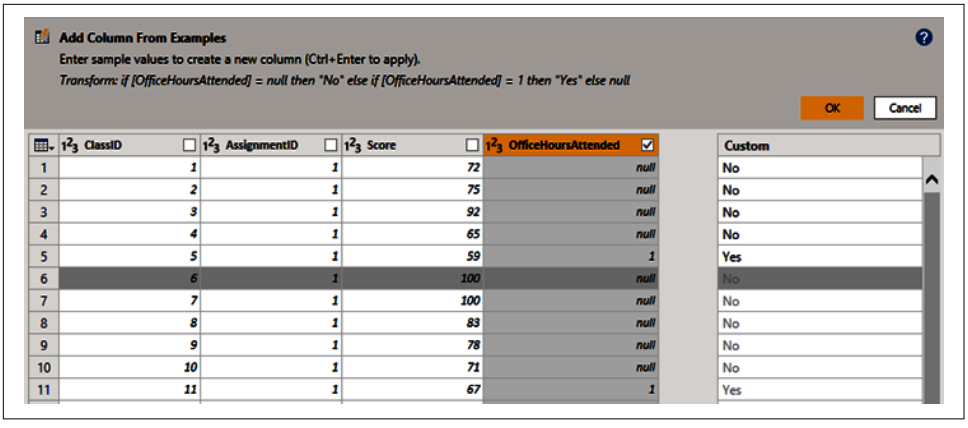


Figure 3-9. The Power BI ribbon will often have multiple places to find certain functionality, but at least they're topical

Column from Examples is actual, factual, black magic. You can select a column or columns to get pieces of data from. Then you'll have to give some examples of what the response would be, and Power BI will attempt to autofill the column as you provide examples to work from. In our Grades query, for example, I'm going to add a column from examples that will say if the OfficeHoursAttended column is null, then no, but otherwise, yes. We can see this in Figure 3-10, and you also have the bonus of seeing the logic it put together in M, which can be another way to see how the language handles different things.

Custom Column will bring up a dialog box where you can create a custom column using M. This can be useful if you have transformations that you want to do that maybe aren't supported by the UI or that you could do more efficiently via code. The dialog box will at least tell you if there is a syntax error in the code, but if you're just learning M, the errors aren't always super helpful.

Invoke Custom Function is an incredibly powerful tool that allows you to take a function and iterate over that function for a given column, finding a specific value and then applying some sort of logic. A simple example is creating a function that would make a new column and then take the value of one column and multiply it by another to get a third value that would be placed in this new column. Did you follow that logic? This is a very powerful tool, but it can also be hard to wrap your head around what it does the first time you work through it.



	ClassID	AssignmentID	Score	OfficeHoursAttended	Custom
1	1	1	72	null	No
2	2	1	75	null	No
3	3	1	92	null	No
4	4	1	65	null	No
5	5	1	59	1	Yes
6	6	1	100	null	No
7	7	1	100	null	No
8	8	1	83	null	No
9	9	1	78	null	No
10	10	1	71	null	No
11	11	1	67	1	Yes

Figure 3-10. A couple of examples of what I want, sprinkle in some AI, and voila, fresh column!

Conditional Column allows you to create a column along the lines of an if-then-else statement. If Column X is less than Column Y, then Yes, else No. You can also have multiple clauses for more complicated or iterative if functions. If you're familiar with SQL, think of this much like a case when statement. Figure 3-11 shows the dialog box for adding a conditional column.

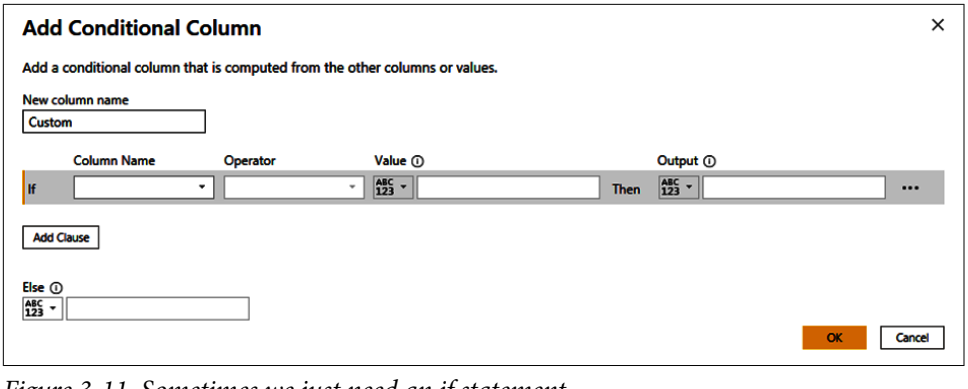


Figure 3-11. Sometimes we just need an if statement

Index Column creates a column that will start from 0 or 1 and create a unique list of values, usually corresponding to the row number. The most important thing about an index column is that it is completely unique and can be used as an impromptu key value if necessary, possibly merging that column with others to pass the index or key value to other tables for the purpose of creating relationships. Ideally, your data already has keys in place, and an index isn't necessary. But if you do need to create an index, it's very simple.

Duplicate Column takes the current column and makes a copy of it. That's it. No witty commentary on that one. It's just copy and paste.

Finally, I want to mention the View tab. The items on the View tab allow you to do some small customizations to the way you interact with Power Query. I want to highlight in the Data Preview section the Column quality, Column distribution, and Column profile checkboxes, as they'll allow you to see more detail around your data at the columnar level. This includes a percentage breakdown of valid, error, and empty values in a column, the numerical distribution of values in a column, and a distribution of data including the number of unique values in a column.

When you're done with all of your changes and you're ready to load your data with your changes, click that Close & Apply button. This will close your Power Query window and bring you back to the Power BI Desktop canvas.

The Model View

Returning back to Power BI, let's take a look at that third view in Power BI Desktop, the Model view. Why do relationships matter? What do they actually accomplish? Can I just ignore relationships and make one big table that can solve world hunger? We'll address these ideas in this section.

Let's take a quick look at the Model view of our current file in Figure 3-12.

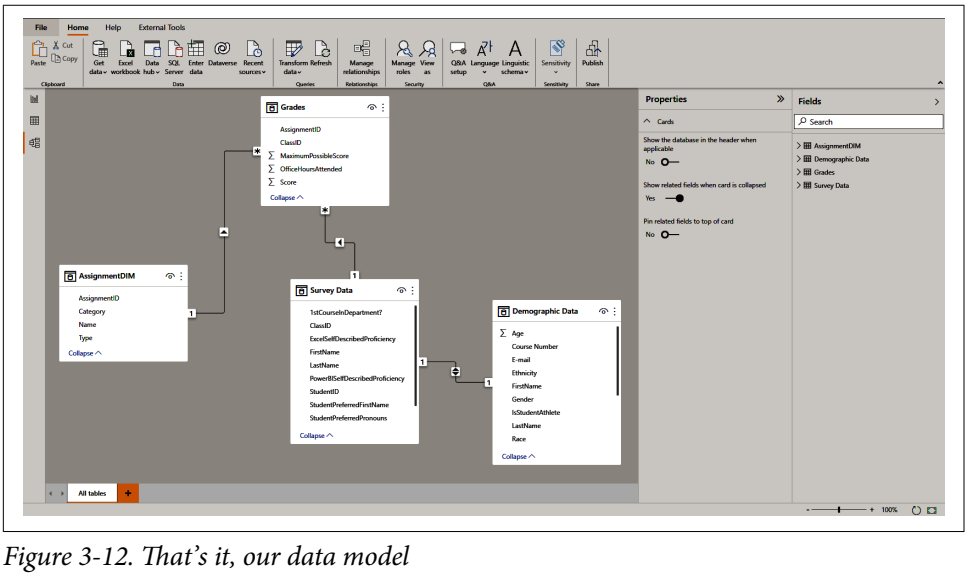


Figure 3-12. That's it, our data model

By default, Power BI will try to detect relationships when importing data and when the data is put together in such a way that Power BI will detect the relationships correctly. Unfortunately, it doesn't always do a good job of this. As a result, you should always double-check your relationships after you import data to make sure your model is constructed as you intended. Your model after your first import may not look like Figure 3-12 when Power BI first attempts to detect relationships and, as we will see here and in Chapter 6, the forms our relationships take really matters!

What Is a Relationship?

A *relationship* is, in the simplest terms, a way to tell Power BI which tables are connected and how. A relationship should be constructed so that the values in one column in one table match those values in another table, such that if we tried to query them, we could get back sensible results. A relationship is a combination of a few things—columns, direction, and cardinality. If we hover over the lines in our data model, they will glow yellow, and if we double-click that, we can see the relationship dialog box as shown in Figure 3-13. In this case, I'm demonstrating the relationship between AssignmentDIM and Grades.

Let's walk through this dialog box and talk about what we have. First, we see two tables are selected. In this case, because we chose the relationship from the Model view, it prepopulated the tables in question. You can see each table has one highlighted column. This is the column that forms the basis of the relationship.

Here we're telling Power BI the following: "When you have to run a query and pull data from both Grades and AssignmentDIM, you can join them on this column." This is critical in any database system, and Power BI isn't any different. Something that is different, though, is that I can't select multiple columns to have a relationship.

"But Jeremey!" I can already hear some of you yelling at the page, "I can write a SQL statement that has multiple join conditions between two tables!" Yes. Yes, you can. However, Power BI does not run SQL when it queries its internal database: it runs DAX. If you need to create a relationship between two tables with multiple columns, my suggestion is to create a column with a composite value of the columns you want to join in both tables and create your single relationship then, with your new concatenated column.

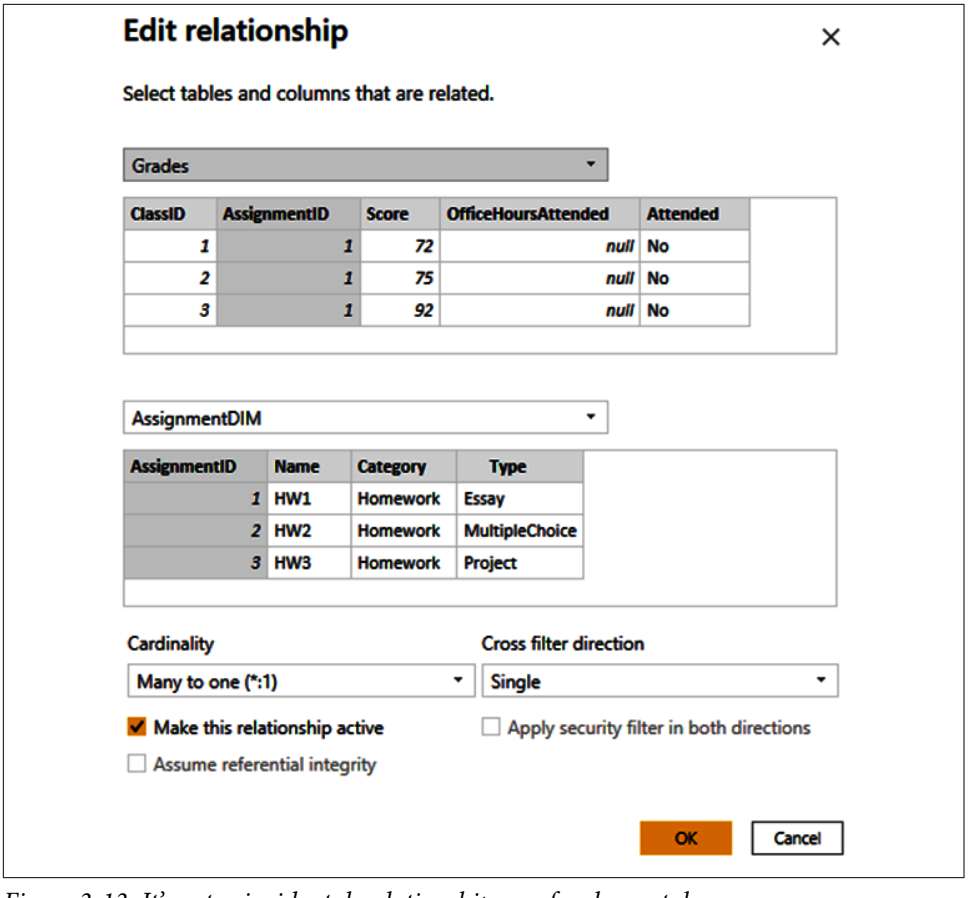


Figure 3-13. It's not coincidental: relationships are fundamental

Next, let's talk about cardinality and direction. These two things go hand in hand. We can create three types of relationships in Power BI: one-to-one relationships, one-to-many relationships, and many-to-many relationships.

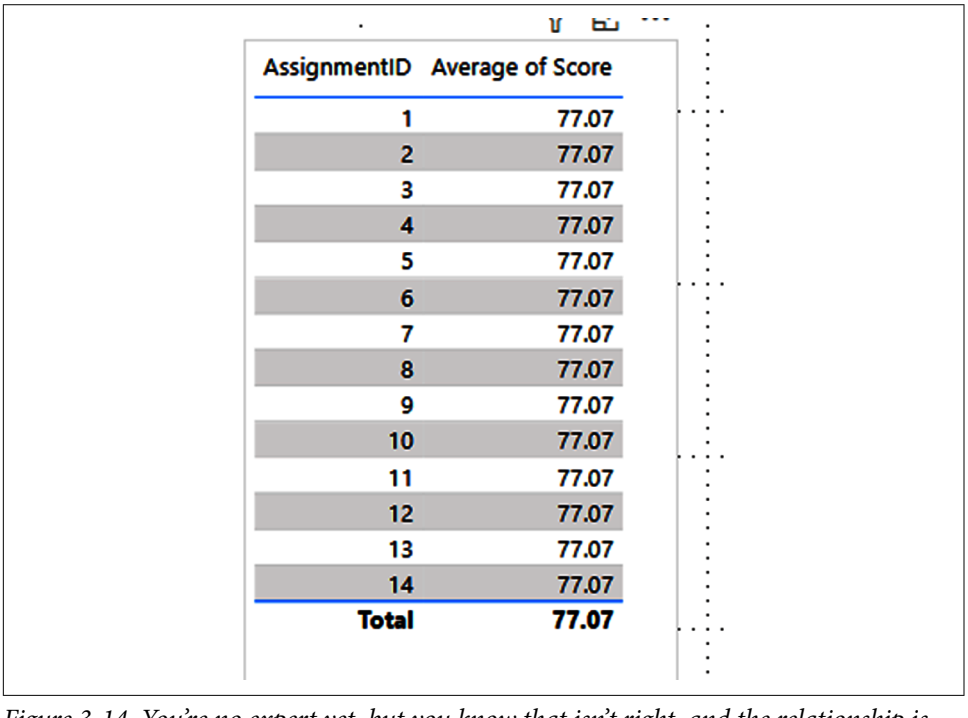
I don't like many-to-many relationships. The best practice when building a data model avoids many-to-many relationships wherever possible because they're not performant and can sometimes give you strange results compared to your expectations. Many-to-many relationships are more akin to a `FULL OUTER JOIN`, for you SQL people. You can quickly identify a relationship is many-to-many by looking at the line connecting the two tables and seeing if there are stars on both ends of the line.

In a one-to-one relationship, all the values in Column A of Table A are unique, and all the values in Column A of Table B are unique. You can quickly identify a one-to-one relationship by seeing the number 1 on both ends of the line connecting two tables.

In a one-to-many relationship, all the values in Column A of Table A are unique, but the values in Column A of Table B aren't unique. You can quickly recognize this type of relationship in your model by seeing that one end of the line will have a 1, and the other end of the line will have a star in the Model view. The benefit of both of these types of relationships is that I'm looking for one value and comparing those values in the other column, as opposed to looking for every copy of that value and comparing it to every other copy of that value.

When we discuss the direction of a relationship, we are discussing which table can filter the other. Can they filter both ways or just one? A one-to-one relationship by default has a filter direction of both. This can be seen in the middle of the line connecting two tables by having arrows pointing both directions. A many-to-many relationship can have only a filter direction of both. A one-to-many relationship defaults to a single filter direction, going from the table with the unique value to the table with the nonunique values. A single directional relationship can be identified because one arrow will be pointing toward the table that is being filtered.

Let's demonstrate a couple of examples to show what happens. First, I'm going to display a table that contains values from these two tables without any relationship at all, and then with the relationship in place, and then demonstrate how the direction functions. Figure 3-14 shows what happens with no relationship.

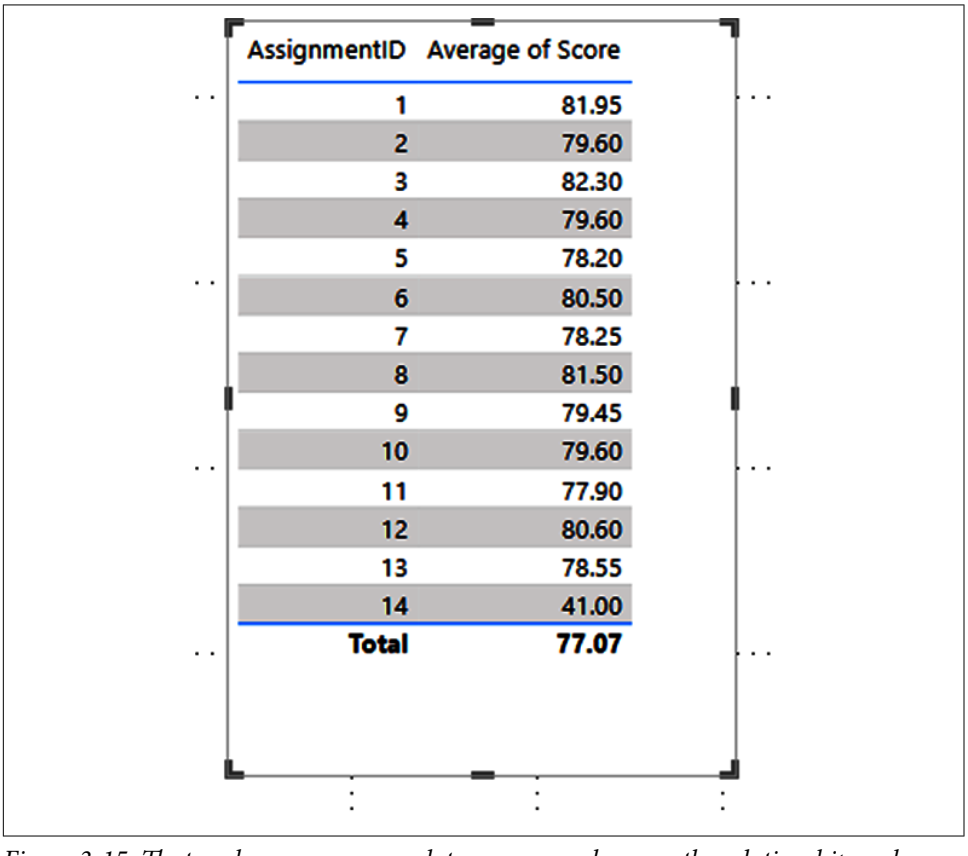


AssignmentID	Average of Score
1	77.07
2	77.07
3	77.07
4	77.07
5	77.07
6	77.07
7	77.07
8	77.07
9	77.07
10	77.07
11	77.07
12	77.07
13	77.07
14	77.07
Total	**77.07**

Figure 3-14. You're no expert yet, but you know that isn't right, and the relationship is why

Here, in Figure 3-14, I've taken the assignment ID code from the AssignmentDIM table and added the average of the score on those assignments. That 77.07 value is the average of the score across everything, but isn't the average score per assignment. Without any relationship, Power BI doesn't know how to generate a query that gets what I'm looking for.

Now let's add the relationship back in and see what we get in Figure 3-15.



AssignmentID	Average of Score
1	81.95
2	79.60
3	82.30
4	79.60
5	78.20
6	80.50
7	78.25
8	81.50
9	79.45
10	79.60
11	77.90
12	80.60
13	78.55
14	41.00
Total	**77.07**

Figure 3-15. That makes more sense, a lot more sense, because the relationship makes the internal queries functional

You'll notice that the total average is still correct; that value doesn't require any interaction with the assignment ID. However, for each individual AssignmentID, I can create a query that basically says, "Where AssignmentID = 1, ignore all the other values in the Grades table where the AssignmentID isn't 1, and then calculate the average score for just that AssignmentID, and then do that again for each AssignmentID." Relationships make this possible.

Now let's talk about filter directions. In Figure 3-16, I have a slicer (a type of visual that filters other visuals on the canvas by applying a set value or values to the other visualizations, like a `WHERE` clause in SQL) on score, and I'd like to see which assignment IDs had that score in it.

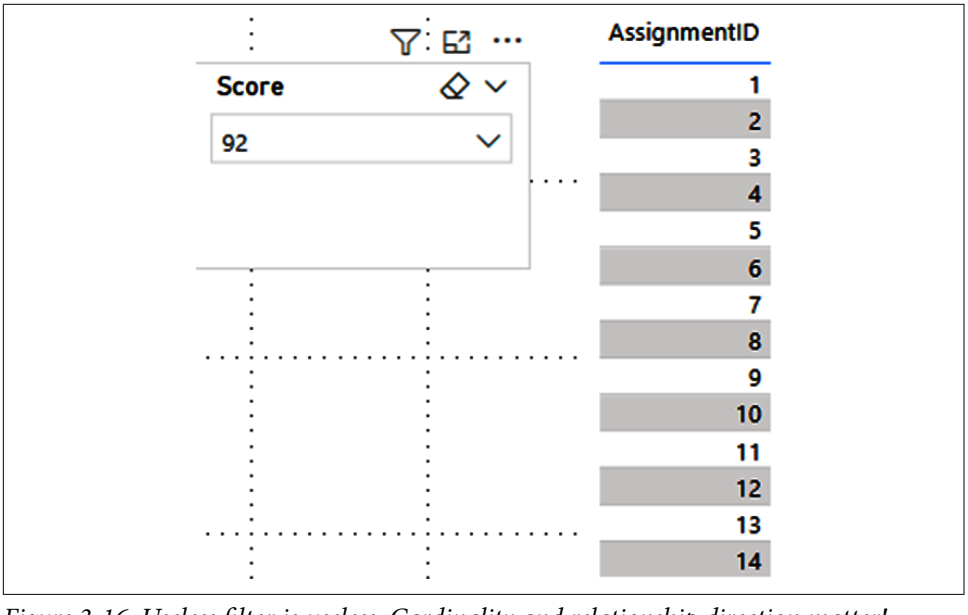


Figure 3-16. Useless filter is useless. Cardinality and relationship direction matter!

Remember, our data model has a one-to-many relationship between AssignmentDIM and Grades, and it filters in only a single direction, from the one in the AssignmentDIM to the many in the Grades table. So, the score from grades cannot filter AssignmentDIM.

Now, let's flip this the other way and put assignment ID on the slicer and the list of scores in the table, and see what we get in Figure 3-17. Then, in Figure 3-18, we can see what happens when the directional filter is set to both.

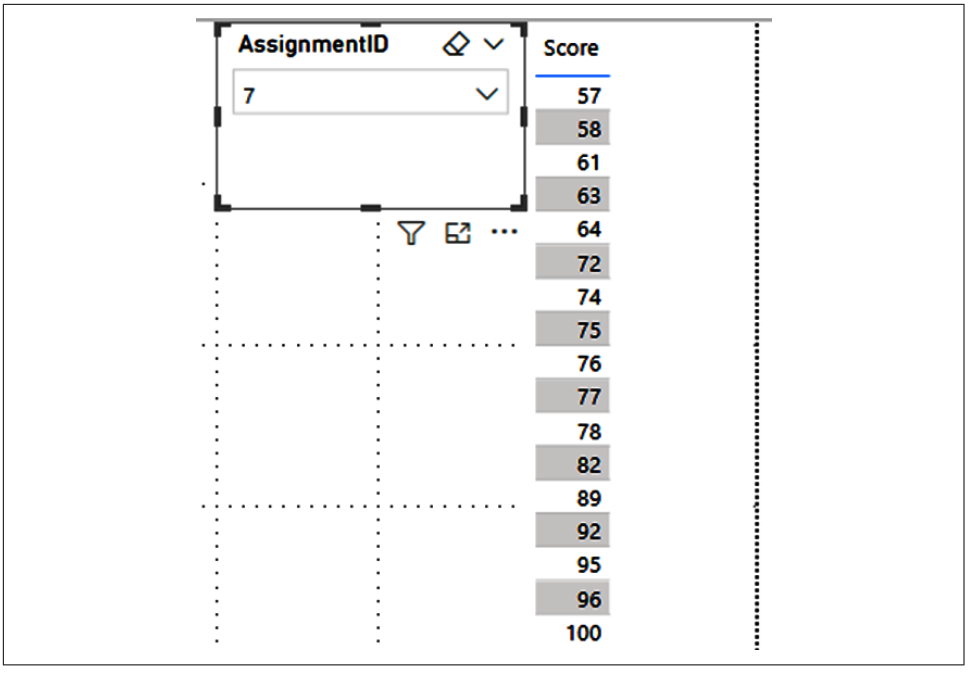


Figure 3-17. Useful filter is useful!

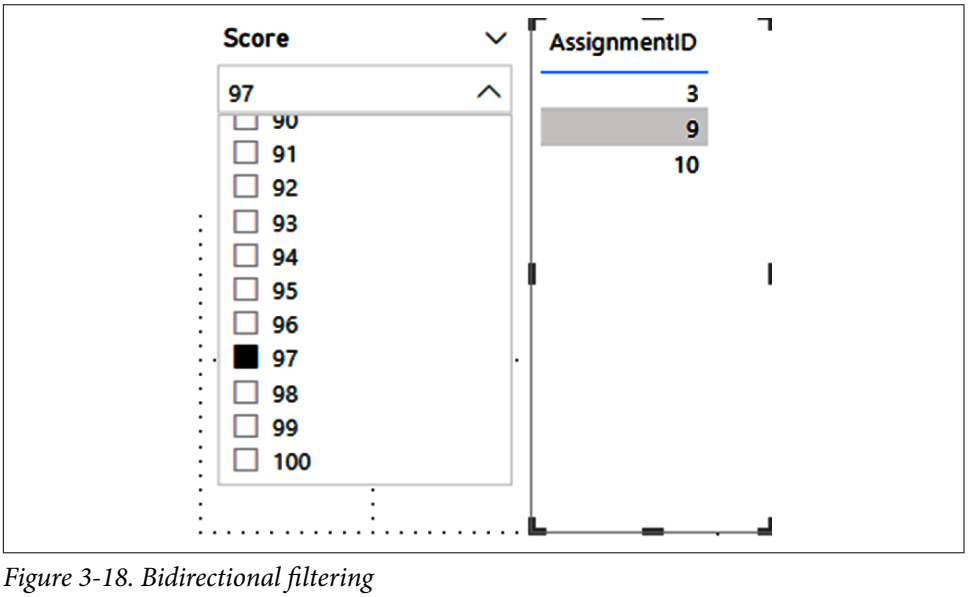


Figure 3-18. Bidirectional filtering

I can hear those cries from the ether again, "But Jeremey, if bidirectional filtering does that, why don't we just make that the default all the time?" The short answer is that it's not as performant, and you can create relationships where *ambiguity* can happen, which prevents other relationships from being used. Generally, the best data modeling practice would be a *star schema*, where you have a table containing your facts and then other smaller tables surrounding it, like a star that filters that table.

OK, well, what about that single table that solves world hunger? Wouldn't that be fine? Well, the short answer is no. A large single table doesn't leverage the benefits of a dimensional model approach, which has several data governance and ease-of-use benefits. Also, a single large table can quickly become unwieldy, as you create many complex edits in Power Query to facilitate the creation of that single table. It really is easier to deal with a table with 5 columns and a table with 10 columns compared to a single table with 15 columns.

In addition, single tables are more prone to breaking over single issues, as opposed to a multitable approach with multiple simpler items. If you are looking for the quick version of a good data model, it's a table that contains your facts, surrounded by tables that can filter those facts with multiple one-to-many relationships. If you're doing that, you'll be in good shape.

The Properties Pane

The Properties pane in the Model view is very contextual. You'll always find the Properties pane on the right side. Whatever data element you've selected will change the Properties pane to be relevant to the type of data object you've selected.

When a table is selected, you can see the Name, Description, Synonyms, Row label, Key column, the Is hidden flag, and the Is featured table flag. In the Advanced section, this pane will show the Storage mode. The Storage mode can be Import, DirectQuery, or Dual. Note that once something is in Import mode, it can't be changed. See an example of the Properties pane in action in Figure 3-19.

The Name field is straightforward. The Description will be blank and can be worth filling in with a summary of that table's contents or its purpose in your data model. The Synonyms are listed for the purpose of the Q&A feature, which we have touched on a little bit but will discuss in more detail later in the book. The Row label allows you to identify a column to serve as the assumed column when doing Q&A with a specific table.

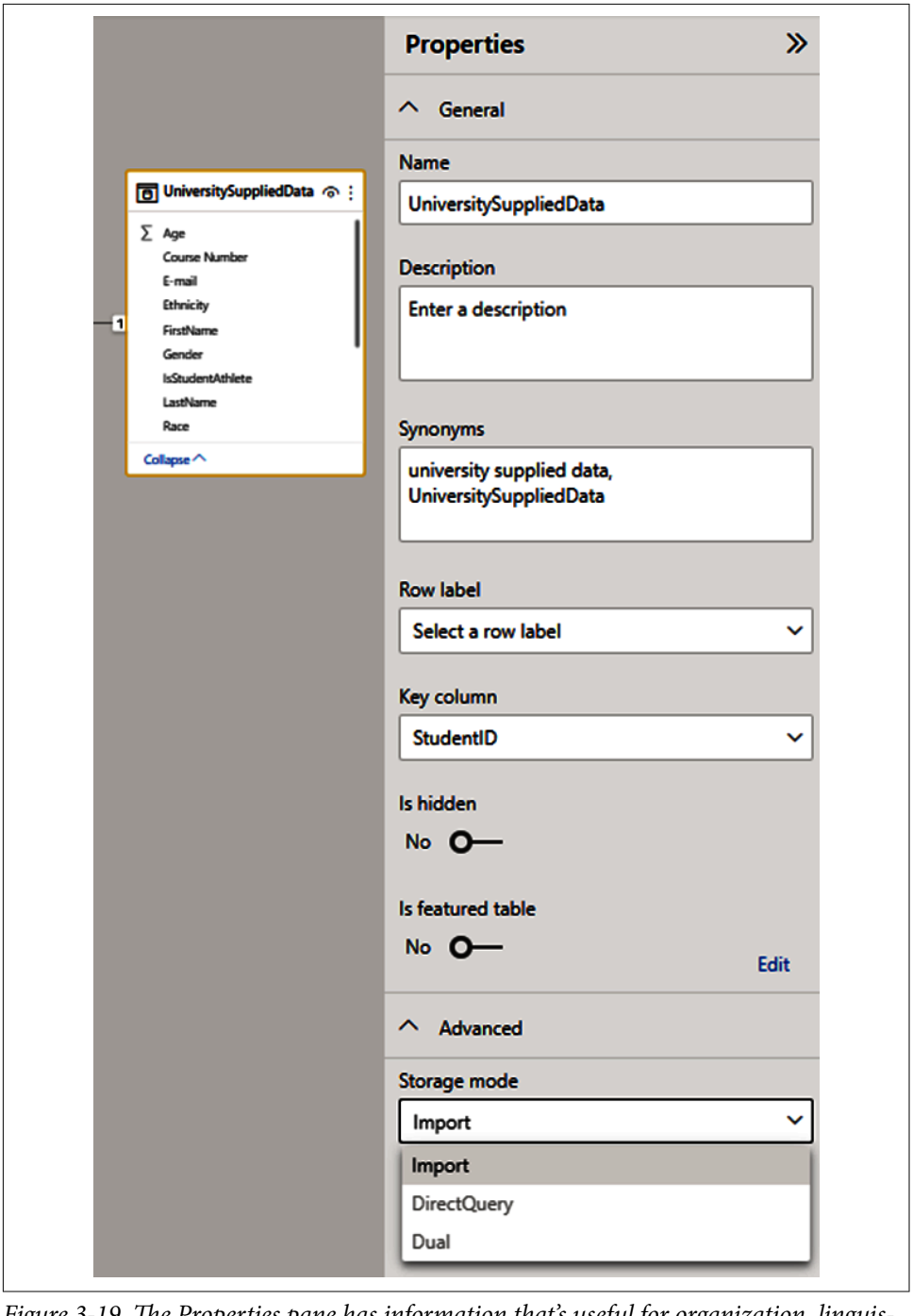


Figure 3-19. The Properties pane has information that's useful for organization, linguistics, keys, and a table's storage mode

The Key column allows you to identify a column that contains only unique values. I like to highlight the column that serves as the basis for that table's relationships with other tables. Also, when a column is identified as the key column, it will get a special icon next to it in the Fields pane.

If "Is hidden" is set to Yes, the table will be hidden from the Report view so that you can't add items from that table to report items. Note that if you already had objects created using that table, those objects will stay visible, but you won't be able to add data elements from that table to new visualizations. Finally, if a table is a featured table, people in an organization with featured tables enabled can search for this table from the Power BI service.

When an individual column is selected, you can see the Name, Description, Synonyms, Display folder, and Is hidden flags. In the Formatting section of the pane, you can see the column's data type and the data's format. Finally, in the Advanced section, you can select another column to sort by, identify a data category if relevant (think of these as identifications for very specific types of data that Power BI might need to use in very specific situations), and set a default summarization. You can also identify whether a column should be able to have null values in this section of the pane. All the guidance from our preceding table section applies, but I want to talk about display folders a little bit.

Display folders can be a great way to keep a data model clean by grouping data elements into a subfolder inside a table. No actual data is modified or manipulated here; this is strictly for visual cleanliness. You can also place measures into display folders, and I find this to be particularly helpful when I want to group specific items together that may not be convenient in the larger alphabetical sorting that Power BI does in the Fields pane.

Conclusion

So, to wrap up this chapter, we got a ton done. We took our first steps into Power Query, loaded our data into our model, have relationships to support our analysis, and now we can start creating our dashboard that will help us learn more about our students' performance over the course of the semester in our class.

To facilitate that, in the next chapter I'll be going into depth on the visualization options in Power BI and discussing use cases for each type of visual. We'll also practice drawing inferences from our data from these visualizations to learn a little bit more about the students. Great job following me so far. You are definitely on your way to earning a Cool School University sweatshirt.

CHAPTER 4

Let's Make Some Pictures (Visualizing Data 101)

Previously we discussed the basics of the Power BI user interface, touching on the Report, Data, and Model views, as well as Power Query. In the preceding chapter, we imported our first set of data from our Cool School University dataset.

In this chapter, we're ready to go over some basic ideas about why we visualize data. Then, using our data from the preceding chapter, we'll do a walk-through of the multiple visuals available by default in Power BI.

Why Visualize Data?

Imagine this. The year is 1950, and you're an accountant at a small manufacturing firm in the Midwest. You served in World War II as an accountant at the Department of War, ensuring those war bond funds were spent efficiently to help the Allied war effort.

To do all your work, you had a ledger book. That was it. So, every day you'd log your transactions from one account to another, making sure all the money was where it was supposed to be.

One day, the floor manager of the plant comes to the accounting office to ask you a few simple questions. "Hey, I'm curious. Which of our products actually makes us the most money? What about on a per unit basis? And are they the same product?"

Now, as a 1950s accountant, would you willingly just hand over your ledger book? Absolutely not. Never. The ledger book was an accountant's lifeblood, and back then someone would have had to pry it from your cold, dead hands before you'd part with it.

What you would do is, using the data compiled, put together a table that would show the list of products, the total profits by product, and the profit per unit for each product. One might call that table a very simple data visualization.

Now, for sake of argument, let's say that a different accountant (not you, you're too smart) would consider just handing over their ledger book, saying, "Sure. You can figure it out. Here's the record."

Would that make sense? No. It doesn't make sense for two reasons. First, the floor manager and their team aren't going to be as familiar with the data. They didn't compile it. They didn't do all the math, and they're likely not accountants. So, even if an accountant did hand over the ledger book, the floor manager and their team might have a hard time following the logic. Second, the accountant had already done all this work, so why would they ask someone to do it again? That's just not efficient.

Let's get back to our example and the data. We discover that widget A has the highest total profitability and widget B has the highest profitability per unit. The follow-up question becomes, "Is that true just for this year or is it true historically?"

I could create an even more complicated table. I could have columns for each year and do the calculation by product and put together a nice matrix. While some people can look at the matrix and follow along, some of our audience now isn't getting the impact of the data.

I want to make the data as comprehensible as possible, so I create a simple graph with an x-axis for year and a y-axis for profitability. I plot the points and draw a very simple line that shows the trend for those products, separating them into their own graph for clarity.

Which do you think will better stick in people's minds? The matrix or the graphs?

Answer this question for yourself. You've likely been in a meeting or presentation where someone showed data in the form of a long, drawn-out table, and maybe that's when you felt yourself start to drift off a bit. Another presenter showed data using graphs and images. Which one did you find more engaging?

I'm willing to bet that the overwhelming majority of people find the graph approach much more engaging. I feel confident of that because we are inherently drawn to stories. We're drawn to stories because we're more naturally able to take a story and learn lessons from it than we can from a list of facts.

The fact that we find it easier to identify with these anecdotes over hard data is taken advantage of. For example, it is possible you've had a bad experience with an undocumented immigrant. That anecdote left an impression and when a new organization pushes individual stories of misdeeds, it becomes easier to latch onto that qualitative story over the reams of data that shows that undocumented workers commit crimes at a far lower rate than native born citizens.

We have all sorts of biases that we must contend with, and we have to be able to view and understand the facts to overcome them. But if the choice is between data that tells no story and a story that serves our bias, the story that serves our bias will win.

Data visualization fundamentally uses that phenomenon of storytelling as teaching to our advantage. Data visualization uniquely triggers all three parts of the ancient Greek modes of persuasion: ethos, pathos, and logos. The art of doing the work to create the visualization demonstrates your mastery of the data, giving you an ethos credibility. Showing the data in the form of images that are easily understood and enable you to tell a story is the core of the pathos, or emotional appeal. Finally, the data itself, assuming it's been collected and managed properly, should only tell you the truth. At its core, the data elements are the facts, and the facts make the argument's logos appeal.

We visualize data because we are storytellers. We don't tell our stories from the whimsy of our imagination. We tell our stories from the facts, establishing our credibility and understanding of those facts. From there, we make that story as digestible as possible. And, again, the story is based on thousands or millions or billions of data points, not just a few anecdotes, which lends to credibility.

Remembering the adage that a picture is worth a thousand words, a good graph can be worth millions or billions of rows of data. You are a storyteller, and you're the best kind of storyteller, one who makes sense of what's really happening. Whether finding the answer or finding the truly important question that needs to be answered, storytelling with data visualization can help you get there.

So, let's talk about the visualization tools Power BI gives us to tell that story with our data. Think of these tools as the alphabet. Once you get familiar with them, you'll learn how to make words from them, then get to the point where you are telling stories with them, and, with time and practice, you'll figure out how to use each visualization to maximum effect. With that in mind, let's talk about where that all begins, the Visualizations pane.

The Visualizations Pane

The *Visualizations pane* is your go-to spot for adding visualizations, modifying them by adding the requisite data points, formatting your visualizations, or adding additional analytics capabilities that Power BI supports in some of these visuals. The Visualizations pane consists of three major parts: Fields, Format, and Analytics. See the recently updated Visualizations pane in Figure 4-1.

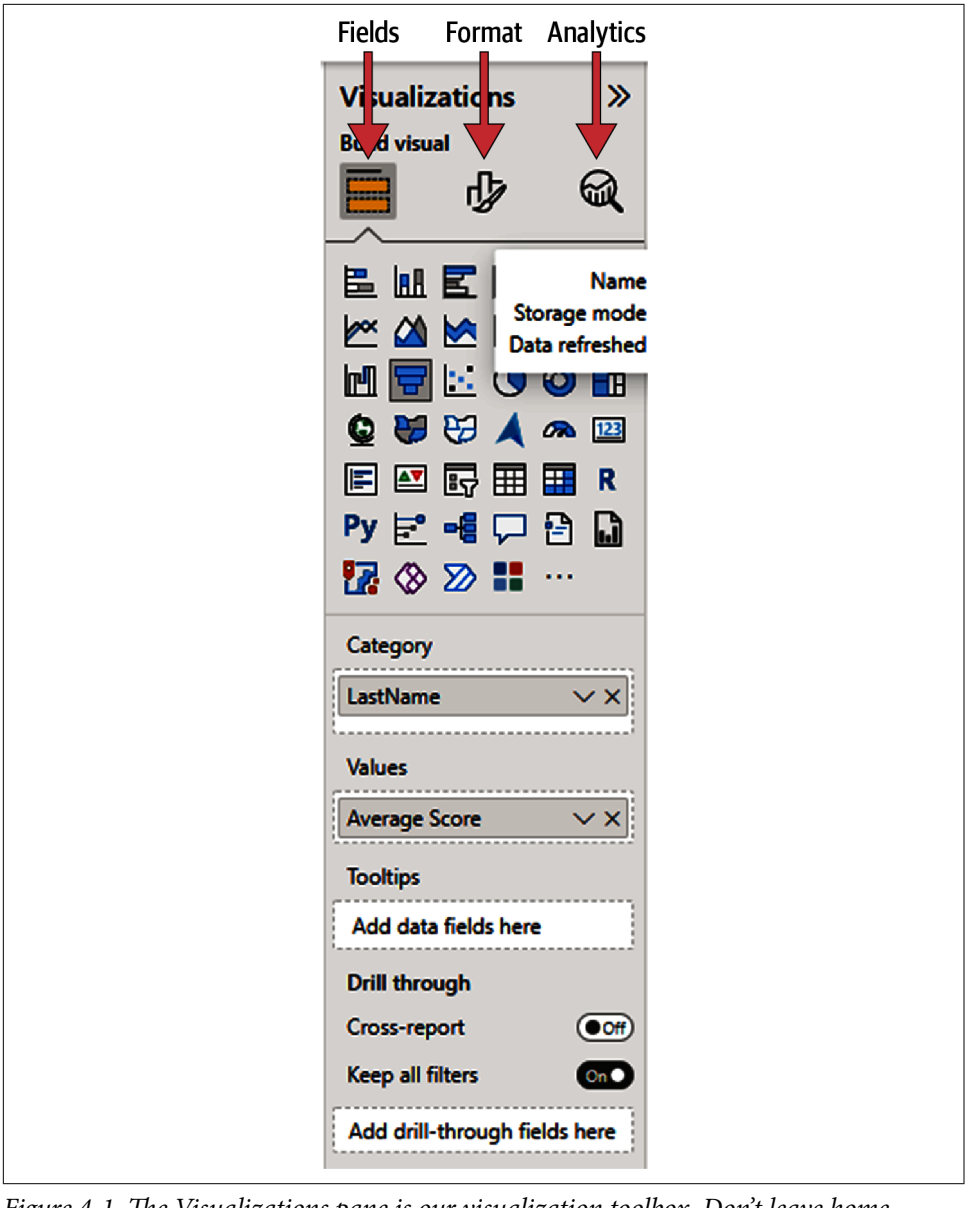


Figure 4-1. The Visualizations pane is our visualization toolbox. Don't leave home without your toolbox!

Fields

It's important to note that each visualization will look different from other visualizations in the Fields area because they all accept different inputs. A map visual isn't going to be the same as a bar chart, which isn't going to be the same as a matrix. If you have fields in a visual already and choose to change the type of that visual into something else, Power BI will try its best to reallocate the selected fields and measures to the new visual; but it's not guaranteed to work as you intended. You can change the type of a visual already on the canvas by selecting that visual and clicking a different visualization in the Visualizations pane. That's it.

Common elements that will show up in many visuals in the Fields pane include Axis, Legend, and Values. An *axis* defines how you are categorizing your data. A *legend* splits the data into subsections and highlights those distinctions. *Values* are the actual values you want to aggregate across those groupings.

In Fields, there will always be a section at the bottom for "Drill through" options. This cool feature allows you to take a visual and apply the filters currently on that visual to another visual on another page, taking you directly to that report page and its set of visuals. "Drill through" is a really great way to take insights from one portion of your report to another and to keep that context in sync.

Format

In previous versions, the Format pane was depicted by a paint-roller icon. Now, when a visual is not selected, it appears as a paintbrush over a page. But when a visual on the canvas is selected, it looks like a paintbrush over a bar graph. Format allows you to customize the look and feel of a given visualization to meet your specific needs.

Much like with Fields, the eligible options under Format are contextual to the visualization being modified. Many options are available, and if you've ever used PowerPoint, many should feel familiar to you. Each section in Format has an arrow next to it that allows it to be open or collapsed. This can be helpful for navigation purposes. Some features under Format have distinct functionality, but for the purpose of this exercise, focus on the thought that Format is where you go to make your visualizations really pop.

Analytics

The Analytics functions, accessed by clicking the icon of a magnifying glass looking at a graph, don't work on all visualizations, and it's important to note that no custom visuals can leverage the Analytics area. However, for visuals where Analytics does work, you can use this functionality to add in constant lines for comparison, minimum value lines to identify when something is below a given threshold, a maximum

line for the obverse purpose, an average line, a median line, a percentile line, or a trend line, or even do anomaly detection.

There's so much functionality under Analytics, but using it effectively is context dependent, so don't be afraid to try things to see what works or doesn't for you and your project.

Visual Interactivity

Before we get into details of actual visuals, we should discuss one of the most powerful features on a Power BI report page: visual interactivity. By default, any visualization you put onto a report page can filter any other visual on the page. This enables a user to quickly get to specific combinations of data they could be looking for.

In Figure 4-2, you see a simple report page with two visuals. One is a map visual showing the number of students I have in my class from each state, and the second is a simple bar showing the average score across all assignments.

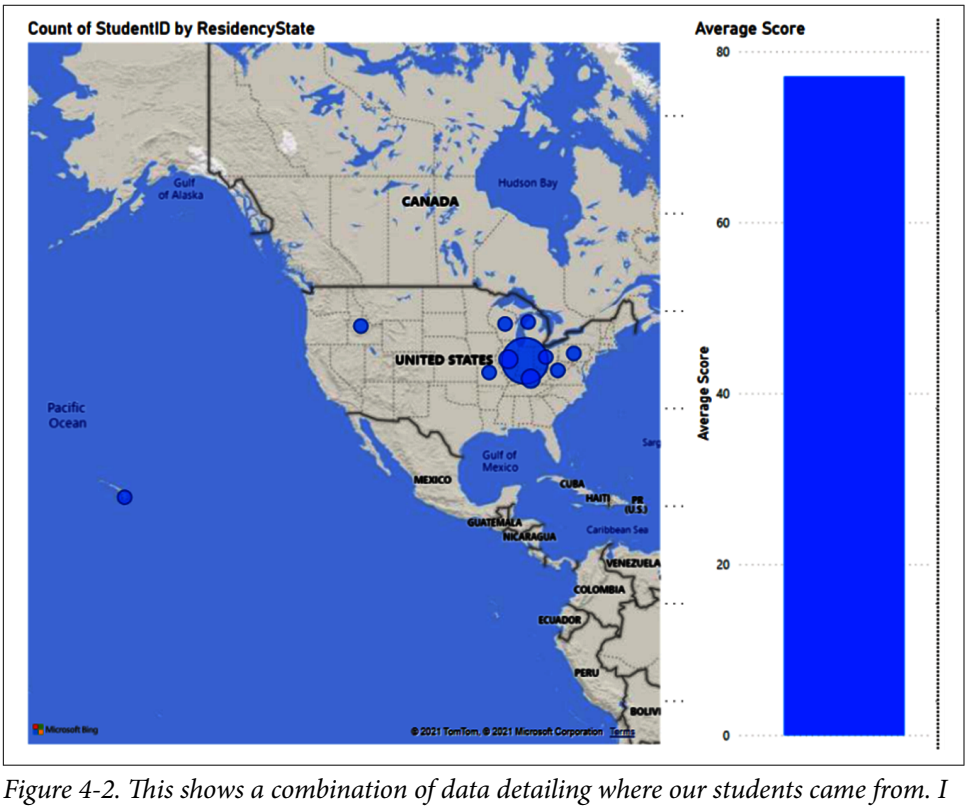


Figure 4-2. This shows a combination of data detailing where our students came from. I think our student from Hawaii is lost.

When I click any of those bubbles in the map, the average score visual will change to reflect the specific subgroup I've selected from the map visual. Looking at the map visual, I can see many of my students are from Indiana. But I want to see how my students from other states might compare to the average, for instance. When I choose the bubble in Michigan, I get the result shown in Figure 4-3. For demonstration purposes, I've captured the image while I was hovering over the result for the column graph to make it clearer to you.

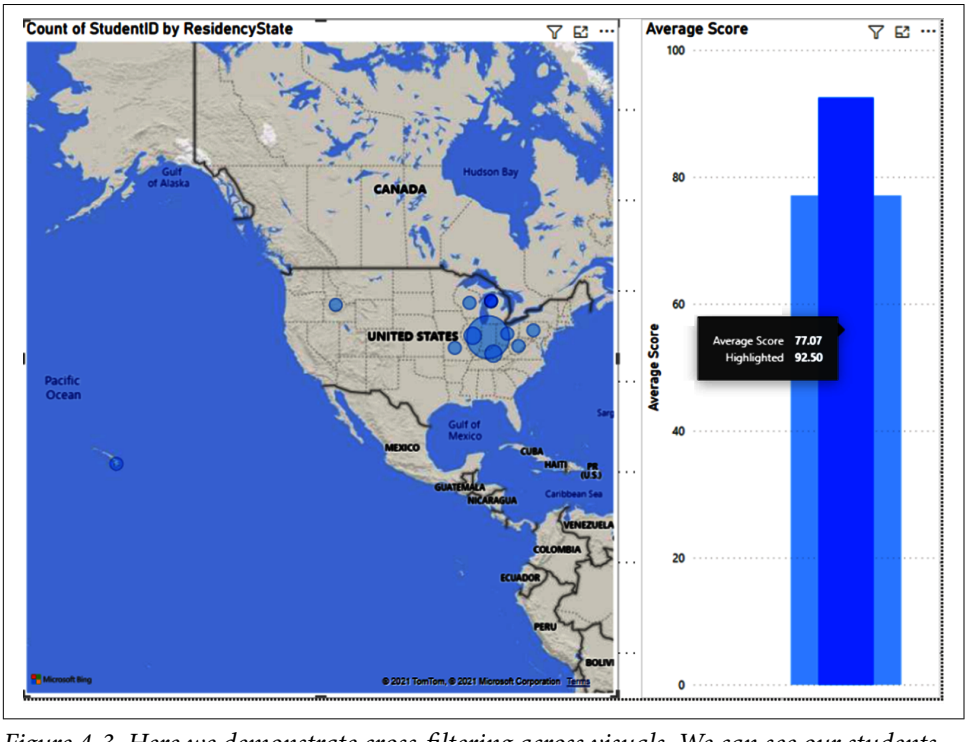


Figure 4-3. Here we demonstrate cross-filtering across visuals. We can see our students from Michigan perform above the average of the rest of the class.

You can see in the map visual, all the other bubbles are transparent now, indicating I've selected one. Now, on the right, you'll see that the column graph shows a new result. It shows a highlighted column, and behind that highlighted column, you can see the original result. From this, I can quickly see that the average score for my Michigan students is higher than my average for the entire group of students. You'll note, though, that it doesn't immediately give me the original average without the Michigan students. This type of cross-filtering, which highlights a value, doesn't remove the selection from the original value.

So, this compares the Michigan student average to the entire student average, which still includes the Michigan students. If we wanted to do something a little different,

we could do so with some custom measures, and we'll discuss that more in our chapter on DAX fundamentals.

Now, at times you might not want a certain visual to cross-filter or be cross-filtered, and not all visuals have the same types of cross-filtering display options. When you have a visual selected, in the ribbon under the Format tab, you'll see a button called "Edit interactions." Unlike other buttons we've discussed, this is either on or off. When it's on, you will see in the corner of each visual on your report page some different icons; again, not every icon will be on every visual.

Let's take, for example, the column graph from our preceding figures; with "Edit interactions" on and the map visual selected, we would see three icons, as shown Figure 4-4. The icons are very small. I wish Microsoft would make these interaction icons a little bit more obvious, but they're not. When I talk about an icon being selected, it will show as being "filled in," as compared to being see-through. In the example, you can see the middle button is filled in, so that's the type of cross-filtering that is done by the map visual against the column visual.

On the left is the Filter option. This would strictly filter the result to show only the filtered result; so, in this case, we would see only the Michiganders' result, instead of the result against the entire average. The second option is the Highlight option, which does what you saw in Figure 4-3. The final option is None, which means that the selected visual will not cross-filter that visual at all.

Figure 4-4. From left to right: Filter, Highlight, and None

Column and Bar Charts

Column and bar charts typically have a very simple x-/y-axis design. Take the values and compare them across two dimensions, and garner some insight from that. Some charts allow us to add in a second y-axis to use when we want to overlay one value against another. In the column and bar chart category, Power BI has the following visuals by default (in their order in the Visualizations pane, left to right, top to bottom, skipping over visuals that aren't relevant to this portion of the text):

- Stacked bar chart
- Stacked column chart
- Clustered bar chart
- Clustered column chart
- 100% stacked bar chart
- 100% stacked column chart
- Waterfall chart

Stacked Bar and Column Charts

The *stacked bar* and *column charts* accomplish the same goal with different verticality. Which one is your x-axis, and which one is your y-axis? As a good rule of thumb, use bar charts when comparing against discrete values and use columns when you're measuring against continuous values like time, for instance. This isn't a hard-and-fast rule, though.

For this chart, I'm going to look at the difference between students for whom this is their first class in the department and those for whom it is not. I'd like to know their average score, and I'd like to see how many office hours were attended by each group.

We can see both the bar and column examples in Figure 4-5. Note that for these two charts, the values you lay on top of each other form a summation of whatever values make up the visualization—in this case, the average assignment score and the sum of each group's office hours. This gives us a combined value that allows us to quickly compare multiple columns and find results that may not be intuitive on the surface.

Looking at both charts, they share the same inputs from the Visualizations pane. You define an axis. You can add a legend as a category to further subdivide the bar or column, the values you want to review, small multiples, and tooltips.

The *tooltip* is what you see when you hover over a certain part of the visual with your mouse cursor. When the tooltip is empty, Power BI will put together a list of values into the tooltip based on what's in the visual. Think of it as a quick table you can make appear for a given set of data to help you read the visual. You can also put things into the tooltip that aren't necessarily in the visual.

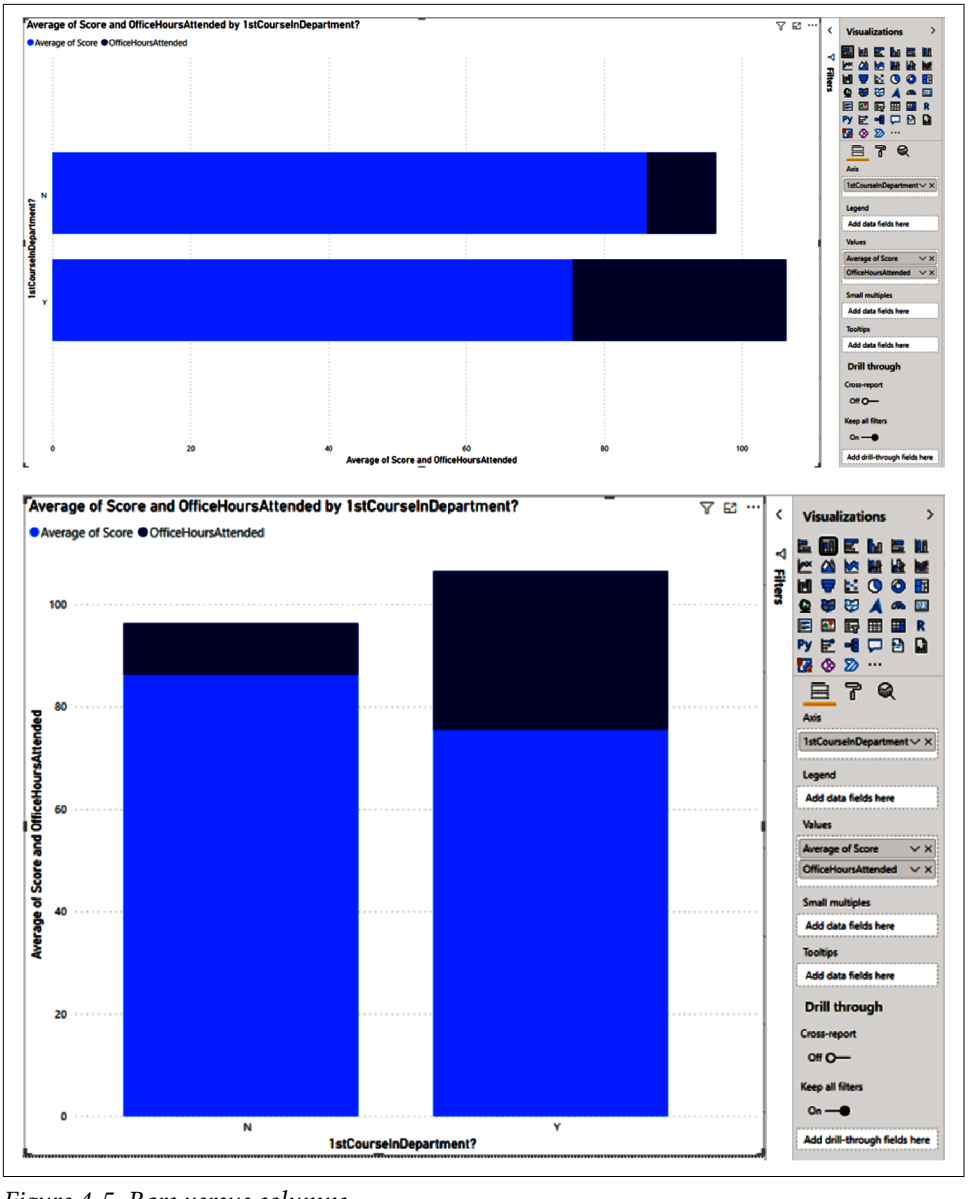


Figure 4-5. Bars versus columns

Clustered Bar and Column Charts

A *clustered bar* or *column chart* takes the values and separates them into discrete items against an axis, as opposed to aggregating them together. In the stacked charts, we basically got one bar or column combining all the values together. In the clustered chart, we get a separate bar or column for each value across our x-axis.

In the example in Figure 4-6, I want to see if there is any real discrepancy between the average scores by ethnicity and by age. I want to see each ethnicity highlighted separately, but I want to see how the ages compare against each other and how the average score compares on a more apples-to-apples basis. I can do this by separating out the values for the average age and average score. Figure 4-6 shows us what this looks like in both bar and column form.

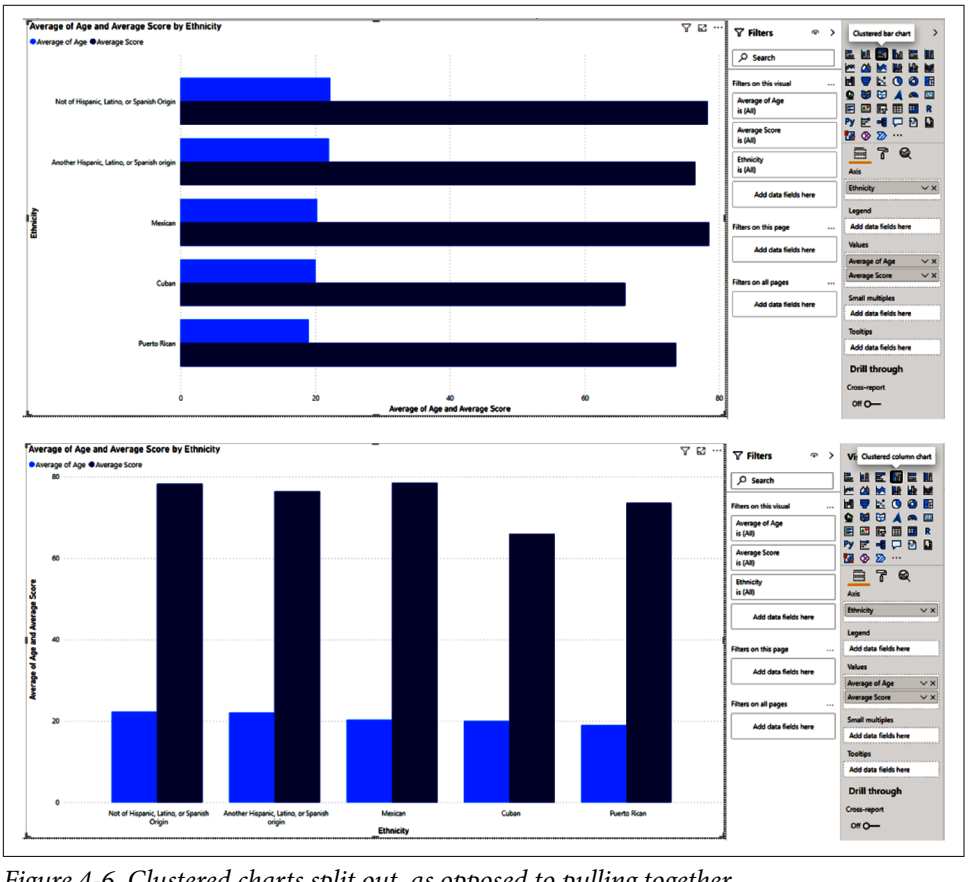


Figure 4-6. Clustered charts split out, as opposed to pulling together

This set of charts does a nice job of showing that the way you present data matters. If we look at the top portion of Figure 4-6, it's easier to see the difference in the average age that exists in each ethnic grouping. I think this is a little harder to see in the column example. Both the column and bar charts here do a good job of showing the difference in the average score, though.

Sometimes changing a value from an x- to a y-axis can make a big difference, and remember that by default axes are dynamic. That's something for you to consider when choosing bar versus column charts or if you feel the need to manually set axis values (which you could do in the fields area for this group of visualizations under the relevant axis category).

100% Stacked Bar and Column Charts

The 100% stacked bar and column charts take a given set of values across dimensions and figure out, for that total, what percent of the total belongs to each specific section of the grouping. This normalizes the result across categories because it's based on percentages instead of absolute values.

For example, in our class we have way fewer student athletes than students who are not athletes. If we were to look at the total number of office hours attended by each group, the nonathletes would just look like a much larger group. However, what if I'm trying to figure out if a particular assignment got more office hours in one group than another? That's an example where normalizing the data can come in handy, as we see in Figure 4-7.

Here we have 13 assignments with office hours attended. We can see that our student athletes attended office hours for only assignments 5, 6, 7, and 12. Assignment 12 noticeably had 20% more office hours than the other assignments. We see that, for the nonathletes, the distribution is fairly uniform across assignments. Not perfectly uniform, but close.

If we were teaching this class, this could lead us to ask some additional questions. Was there an issue in sporting schedules that made getting to office hours more difficult? Was the extra interest at the end of the semester because the student athletes weren't performing well, or was it just coincidence? Some of these questions I can answer from the data, and some of them I probably can't, but hopefully you can see some example questions I might want to ask as I develop my report or my research into the topic.

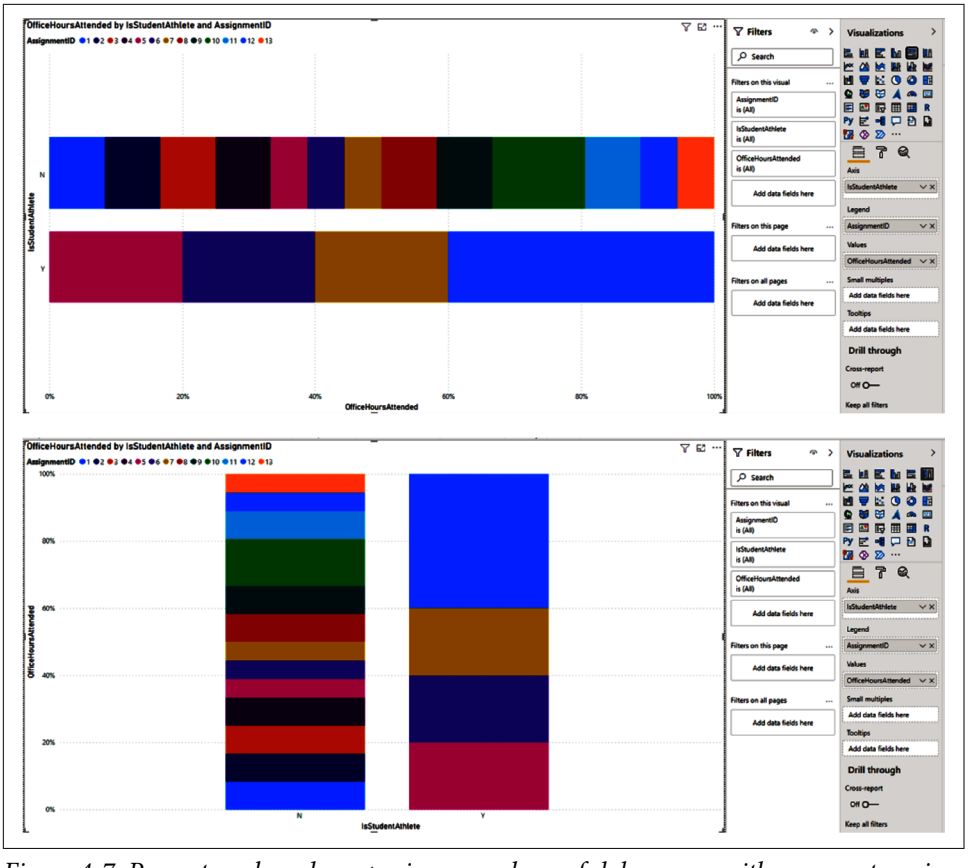


Figure 4-7. Percentage-based comparisons can be useful; however, with many categories it can become unreadable

Small Multiples

Small multiples is a feature that lets you split the visual into slices while maintaining common axes. Say I wanted to divide this into four quadrants using the student athlete identifier and the gender flag. I could see this broken out for all four combinations—not an athlete and female, not an athlete and male, is an athlete and female, is an athlete and male—while keeping my core axis value. That gets us the view represented in Figure 4-8, which also contains an example of a tooltip value that isn't elsewhere in the visual (in this case, the average age for that grouping of data).

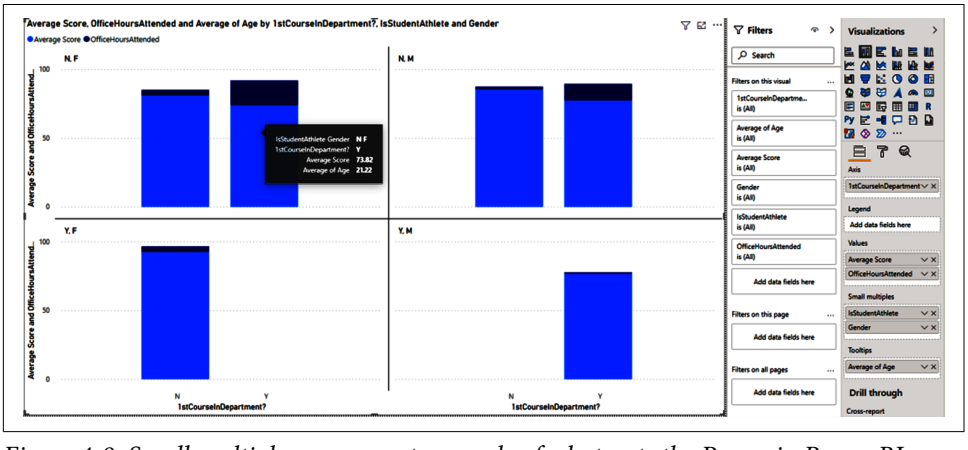


Figure 4-8. Small multiples are a great example of what puts the Power in Power BI

Let's take a second and talk about the inferences we can draw. We know that there are no male athletes for whom this is not their first course. We know the inverse is true of female athletes. We can see the average score is higher across all groups for those people for whom it is not their first class. And, generally, we know that those who were taking their first class in the department attended more office hours, but those office hours didn't quite get the first-timers up to the level of the more experienced students in the department.

Waterfall Chart

A *waterfall chart* compiles by a given category how a value changed over that category until it shows you the final total value. This can be useful when you have a combination of positive and negative features that contribute to a total, so that you can break them out and compare them to each other. We don't have negative grades for anyone, so Figure 4-9 demonstrates a single-directional waterfall chart showing the calculation of office hours attended by AssignmentID before showing the total number of office hours attended for the semester.

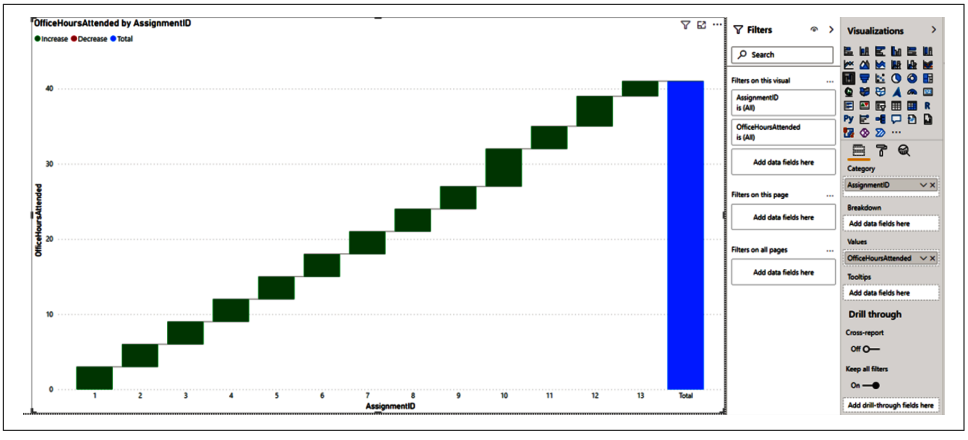


Figure 4-9. Sometimes it's OK to chase those waterfalls!

Line and Area Charts

Line and area charts, like column and bar charts, have a very x- and y-axis focused theme. The difference is often that it can be easier to see trends or do comparisons with lines or areas, seeing where data in a time series might overlap or observing where certain categories might intersect.

Also, Power BI has a set of charts that combine column charts with line charts that we will discuss in this section. Again, the list of visualizations in this category is read from left to right, top to bottom, skipping visualizations that aren't in this section:

- Line chart
- Area chart
- Stacked area chart
- Line and stacked column chart
- Line and clustered column chart
- Ribbon chart

Line Chart

A *line chart* isn't really that different from a column chart, except that it's easier to see trends with lines than it is to see them with columns. Line charts also work best with a continuous axis because when there's a gap, the line chart will break the line and pick it back up for the next value in the axis series. If you look at the options in the Visualizations pane for column and line charts, you'll see that they look incredibly similar, except that the line chart has one additional option for Secondary values. That section is there in case we want to do two y-axes against each other, which is the unique feature about line-type charts. This can be useful when you want to compare trends of two values, but they might have very different orders of magnitude.

A good business example of this is comparing my average product price to my total profit. Average price for my products is going to be lower than my total profit (or at least it should be, or you have much bigger problems than this book can really solve.) If I were to put those values on the same axis—say, profit in millions and average price in the hundreds—the average price line would look virtually flat and near zero compared to millions in profits. However, if I put them on different axes, with each y-axis measuring its own order of magnitude, we can solve that problem and better see the trends together.

In Figure 4-10, I've put a line chart together showing average score by assignment ID alongside the student ID count for each assignment. Even in the example provided, the number of students doesn't reach the level of the average score on any assignment, even the lowest-scoring one.

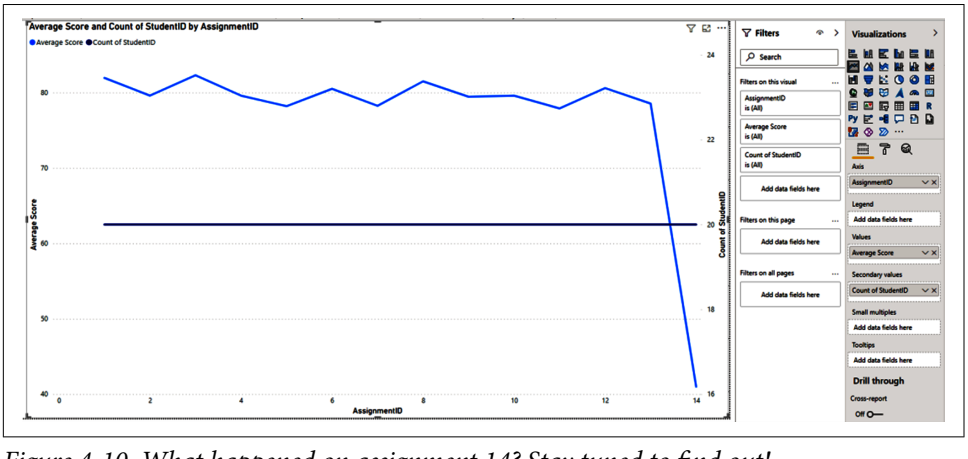


Figure 4-10. What happened on assignment 14? Stay tuned to find out!

Area Chart

An *area chart* has all the same category options as a line chart. Think of an area chart as a line chart with the values below the line filled in. Voila, area chart! The area chart does two things in my mind that provide good use cases. The first use case is when you have data that changes over time, and you want to give the reader a sense of the proportion of that change. A good example of this is looking at the change in population over time.

You can also use an area chart to see more easily where two or more values overlap, or —usually the more interesting case to me—where they don't. Figure 4-11 is the same as Figure 4-10, except it's an area chart. At the very end of the chart, for assignment 14, you'll see that the area that's filled in under the student count line isn't also filled in by the average score because the average score dropped. That filled-in area serves

as a great visual indicator that something there is abnormal or may be worth further investigation.

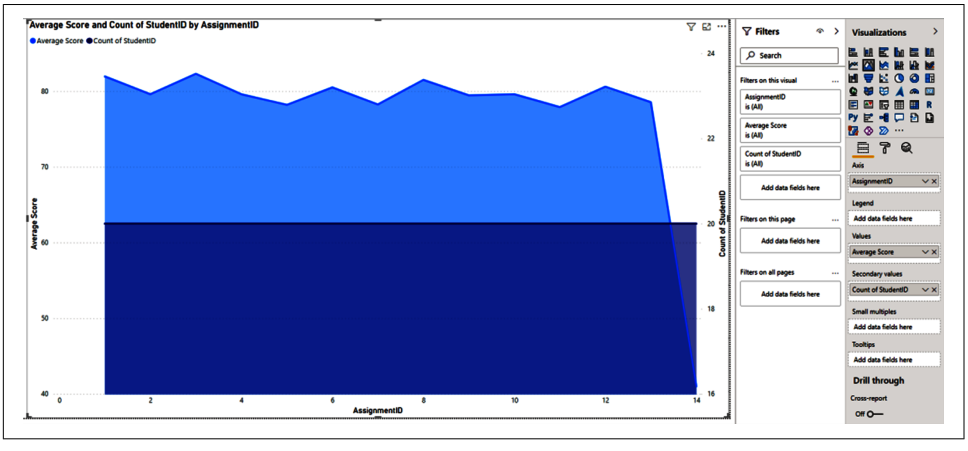


Figure 4-11. That little triangle at the end begs so many questions!

Stacked Area Chart

A *stacked area chart* is a bit different from an area chart in that it not only shows you the individual values in the area, but also creates an aggregate of the values of the area, allowing you to see both the individual parts of a total and the total at the same time.

Imagine you are in a business that has multiple subscription models: silver, gold, and platinum. The stacked area chart can be great in an example like this because it will show you the silver, gold, and platinum areas on top of one another, allowing you to see the combined subscriptions as well as their component parts.

Figure 4-12 demonstrates a stacked area chart so that we can see our average assignment scores per assignment by the number of years a student has been in school. Looking at AssignmentID 3, we can see that, for some reason, students with one year in school really struggled with this assignment. Maybe they've gotten used to sleeping in already?

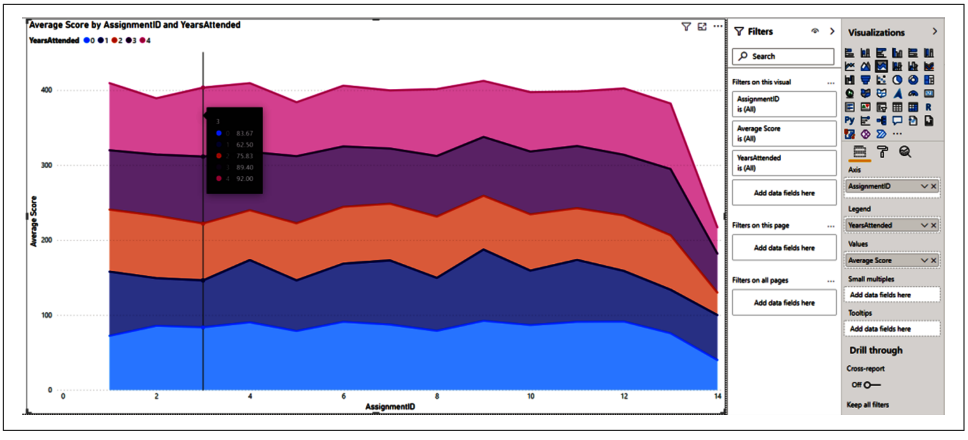


Figure 4-12. Students with one or two years of attendance seem to struggle on this one

Line and Stacked Column Chart/Clustered Column Chart

We discussed stacked and clustered column charts earlier in this chapter. What does adding a line do for these charts? Quite a bit, as it turns out! The ability to take a column chart and then overlay a line value on a different axis can really expand analysis.

For example, in Figure 4-13, I break down my average score by race for the line, but use a clustered column on the total sum of all the scores. This view tells me very quickly that White people are the majority in my class, but the Black or African American students have the highest average score. However, the inclusion of the second y-axis also tells me that the difference in the average score between my racial groups isn't that large, ranging from about 76 to a high of 80. If I were a teacher who was concerned about my course being pedagogically attuned to the needs of all my students, I would take this result in a very positive light!

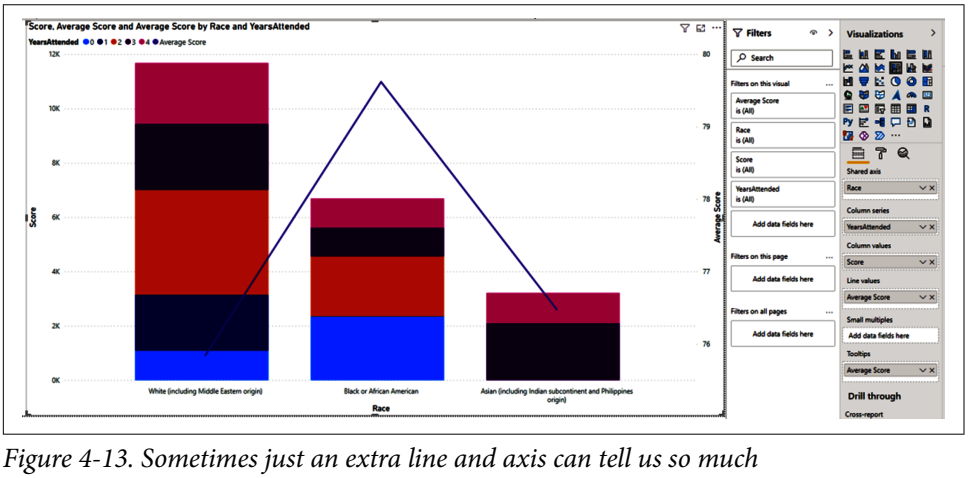


Figure 4-13. Sometimes just an extra line and axis can tell us so much

Ribbon Chart

A *ribbon chart* is somewhat like an area chart, but what it really excels at is showing how things rank against each other. You can see how the ribbon flows across the category. The tooltips for ribbon charts are also exceptionally detailed when hovering over the "transition" part of the ribbon. That's what I call the portion of the charts that aren't the columns being compared.

You can get a good idea of a simple ribbon chart in Figure 4-14, where we're looking at the rank of the average score for those who attended office hours versus those who didn't. We can see at the beginning of the semester that those who didn't attend office hours were doing better, but then that changes in Week 5, so that those who were attending office hours were doing better. What are some of the questions this raises in your mind?

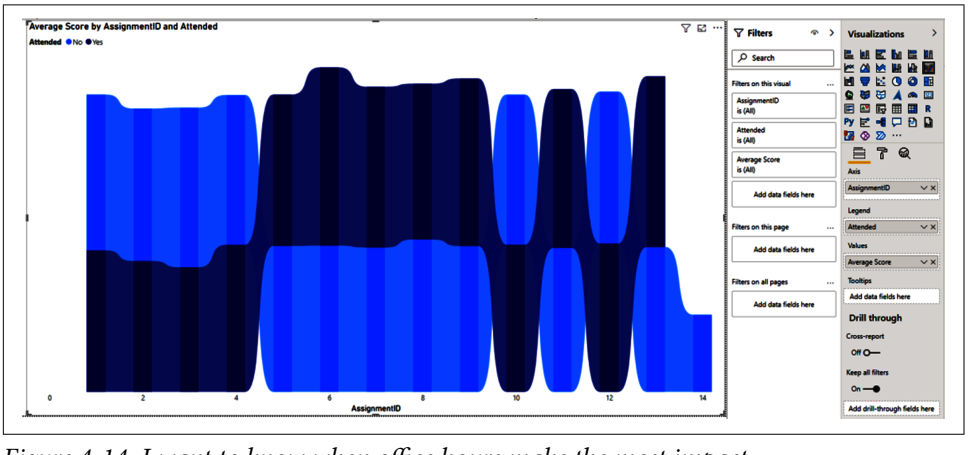


Figure 4-14. I want to know when office hours make the most impact

Donuts, Dots, and Maps, Oh My!

This next section of charts covers a bit of a broader spectrum than the previous two categories. I like to group these things together because they don't necessarily fit as neatly into other categories for me. They tend to be about demonstrating the effect of categories rather than summarizing a value across a category. Put another way, what does a given category contribute to something? That brings us to the following list of charts, again listed in their order in the Visualizations pane, reading from right to left, top to bottom:

- Funnel chart
- Scatter chart
- Pie chart
- Donut chart
- Treemap

Funnel Chart

A *funnel chart* is a flexible visualization. At its core, a funnel chart is about comparing a collection of data to another collection of data to see how close or far away it is.

One of my favorite examples of a funnel chart was from when I worked in operations analytics in a call center. That call center did telephonic coaching, and it was important to know how many times we would successfully connect or engage. I would use a funnel chart to show off our total eligible population, and then the number of people we engaged with once, then twice, then three times, etc. Each successive reach was harder to get, and you couldn't reach someone for a third time unless you'd reached them a second time. This allowed us to quickly understand our conversion rate at each level of customer engagement.

In our example in Figure 4-15, we're looking at a different use case for the funnel: a presorted list of average scores by student. Pay special attention to the tooltip, the information in the black box in Figure 4-15. It shows the percentage of the highlighted value in comparison to the top value. Mr. Schmitz, with an average score of 85.36, has an average that is 92.28% of the top score (Montegalegre's) and an average score that is 97.47% of Boomhower's.

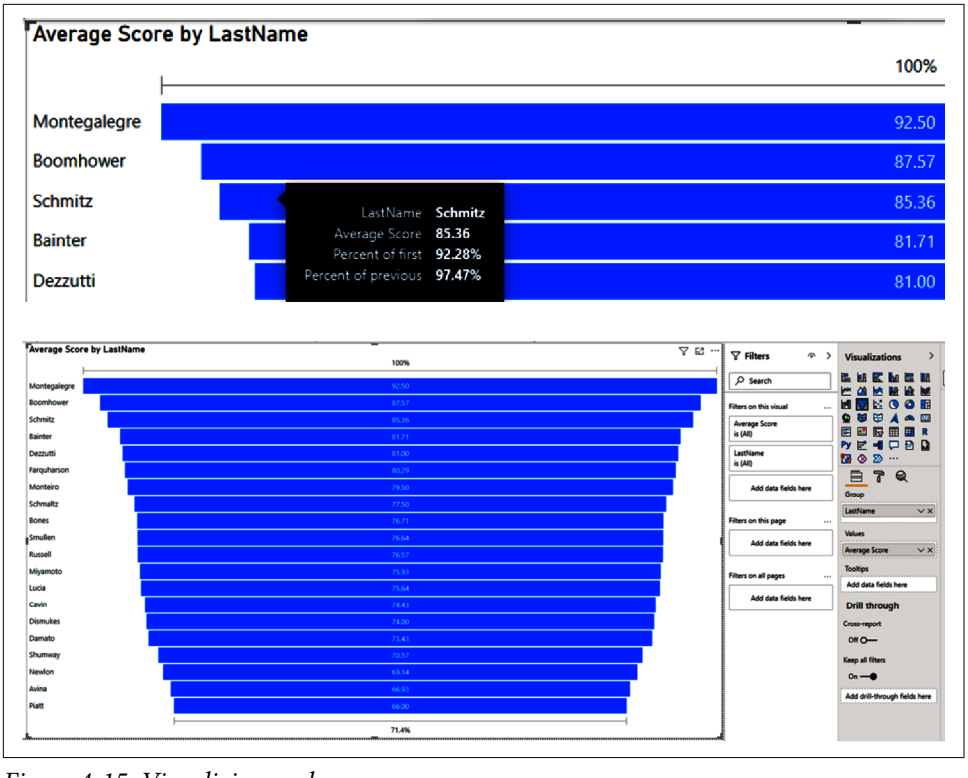


Figure 4-15. Visualizing rank

Scatter Chart

The *scatter chart* is one of the most useful and most maddening visuals in Power BI. I'll be blunt: it's fickle. There are way too many ways to get an error out of this visual when you are constructing it. If you have data that you can represent nicely in X and Y pairs, the scatter chart is fantastic. One of its other uses is to display how values change over time. Just as an additional note, your y-axis must always be numeric; it cannot be categorical. Your x-axis can be either numeric or categorical.

In the example in Figure 4-16, we are looking at our average score by assignment between student athletes and nonathletes. What we have added that is unique to the scatter chart is the Play axis, which allows us to cycle through some categorical filtering in sequence to see how these values change over time. This can work really well with continuous data that uses dates or, as in this case, I'm using the assignment IDs, which are numerical, to play through the change in assignment order.

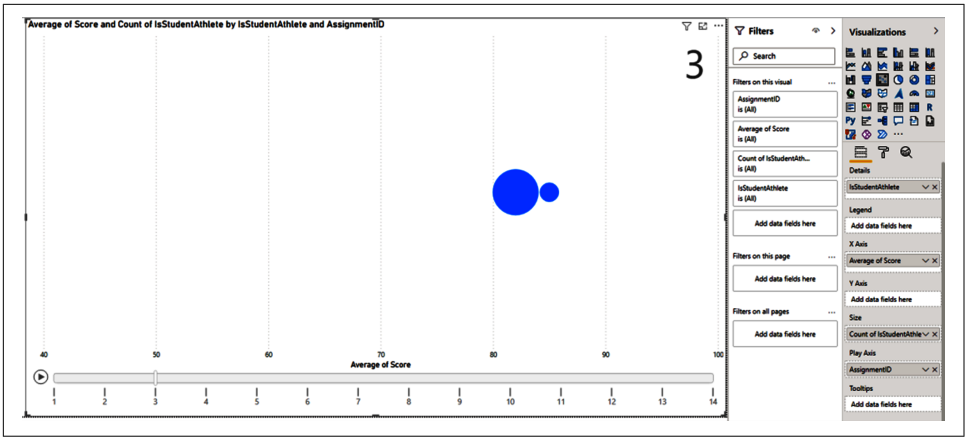


Figure 4-16. Moving pictures. They're weird, but I bet they'll be big someday.

Pie and Donut Chart

Oh, I can hear the screaming of finance professionals everywhere, "Jeremey! Why are these together? They're *totally* not the same thing!" I want everyone to be clear on this. A *donut chart* is a pie chart with a hole in the middle. They do the exact same thing, which is demonstrate the percent of a total value that represents a certain category.

Now look at me, and by look at me, I mean stop reading, lift your eyes to the sky and hear my disembodied voice in your head. Pie and donut charts are overrated and overused. Does this mean they are bad? No, of course not. However, naturally it is easier to compare lines and bars against each other than it is to compare "areas" of values.

Does your pie chart have 74 values that it is comparing? That's bad. Is it a real sugar crème pie from Zionsville, Indiana? Then it's good. Is your donut made of some vegan, gluten-free flour substitute from a back alley in Portland, Oregon? Probably not good. Seriously, go to Coco's. Voodoo is overrated. Figures 4-17 and 4-18 show good pies and donuts versus bad ones.

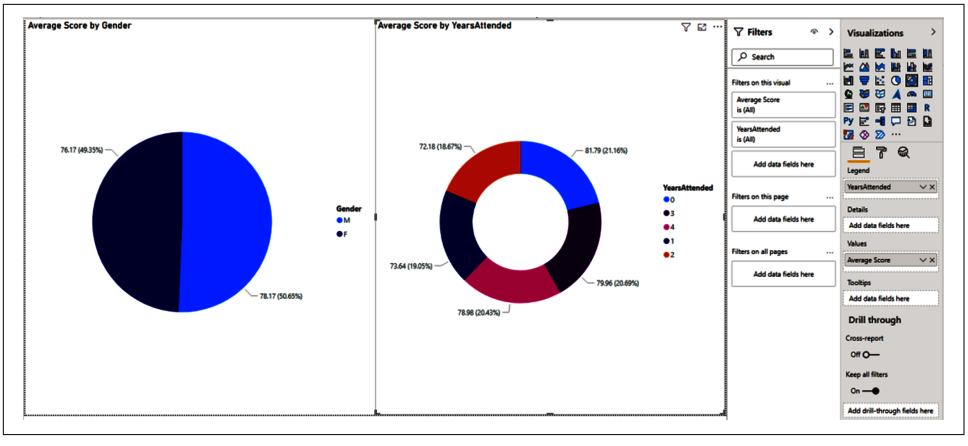


Figure 4-17. Good pie, good donut. Why? Because they're both readable.

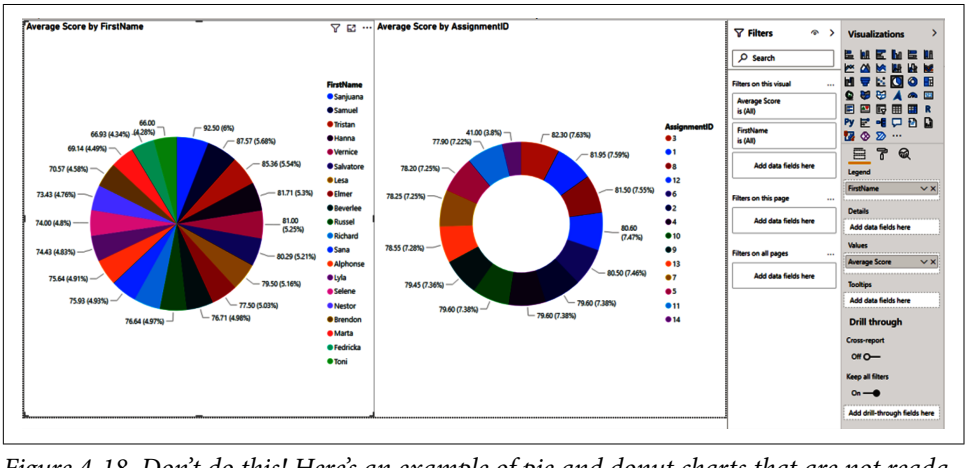


Figure 4-18. Don't do this! Here's an example of pie and donut charts that are not readable. As the kids say, "Y u do dis?"

Treemap

The *treemap* is the donut chart for the 21st century, which is to say, it can be used well and can be destroyed by too many categories filling it up. However, one advantage the treemap has over its pie and donut counterparts is that it is easier to tell the difference between big squares and little squares. I like to use treemaps as a cross-filter on many report pages where categories and subcategories exist naturally to highlight specific subsections of data for more analysis.

A larger treemap like the one in Figure 4-19 is helpful for identifying large groups at a glance. In this case, we are looking at combinations of gender and ethnicity to see which groupings attended the highest number of office hours. We can easily see

females attended more hours than males, and we can see which ethnic groups attended those hours.

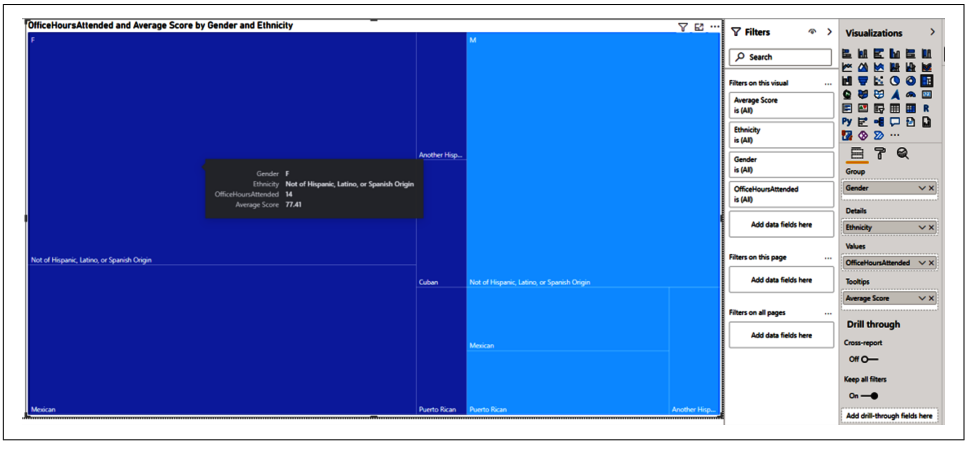


Figure 4-19. Group and Detail divisions make treemaps shine

Map Visuals

Map visuals do exactly what you think they do: they align data with geographic categories to show you details about data across those categories. Pretty straightforward. Power BI has several map visuals that can help you get to where you want to go.

The basic map visual offers the ability to define a location or to offer data points for latitude and longitude to define your map parameters. The filled map is basically the same as the map, except it fills in the relevant geographic categories, as opposed to putting in size-based dots.

By the time you get this book, the shape map visual might finally be out of beta (where it has been for years). The shape map does not use Bing or Azure to power it, but it uses custom TopoJSONs to define the map's shape and structure. A *TopoJSON* is a special file format that contains semistructured geographic data. If you are in a place where you need a custom map, check to see if you have a TopoJSON built in-house or find one of the many great resources online to get a TopoJSON of the map you need.

The Azure map allows you to define latitude and longitudinal boundaries that can be passed to TomTom to generate a map much like the shape map visual. With map visuals, my suggestion is to try each map visual and see which one works best for you and your needs.

The "Flat" Visuals

Flat visuals exist to display simple, straightforward information that you want your reader to see. These visuals generally do not cross-filter others, but are cross-filtered themselves, with one obvious exception: the slicer visual. These visuals may seem simple, but they often add that magical, extra little bit of context to a report that turns the data into a story that makes sense. They do so by highlighting those specific things that you really want your audience to understand. In this category, we have the following visuals:

- Gauge
- Card
- Multi-row card
- KPI
- Slicer
- Table
- Matrix

Gauge

Gauges are one of the oldest forms of data visualization we have. They've been used in machines and engineering for most of the 20th century. A *gauge* fundamentally tells you how a value is doing compared to its minimum and maximum values alongside a target. The gauge is helpful for setting targets and seeing quickly if you are above or below that target value. It can also be useful when you want to keep a value in a specific range, not too hot or not too cold.

In the example in Figure 4-20, we compare the average score with our goal average score measure.

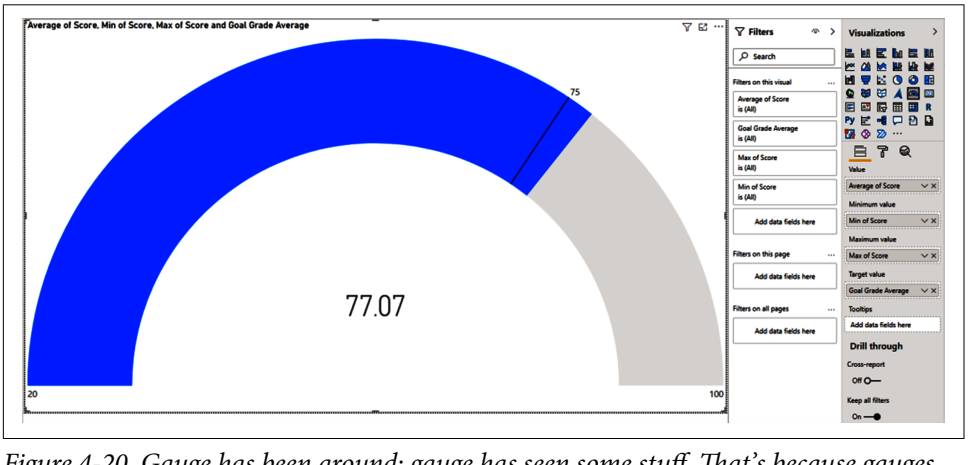


Figure 4-20. Gauge has been around; gauge has seen some stuff. That's because gauges are among some of the earliest data visualizations.

Card/Multi-Row Card

The *card visual* is one of the simplest visuals in Power BI. It's also one of the most self-explanatory from its name. When given a value, it takes that value and puts it into a square card with a brief note on what it is that's being viewed.

For me, the card does two things well. First, in its simplicity, it's easy to understand what you're reading. Combine this with cross-filtering, and the card visual can quickly highlight a specific value for any combination of data easily. Second, it helps the storytelling process by drawing readers to specific values you think they should care about, either because they're important on their own or because they provide necessary context that makes the other visuals on your report page more meaningful.

The *multi-row card visual* is like the card visual's cousin whom your aunt and uncle dote on constantly at Thanksgiving, but you're not actually sure they're all that great. The multi-row card puts, unaspiringly, multiple values into a single card-like space. If all the values are aggregations, it will look fairly clean. However, if you have aggregations and then some dimension that categorizes those aggregations, the multi-row card will create multiple rows on the card, detailing the aggregated values for each categorical value.

In Figure 4-21, we have a simple card on the left and two multi-row cards on the right: one with only aggregations at the top, and sliced by StudentID on the bottom to tell the difference more easily. Note how the second multi-row visual also has a scroll bar to help navigate the visual because it's now longer than the assigned space.

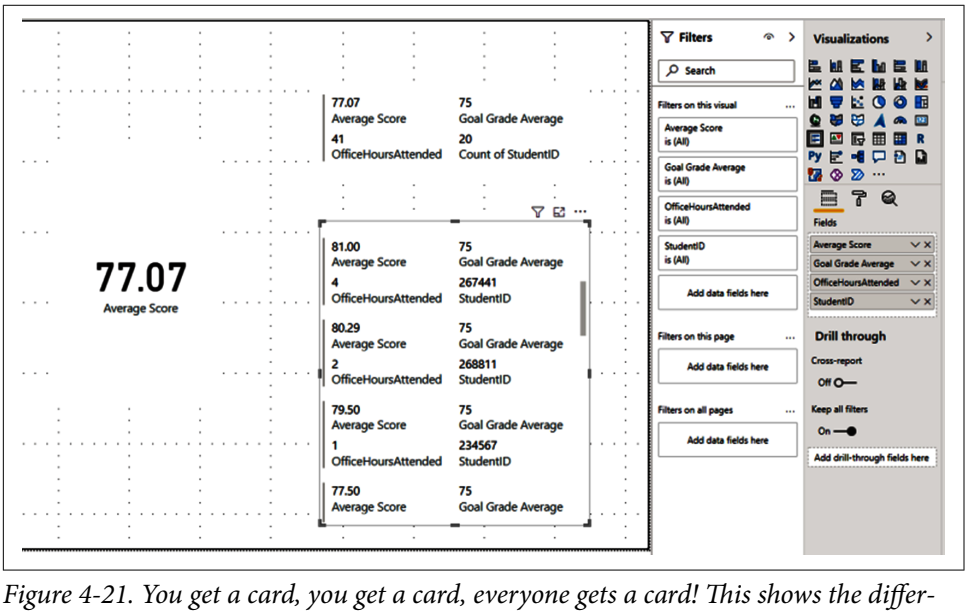


Figure 4-21. You get a card, you get a card, everyone gets a card! This shows the difference between a card and a multi-row card.

KPI

The *key performance indicator (KPI)* visual is one of those things that on the surface sounds great, but inevitably leads to a place of frustration. It's not as bad as the scatter chart, but the KPI visual is not intuitive at first.

There is an indicator field, and this is what you are actually measuring. There's a trend axis, which is how the visual will display the results on an x-axis that isn't displayed. Then there's the target goal, which we should be either higher or lower than.

A classic example of a KPI use case is something like current year revenue versus previous year revenue by fiscal month. In our example, we are looking at our average score compared to our goal grade average of 75. The visual then shows how we did compared to that goal.

The infuriating thing about the KPI is that it always displays the value for the last value in the axis, regardless of what happened before it, even though it will visualize those values in the chart portion. You'll notice in Figure 4-22 that I've left the Filters pane open so you can see what the visual looks like in two scenarios: one where I ignore Assignment 14, which is special, and one where I do not, so you can see the difference in the way the KPI visualizes those results.

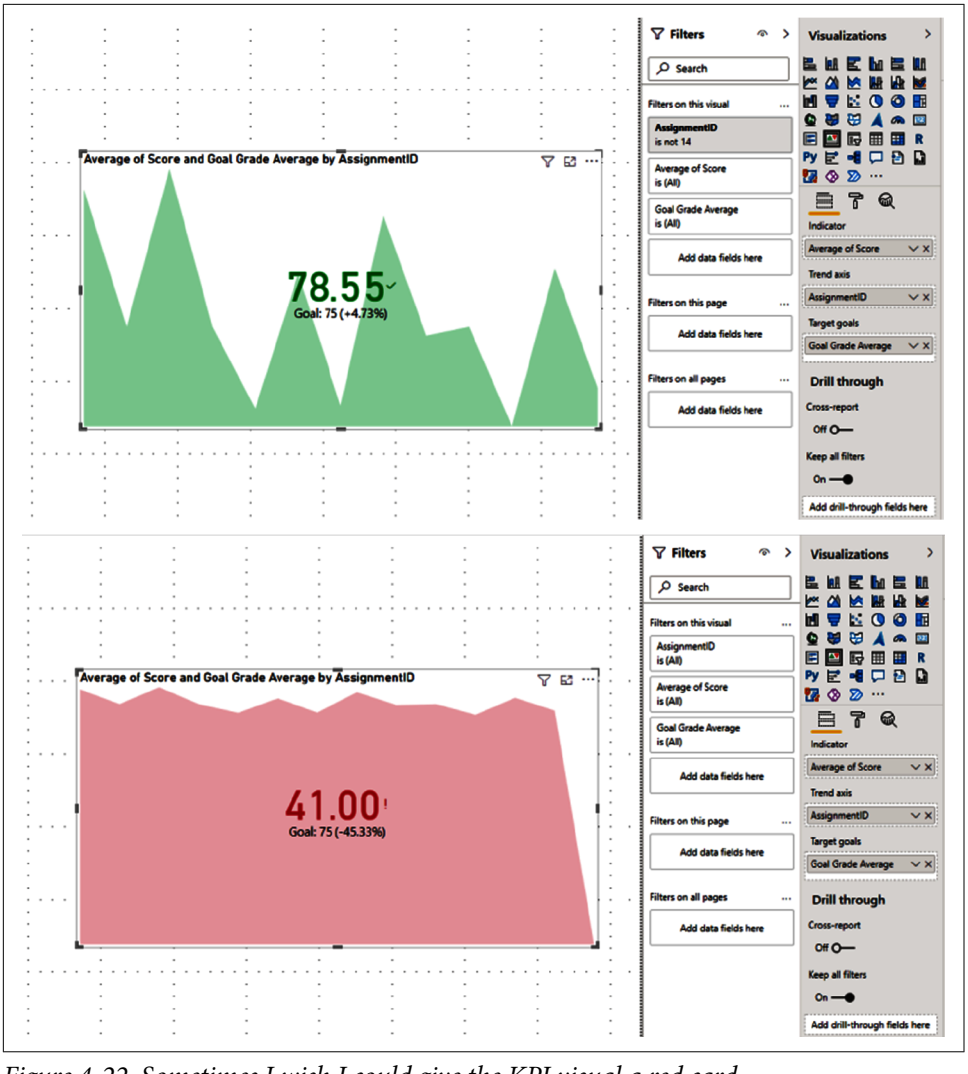


Figure 4-22. Sometimes I wish I could give the KPI visual a red card

Table/Matrix

So, I'm going to apologize, because this is one time I'm going to deviate from the order and skip over Slicer. I'll come back to it after the table and matrix visuals. These are easy to understand if you've used Excel or Google Sheets or looked at a database table.

The *table* is exactly what it sounds like. No bells and whistles here. The table visual, in the Visualizations pane, has only one insert, and that is into a values field. Everything is a field (column), and all the values are assigned to that column. It might seem

counterintuitive to have a table visual in a data visualization tool, but the table visual can provide some more specific detail that can offer extra context.

In many scenarios, I might prefer a table to a multi-row card for highlighting specific data points. The other cool thing I've done with table visuals is put them at the end of reports to make for easy data extraction for analysts who might want to use the data of that table for other analysis.

The *matrix* is more akin to a pivot table in Excel, with the ability to have multiple levels of row features to drill into. Matrices can also be overused, but when used to highlight specific sets or combinations of data, they can help illuminate specific items for readers or provide extra context to analysts who can figure out what questions they need to go answer quickly.

For many years, exporting data from a matrix visual would lose its matrix formatting, as Power BI would put it into a table first and then export it. However, that's not true anymore, so if you have a need to export data in a matrix format, maybe for a presentation or something, you can do that as well. Figure 4-23 shows a table on the left and a matrix on the right.

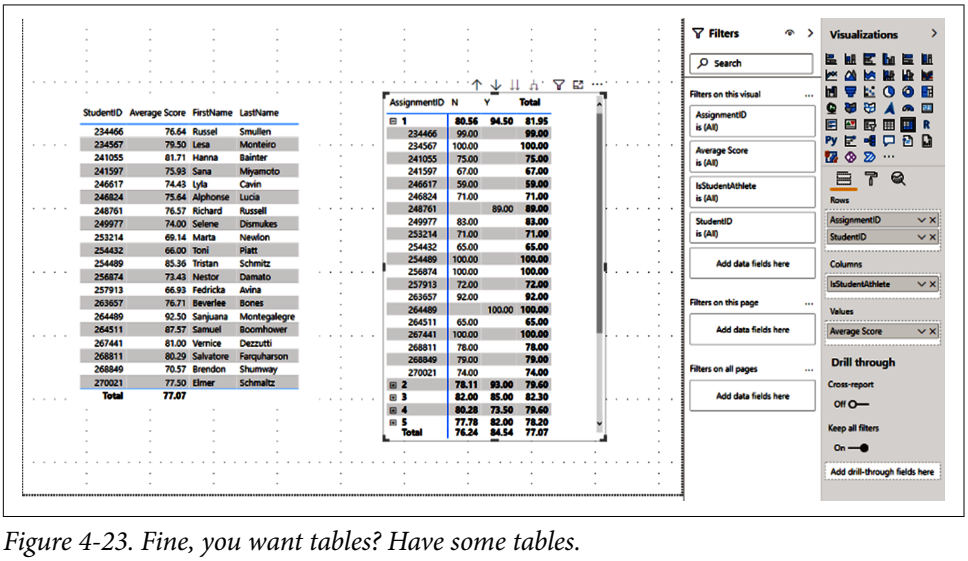


Figure 4-23. Fine, you want tables? Have some tables.

Slicer

I saved the slicer for last because its functionality is fundamentally different from every other visual we have reviewed, but that doesn't mean it's less important. A *slicer* takes the visuals on a page and filters them in alignment with the selected value(s) on the slicer.

A slicer isn't too different from having a column selected via the "Filters on this page" button in the Filters pane. What is different, though, is that as a visual on a report page, you can edit how it interacts with every other visual on the report page by using the "Edit interactions" function on the Format tab of the ribbon; and slicers can be synced across pages of your choosing using the "Sync slicers" pane. This can make slicers much more flexible and more intuitive for your report readers. This also gives you, as the author, another chance to identify which dimensions you feel are important for helping your readers understand how they should be thinking about the data.

In Figure 4-24, you can see the slicer visual selected in the bottom-left corner, using the assignment ID. Note how the values change when I select different combinations of the assignment ID I want to look at.

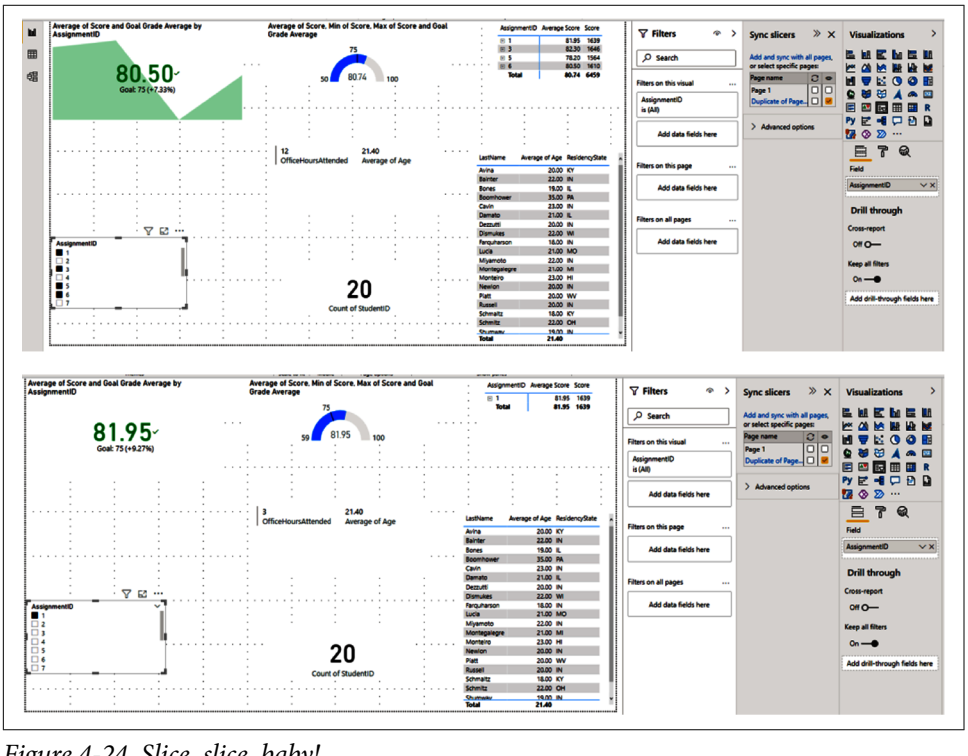


Figure 4-24. Slice, slice, baby!

Conclusion

Yes, the Visualizations pane has a few other visuals, but those aren't really visuals for the 101 section. If you're able to do R or Python scripting, you already know how to use the R and Python visuals, and we'll discuss the AI-powered visuals a bit more in Chapter 7. Power Apps, Power Automate, and Paginated Reports are a bit beyond the scope of this book, but plenty of resources are available if you have an interest in those topics.

In this chapter, we've gone through the basics of visualization in Power BI and walked through many of the visuals that are available right out of the box in Power BI Desktop. And we've discussed some of their use cases. In many of the visual examples, we used a simple measure, the average score, to use as a point of reference, but how did we make that measure? That's where DAX comes into play, and that's what we'll be moving to next. Excited? You should be.

CHAPTER 5

Aggregations, Measures, and DAX

In Chapter 1, we had a long conversation about the storage engine and the formula engine of Power BI. In Chapter 3, we were really talking about how the storage engine works and what it means to store data in your own personal Analysis Services instance. Now we'll dive into the other half of what makes Power BI special: the formula engine.

Taking stock of our progress so far, we've put our data in Power BI and reviewed most of the visuals available in Power BI out of the box. We dragged and dropped values into visualizations to get results, but how did Power BI know what to display?

This chapter details the roles of aggregations, measures, and DAX as they relate to visualizations. What is an aggregation? What is a measure? What exactly is DAX? We'll answer all these questions and explain what you need to know.

A Primer on the DAX Language

Data Analysis Expressions (DAX) is the language of the formula engine of Analysis Services Tabular and Power BI. It is a multifunctional query language that can be used to obtain specific results or create calculated tables or columns. Anytime you create a visual in Power BI, it generates DAX behind the scenes to get the data from the Power BI storage engine.

DAX is incredibly powerful, but like everything else in Power BI, it is really defined at the columnar or table level. That's different from software like Excel, where things are defined at the individual cell level. DAX cannot modify individual points in space or cells like Excel. It has to modify a table or column of data. Remember, our underlying database is columnar, so we need a language that can modify and query columns, not individual cells of data. Being able to modify and query columns is much more

powerful because it's faster, and you don't have all the overhead of needing to be able to write formulas against specific cells.

Measures

A *measure* is the result of a DAX formula that leads to a single-value result. This result can be modified by either row or filter context. You will discover that row and filter context are two of the most important concepts in DAX, so we'll discuss them in more detail later in the chapter. The short version for now is that row context occurs when you are dealing with records in a table; filter context happens when things try to cross-apply to one another, like, for instance, using a slicer visual.

In Power BI, this context can be passed implicitly through other factors in a visual. For example, when we discussed the "average score" previously, that was a measure. It's a DAX statement that will return the average score based on whatever context exists, either explicitly in the DAX statement itself or implicitly through visual implicit context.

Think about it with a simple table visual. With no context and just the measure, I will get the average score across all assignments for all students. When we add assignments to the table, we then get the average score for all students for each specific assignment. If I add student last name to that table, I'll get the average score for an individual student for an individual assignment. These examples show how a measure can be contextual.

Calculated Columns

A *calculated column* is the result of a DAX statement that will return a result for each individual row in a given table. A simple example of this is to concatenate the last name and first name into a single column. We would write a DAX statement that would return a value for each record.

In Power BI Desktop, when you right-click the Fields pane, you'll see the options to create new measures or calculated columns. These options help Power BI identify how it should treat the DAX statement. If it knows the goal is to create a calculated column, it will evaluate the DAX in that context, and the same for a measure.

A common example is the desire to concatenate last name and first name. DAX has a concatenate statement, but if I try to do this with a measure, the IntelliSense in Power BI won't allow me to choose the columns. However, it will allow me to do that as a calculated column. I recommend that you create columns in Power Query and use DAX-calculated columns as a last resort. My general rule is that we always want to modify our data as close to the source system as possible. A DAX-calculated column is really the furthest point away from that data source.

Calculated Tables

A *calculated table* returns a table of values, rows, and columns, based on a DAX statement that references other tables in the same data model. You can think of a calculated table almost as a SQL query result. You query a database in SQL, and you get a set of results in the form of a table based on which columns you selected.

A calculated table is the same idea, except it exists in memory and can be referenced in the data model as its own unique object. It can also be used in relationships. If you find yourself querying a Power BI dataset or Analysis Services instance, thinking about DAX in this context will be helpful.

The other common use of calculated tables in Power BI development is in the process of "role-playing" dimensions. In the most common example, you have a fact table with multiple dates and need to be able to interact with different dates based on the reporting requirement. Your date table can have only one active relationship. So you can use a calculated table to create another set of dates to build another relationship to that fact table. Then you have two different date tables that you can use, depending on which date you might need to use from a given fact table.

Types of Functions

DAX functions are grouped into families, or *types*, that identify the goal that they should accomplish. A DAX formula is a construction of one or more DAX functions.

I certainly don't use every DAX function available within the examples in this book, simply because there are hundreds. For that reason, it can be helpful if you know how DAX functions are grouped in case you need to quickly look up the details on how a specific function works or you're trying to find a function that fits the type of analysis or data manipulation you are trying to perform. Here's a list of how DAX functions are grouped:

- Aggregation functions
- Date and time functions
- Filter functions
- Financial functions
- Information functions
- Logical functions
- Math and trigonometric functions
- Other functions
- Parent and child functions
- Relationship functions
- Statistical functions
- Table manipulation functions
- Text functions
- Time intelligence functions

To see sample syntax of some commonly used functions, please refer to Appendix A.

Aggregations, More Than Some Sums

The mysteries of the complexities of database storage aren't really that important to an end user, but figuring out how to make that stored data say something meaningful is. This is what DAX lets us do. It takes the data and allows us to aggregate it into insights that enable us to tell a story about what is happening.

I don't know about you, but I can't read 5,000 records, much less 5 million. I can, however, figure out an average value across a certain column of that data, tell you the earliest or most recent date of activity, tell you the first or last relevant value to a given combination of data, or give you a count of records that match a certain data collection. These are all *aggregations*, and Power BI allows us to use each of them with specific types of data.

Aggregations are more than just sums. Table 5-1 helps demonstrate the types of aggregations, the types of data that can have that aggregation applied, and then, finally, whether it can be set as a default aggregation. I'll discuss default aggregations a little later in the chapter, but for now, let's go through the aggregation types at a high level and talk about possible use cases for some of them. If you see an X in the table, that's because that aggregation type doesn't make sense for that data type.

Table 5-1. The selectable aggregations by data type in Power BI

Aggregation type	Numeric	Text	Date	Default eligible?
Sum	Y	X	X	Y
Average	Y	X	X	Y
Minimum	Y	X	X	Y
Maximum	Y	X	X	Y
Count (distinct)	Y	Y	Y	Y (only for numeric)
Count	Y	Y	Y	Y (only for numeric)
Standard deviation	Y	X	X	X
Variance	Y	X	X	X
Median	Y	X	X	X
Earliest	X	X	Y	X
Latest	X	X	Y	X
First	X	Y	N	X
Last	X	Y	N	X
Don't summarize	Y	On by default	On by default	Y (only for numeric)

Sum

The old reliable. We all know what a *sum* is. It's addition. You've known how to add numbers forever. If you're reading this book, I'm going to go out on a limb and say you've probably already used sum functions in Excel or similar products. The good

news is that Sum functions in the same way in Power BI. For a given column of numbers, we will get a sum, or addition, of those numerical values for each given combination of data that is represented in a visual.

This, like so many data concepts, is easier to understand visually. Since that is why we are here, to visualize data, it seems fair to show you rather than tell you what I mean. In Figure 5-1, we see two tables. Both have a sum of office hours attended. They both get the same total, but they have different values for each combination of data.

Course Number	Term Start Date	StudentPreferredPronouns	UsedPowerBI?	OfficeHoursAttended
ISOM 210	Monday, January 04, 2021	He / Him	N	8
ISOM 210	Monday, January 04, 2021	He / Him	Y	6
ISOM 210	Monday, January 04, 2021	She / Her	N	22
ISOM 210	Monday, January 04, 2021	She / Her	Y	4
ISOM 210	Monday, January 04, 2021	They / Them	N	1
Total				**41**

LastName	AssignmentID	OfficeHoursAttended
Avina	12	1
Bainter	8	1
Bainter	9	1
Bainter	10	1
Bones	2	1
Bones	6	1
Bones	7	1
Bones	11	1
Boomhower	4	1
Boomhower	8	1
Cavin	1	1
Cavin	5	1
Cavin	13	1
Damato	10	1
Dezzutti	3	1
Dezzutti	7	1
Dezzutti	11	1
Dezzutti	12	1
Dismukes	8	1
Farquharson	9	1
Farquharson	13	1
Lucia	4	1
Lucia	10	1
Miyamoto	1	1
Miyamoto	2	1
Miyamoto	11	1
Montegalegre	5	1
Montegalegre	6	1
Montegalegre	7	1
Montegalegre	12	1
Monteiro	3	1
Newlon	3	1
Piatt	4	1
Total		**41**

Figure 5-1. Yeah, you get sum!

The table at the top shows the sum of office hours attended by several categorical groupings. So, in this case, the people who attended the ISOM 210 course that started on January 4, 2021, who have the preferred pronouns of she/her, and never used Power BI before the course started, totaled 22 of the 41 total office hours. Here, the total represents the sum of the values in the OfficeHoursAttended column.

The table at the bottom is much different. It shows the breakdown by a student's last name and, for a given assignment ID, the number of office hours they attended. We can see we get the same total hours, but the distribution is different.

If you were to look at the Grades table, you'd note that no student attended more than one office hour for any given assignment ID. In this case, the sum is still calculating a summation; it just happens to be a summation that gets down to one cell's worth of data.

The reason I wanted to show this example is to demonstrate that, by default, Power BI will not show data collections that don't return a value for a given summation. So, we know Ms. Avina attended only one office hour, and that was for Assignment ID 12. We can tell that much more quickly by seeing only data where an actual value is returned, as opposed to viewing results that don't return any data.

Average

There are lots of types of averages. To describe the default aggregation as shown in the options under the Visualizations pane, Power BI is creating a simple average. That simple *average* can be defined as the sum of a given set of values, filtered by all the relevant categories on a visual, then divided by the count of records that are also filtered by all relevant categories on a visual. So, if we had, for a given combination of data, a sum score of 240, and three records made up those 240 points, we would have an average of 80.

Just like the sum, if we end up getting to a combination of categories that returns only one record's worth of data, a value divided by one is itself; that's still technically an average. In Figure 5-2, I've created two new tables with average scores, but I've also included on the left the sum of office hours attended, which we saw in Figure 5-1, and the average of the office hours attended on the right.

Course Number	Term Start Date	StudentPreferredPronouns	UsedPowerBI?	OfficeHoursAttended
ISOM 210	Monday, January 04, 2021	He / Him	N	8
ISOM 210	Monday, January 04, 2021	He / Him	Y	6
ISOM 210	Monday, January 04, 2021	She / Her	N	22
ISOM 210	Monday, January 04, 2021	She / Her	Y	4
ISOM 210	Monday, January 04, 2021	They / Them	N	1
Total				**41**

LastName	AssignmentID	OfficeHoursAttended
Avina	12	1
Bainter	8	1
Bainter	9	1
Bainter	10	1
Bones	2	1
Bones	6	1
Bones	7	1
Bones	11	1
Boomhower	4	1
Boomhower	8	1
Cavin	1	1
Cavin	5	1
Cavin	13	1
Damato	10	1
Dezzutti	3	1
Dezzutti	7	1
Dezzutti	11	1
Dezzutti	12	1
Dismukes	8	1
Farquharson	9	1
Farquharson	13	1
Lucia	4	1
Lucia	10	1
Total		**41**

Figure 5-2. Always be careful with averages, and avoid averages of averages at all costs

Two things about Figure 5-2 might pop out at you. First, just like the sum in Figure 5-1, the total Average of Score across both tables is the same. Second, doesn't the Average of OfficeHoursAttended on the right look strange? It's an average of 1, but there are blank values. What does that mean? Why are there blank values? Didn't I just say the default behavior was not to show values where there is no data? The table at the bottom of Figure 5-1 showed us that, indeed, for any given assignment, no one attended more or less than one office hour. However, blanks are not zeros. True blanks, or *nulls* in database parlance, are not uncommon in many datasets.

The important takeaway is that Power BI does not treat nulls as zeros and ignores them when generating a count of values. If nulls are ignored in generating a count, our calculation description for the average in Power BI still holds true, and that total average in Figure 5-2's right table still makes sense.

Now, the big question is how to calculate an average for Ms. Avina. Should it be 1 hour divided by 1 instance of attending office hours, or should it be 1 hour divided by 14 opportunities to attend office hours, with 13 zeros? It's a question we can only answer for ourselves, as the analyst or report author, and that really depends on what we want our average to mean.

The second question is why are there blank values being returned for the Average of OfficeHoursAttended on the right table in Figure 5-2? I did say that the default behavior was not to return values when there would be no data to display. However, on a visual where there is a second aggregation that does return a value for a given combination of data, all other aggregations will still display, even if they return a blank value.

Figure 5-3 is a simple rendition, taking Figure 5-2's right table and making a second copy of it without the average score. You can see the two tables together and find that, indeed, it is the inclusion of that second aggregation that causes the blank values to appear in the visual. It also helps demonstrate the previous point about average calculation ignoring blank values.

LastName	AssignmentID	Average of Office Hours Attended
Avina	12	1.00
Bainter	8	1.00
Bainter	9	1.00
Bainter	10	1.00
Bones	2	1.00
Bones	6	1.00
Bones	7	1.00
Bones	11	1.00
Boomhower	4	1.00
Boomhower	8	1.00
Cavin	1	1.00
Cavin	5	1.00
Cavin	13	1.00
Damato	10	1.00
Dezzutti	3	1.00
Dezzutti	7	1.00
Dezzutti	11	1.00
Dezzutti	12	1.00
Dismukes	8	1.00
Farquharson	9	1.00
Farquharson	13	1.00
Lucia	4	1.00
Lucia	10	1.00
Miyamoto	1	1.00
Miyamoto	2	1.00
Miyamoto	11	1.00
Total		**1.00**

LastName	AssignmentID	Average of Score	Average of Office Hours Attended
Avina	1	72.00	
Avina	2	76.00	
Avina	3	72.00	
Avina	4	71.00	
Avina	5	90.00	
Avina	6	94.00	
Avina	7	61.00	
Avina	8	74.00	
Avina	9	54.00	
Avina	10	66.00	
Avina	11	66.00	
Avina	12	55.00	1.00
Avina	13	66.00	
Avina	14	20.00	
Bainter	1	75.00	
Bainter	2	74.00	
Bainter	3	99.00	
Bainter	4	100.00	
Bainter	5	93.00	
Bainter	6	100.00	
Bainter	7	64.00	
Bainter	8	89.00	1.00
Bainter	9	77.00	1.00
Bainter	10	88.00	1.00
Bainter	11	68.00	
Bainter	12	100.00	
Total		**77.07**	**1.00**

Figure 5-3. Blanks? We don't need no stinkin' blanks! Yet including a second aggregation will cause blank values to appear in a visual.

Minimum and Maximum

Minimum and Maximum can be tricky because they don't always lead to the results you're looking for. These are two separate summarizations, but they are inverses of each other.

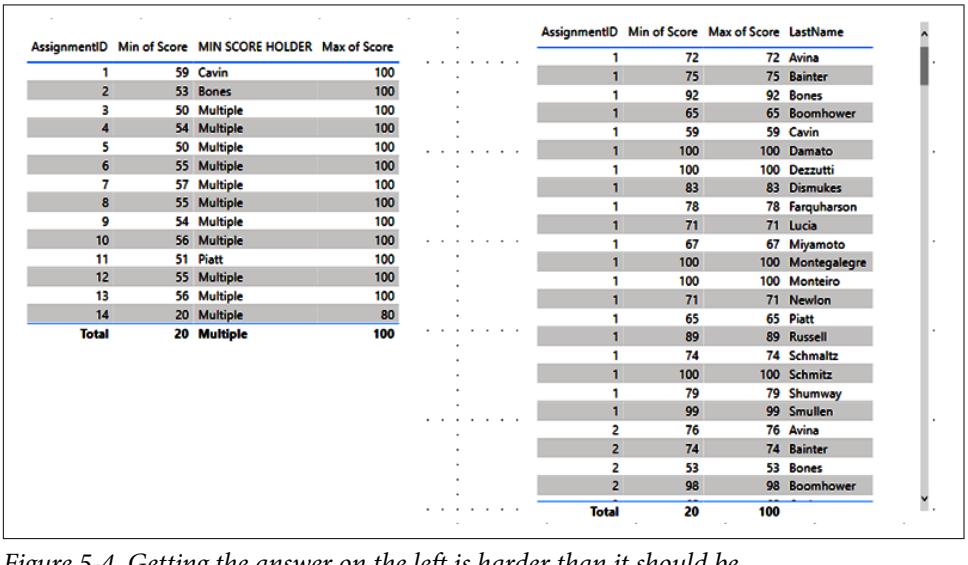
We've all been in a scenario where we needed to know the highest and lowest values for a given category. Imagine being an engineer reviewing data for how a new machine is performing. You know what the tolerances are, let's say, for the internal temperature of the machine. There's a sensor that's giving you readings of the internal temperature and sending that data to your data warehouse, where you are looking at it in Power BI. You need to know if the machine is ever getting too hot or too cold. A quick check of the minimum and maximum temperatures might help you do that.

In our school scenario, we want to know the highest and lowest score for each given assignment. While we are not grading this class on a curve, it's helpful to know how big the gap was between our top performer(s) and our bottom performer(s). You can imagine a teacher wanting to know if the gap is consistent. Was there a specific

assignment that was possibly too hard or too easy? Understanding the local minimum and local maximum can help answer those questions.

Remember that, as with all aggregations, the minimum and maximum are context dependent. If I add last name or first name to the minimum value, I'm going to see that individual's minimum value. Don't confuse the minimum and maximum with global minimum or maximum! When you add extra columns or use a slicer, remember that your new min or max is the min or max in the context you have provided. We can see an example of this in Figure 5-4. I show the min and max scores by AssignmentID on the left. On the right I do the same, except I add LastName. But it doesn't give me the result I'm looking for. Instead, it adds LastName as a category to the visual.

Now, for the example, I must create a way to take the value result and link it back to whatever criteria I want to discover about the minimum or maximum. I created a DAX measure that gives me the score holder's name, if one person matches, and tells me its multiple if multiple people have that minimum score and assignment combination.



AssignmentID	Min of Score	MIN SCORE HOLDER	Max of Score
1	59	Cavin	100
2	53	Bones	100
3	50	Multiple	100
4	54	Multiple	100
5	50	Multiple	100
6	55	Multiple	100
7	57	Multiple	100
8	55	Multiple	100
9	54	Multiple	100
10	56	Multiple	100
11	51	Piatt	100
12	55	Multiple	100
13	56	Multiple	100
14	20	Multiple	80
Total	**20**	**Multiple**	**100**

AssignmentID	Min of Score	Max of Score	LastName
1	72	72	Avina
1	75	75	Bainter
1	92	92	Bones
1	65	65	Boomhower
1	59	59	Cavin
1	100	100	Damato
1	100	100	Dezzutti
1	83	83	Dismukes
1	78	78	Farquharson
1	71	71	Lucia
1	67	67	Miyamoto
1	100	100	Montegalegre
1	100	100	Monteiro
1	71	71	Newlon
1	65	65	Piatt
1	89	89	Russell
1	74	74	Schmaltz
1	100	100	Schmitz
1	79	79	Shumway
1	99	99	Smullen
2	76	76	Avina
2	74	74	Bainter
2	53	53	Bones
2	98	98	Boomhower
Total	**20**	**100**	

Figure 5-4. Getting the answer on the left is harder than it should be

For this type of example, we might be better off trying to shape our data a little bit to help us target the type of result we're looking for. We could go back to the source data (an Excel spreadsheet) and do some calculations there that would add that data preingestion, maybe do a Power Query transformation to get the student's name into the Grades table. Or we could write a DAX measure that would return a specific value. Remember, our general rule for data transformation is to do transformation as close to the data source as possible.

We can't do complex data shaping in Excel, but we could probably add some columns to our Grades worksheet with some `MINIFS` and `MAXIFS` functions, and then do some `VLOOKUP` magic on those values. But in Excel, that would return only the first value where those conditions were true, not all of them, and it wouldn't identify if there were multiple. Could we continue down this Excel rabbit hole until we got to a point where it was working? Sure. Am I going to tell you that you're wrong if you were to do that? Absolutely not.

If this were in a SQL Server database and you wanted to write a query against the table that got the min and max values grouped by AssignmentID, then wrote some sort of subquery to join on those results, and then got the name or names of the people who had those scores, would I tell you that you're wrong? Again, no. In my case, because this is the Aggregations, Measures, and DAX chapter, I chose to do an example with a DAX measure. What I would say is that if you feel like you need to modify the shape or form of data to get a result that you're looking for, make sure you document your work and changes for later!

Standard Deviation, Variance, and Median

If you look at Table 5-1, Standard Deviation, Variance, and Median are the last of the numeric-only aggregations, and these are not selectable as default aggregations. These aggregations are more statistical in nature and tend to have more specific use cases, which is why they're not available to be default summarizations. Microsoft even helps us a little by putting them at the bottom of the list, so as to not draw attention to them to prevent confusion, as we can see in Figure 5-5.

Out of these three, the median is the most familiar. For a given array of *N* numbers in numerical order, the *median* is the number that leaves an equal amount of values on either side of the array from that value. If *N* is even, then the median is the average of the two values in the middle of the array that leave an equal number of values on either side of the array. In shorthand, it would be okay to call the median the middle number of an array.

Variance and standard deviation go hand in hand. Variance measures how spread out a set of numbers is from that set's average value. To calculate variance, you get the average value for a set of numbers and then, for each and every value in that dataset, you take the square of that value minus the average and sum all of those variances to get the total variance. The standard deviation is the square root of the variance. The *standard deviation* is often used to describe how close values tend to be to the average for that set.

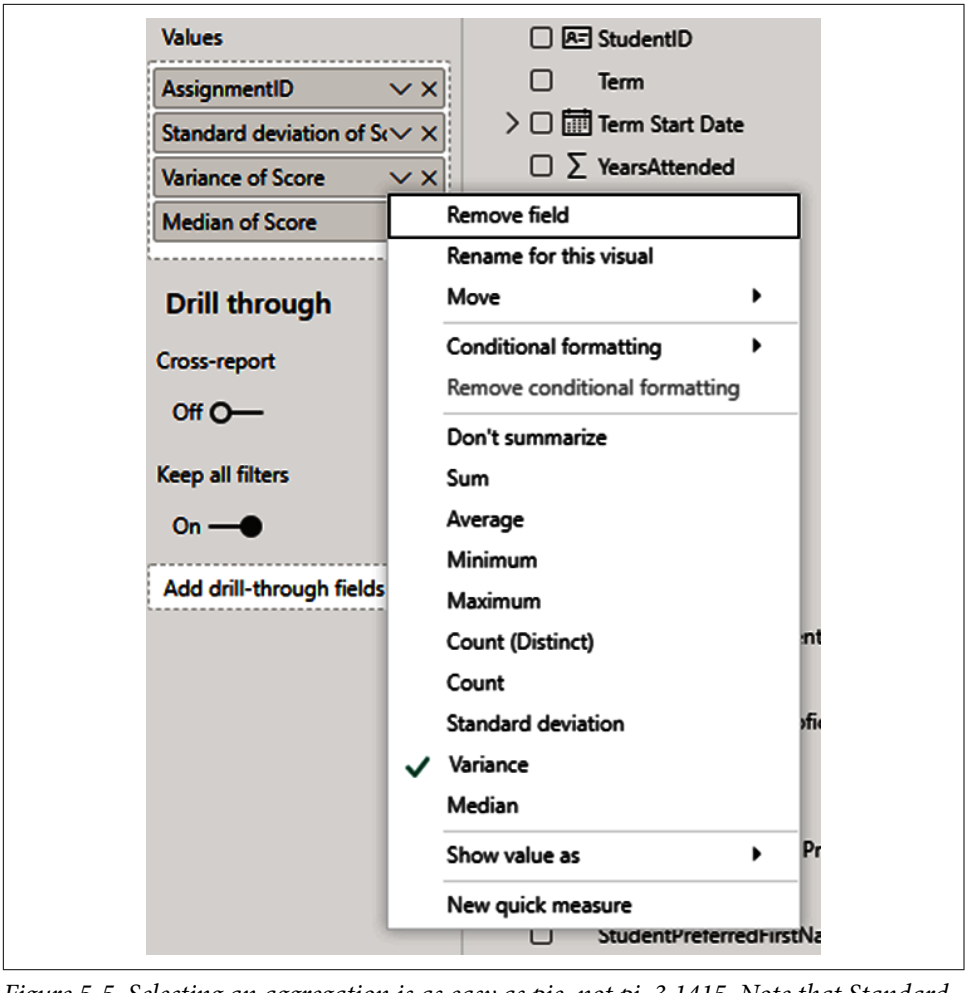


Figure 5-5. Selecting an aggregation is as easy as pie, not pi, 3.1415. Note that Standard deviation, Variance, and Median cannot be defaults.

Count and Count (Distinct)

Count and Count (Distinct) are two very useful aggregations that can be used by any data type. You can use these to count occurrences of text, dates, or numerical instances of data. The difference between the selections Count and Count (Distinct) are that Count will count duplicate instances of that data, whereas Distinct won't. This count is performed against the column of data that is being referenced.

Figure 5-6 has four demonstrations of Count and Count (Distinct). First, on the top left is a list of scores across all assignments. For that table, I am not aggregating the score, so I'm getting the raw values and then performing a Count of score and a

Count (Distinct) of score to see the number of times that score appeared for that assignment.

One thing to note, with most aggregations, Power BI will create an alias to help readers identify the aggregation if it isn't sum. However, Power BI aliases Count (Distinct) in the same way it aliases Count, so I've manually aliased Count (Distinct) in the visuals for clarity. You can alias any object in a visual by double-clicking the item in the Values section of the Visualizations pane and typing in a new name.

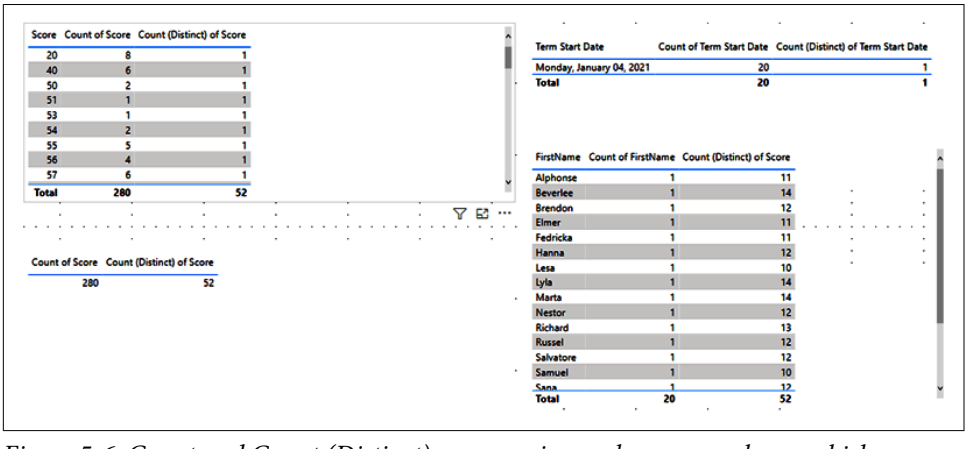


Figure 5-6. Count and Count (Distinct) are amazing, as long as you know which one you're looking at

Note in the top-left example, we have the raw score, the number of times that score appears in the dataset, and then the distinct count, which is one for every value. The total shows 52 unique values. But in the visual where each value is listed, the distinct count of that individual value will always be 1. When we look at the bottom left, it's the same visual, just with the score value removed, and we can see the total number of scores, 280, and the number of distinct score values, which is 52.

The top-right example shows us a count for the occurrences of a specific date, in this case, the term start date. At this time, we have only one semester's worth of data in the dataset, so we have one unique term start date. That value appears 20 times in the table from which it originates. Remember, the way this table is constructed, the distinct count would be 1 no matter what because the table specifies a value, and a distinct count of that value will always be 1.

The bottom-right example shows the scenarios we've looked at in a bit of a different light. We have a list of students' first names and the count of those names, which are all 1. This is not a distinct count; we just happen to have no names that appear twice. But then we can take the Count (Distinct) of scores and can see how many unique scores each individual obtained. With 14 assignments, we would expect the distinct

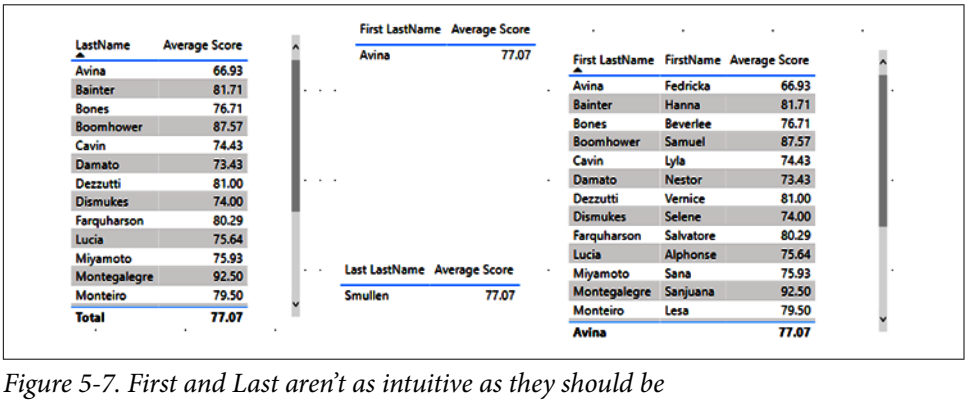
count of scores by person to be high, but notice it's not uniformly 14 either. Some people had the same score more than once over the course of the semester.

First, Last, Earliest, and Latest

I've grouped these together because they're not really aggregations in the classic sense. These do not group together; in fact, they really do the opposite. They also don't do what you think they would, which would be to serve as a filter (or at least they don't do that without additional context or having a bidirectional relationship). As we note in Table 5-1, First and Last are unique to text fields, while Earliest and Latest are unique to date and time fields.

First will provide the first value, alphabetically, that matches a given set of data criteria as listed in the visual. If it's used by itself, First will provide the first alphanumeric value in the column.

Last does the inverse of this. It will provide the last value, alphabetically, that matches the given criteria. A quick example can be seen in Figure 5-7, where we see on the left a list of students by their last names and their average scores for their assignments. But notice that Ms. Avina's average score in the table on the right doesn't match what it is on the left. In fact, the average score on the right is just the average score of the class. This is happening because our relationship between the Survey Data table and the Grades table is unidirectional. The same thing happens if we were to use the last LastName. Note, though, that when we give just a little extra context, as we do on the far right side of Figure 5-7, we get the expected result.



LastName	Average Score
Avina	66.93
Bainter	81.71
Bones	76.71
Boomhower	87.57
Cavin	74.43
Damato	73.43
Dezzutti	81.00
Dismukes	74.00
Farquharson	80.29
Lucia	75.64
Miyamoto	75.93
Montegalegre	92.50
Monteiro	79.50
Total	**77.07**

First LastName	Average Score
Avina	77.07

Last LastName	Average Score
Smullen	77.07

First LastName	FirstName	Average Score
Avina	Fedricka	66.93
Bainter	Hanna	81.71
Bones	Beverlee	76.71
Boomhower	Samuel	87.57
Cavin	Lyla	74.43
Damato	Nestor	73.43
Dezzutti	Vernice	81.00
Dismukes	Selene	74.00
Farquharson	Salvatore	80.29
Lucia	Alphonse	75.64
Miyamoto	Sana	75.93
Montegalegre	Sanjuana	92.50
Monteiro	Lesa	79.50
Avina		**77.07**

Figure 5-7. First and Last aren't as intuitive as they should be

In the figure, we can see the average scores for the students, then see the weirdness that happens with First and Last when left alone. Then, on the far right, we see what happens when First and/or Last is given additional context. My general rule of thumb when using First or Last is to not use them as filter conditions, but treat them more

like values you are seeking to find. What is the first value where conditions A, B, and C are true? What is the last value where those conditions are true?

Earliest and *Latest* function the exact same way, but they do it with dates instead of text and order the items chronologically. It is important to note that there is also an `EARLIEST` DAX function that is not quite identical to the aggregation happening here, so if someone does mention Earliest, you can ask if they're talking about the default aggregation options for dates or the DAX function.

Measures and DAX Fundamentals

We aggregate data so we can understand the data points underneath. Sometimes we want to make sure that the calculation is performed in a specific way, or that future users can see an explicit calculation in our data model. Sometimes our column name is sufficient for understanding what an aggregation is doing. What is often not understood, though, is that whether you are dragging a column into the Values section to get a sum or average or creating a DAX measure to perform a calculation, a measure is being used to create that aggregation in both scenarios.

Implicit and Explicit Measures

Since Power BI writes DAX behind the scenes to power every visual, and we aren't required to write out every measure, we see that there are both implicit measures and explicit measures.

An *implicit measure* is not strictly defined before being brought into a visual. This happens when you drag a column in, and it sums, or you tell it to average or perform some other aggregation.

An *explicit measure*, on the other hand, is a specific DAX measure that you create in your data model with a predefined calculation that you then add to a visual. Implicit measures are convenient but are limited to the aggregations we talked about previously. Explicit measures allow for more complicated calculations or specific groupings that might be hard to achieve without additional fields or columnar context.

It is also entirely possible to see the DAX that is generated when you use an implicit measure. You can, in fact, see the DAX that generates an entire visual in Power BI! As in Chapter 3 when we discussed using the Advanced Editor to see M that is generated in Power Query, you can use the "Performance analyzer" pane to see DAX that is generated when a visual is refreshed.

I've created a simple table that shows the Average Score by AssignmentID (Figure 5-8). We've seen this before. What I'm doing differently here is using the measure for Average Score and the implicit measure by using the Score column and

setting the aggregation to average. You'll note that they get the same results. That's a good sign!

LastName	Average Score
Avina	66.93
Bainter	81.71
Bones	76.71
Boomhower	87.57
Cavin	74.43
Damato	73.43
Dezzutti	81.00
Dismukes	74.00
Farquharson	80.29
Lucia	75.64
Miyamoto	75.93
Montegalegre	92.50
Total	**77.07**

First LastName	Average Score
Avina	77.07

Last LastName	Average Score
Smullen	77.07

First LastName	FirstName	Average Score
Lucia	Alphonse	75.64
Bones	Beverlee	76.71
Shumway	Brendon	70.57
Schmaltz	Elmer	77.50
Avina	Fedricka	66.93
Bainter	Hanna	81.71
Monteiro	Lesa	79.50
Cavin	Lyla	74.43
Newlon	Marta	69.14
Damato	Nestor	73.43
Russell	Richard	76.57
Smullen	Russel	76.64
Avina		**77.07**

Figure 5-8. If it gets aggregated, it's a measure at some point

Now if we click the "Copy query" link in the "Performance analyzer," we can see the DAX that is generated. In Figure 5-9, I've copied the DAX and put it into my favorite DAX writing tool, DAX Studio.

I want you to focus on lines 6 and 7. The other lines aren't important right now. Line 6 is calling our explicit measure, the Average Score measure. Line 7 is calling an implicit measure, our chosen aggregation of Average of Score.

```
1  // DAX Query
2  DEFINE
3    VAR __DS0Core =
4      SUMMARIZECOLUMNS(
5        ROLLUPADDISSUBTOTAL('Grades'[AssignmentID], "IsGrandTotalRowTotal"),
6        "Average_Score", 'Grades'[Average Score],
7        "AverageScore", CALCULATE(AVERAGE('Grades'[Score]))
8      )
9
10   VAR __DS0PrimaryWindowed =
11     TOPN(502, __DS0Core, [IsGrandTotalRowTotal], 0, 'Grades'[AssignmentID], 1)
12
13 EVALUATE
14   __DS0PrimaryWindowed
15
16 ORDER BY
17   [IsGrandTotalRowTotal] DESC, 'Grades'[AssignmentID]
18
```

Figure 5-9. Power BI's DAX generator knows the power of CALCULATE, and soon you will too

When Power BI needs to create a measure to satisfy the implicit need, we can see it creates an explicit piece of code to generate that measure for the internal calculation engine. In this case, that looks like this:

```
CALCULATE(AVERAGE('Grades'[Score]))
```

If you go into the PBIX file for Cool School University ISOM 210 and look at the measure for Average Score that already exists, you'll notice it's the exact same syntax. `Average_Score` and `AverageScore` from lines 6 and 7 are actually the same, except in line 6 it's calling the explicit measure I've created, and in line 7 it's creating an implicit measure to accomplish the same task. And Power BI also happened to generate the same code I used to create my measure.

A lot is going on in Figure 5-9, and not all of it is super relevant to measure creation in DAX, but what we can do is evaluate code that is generated and try to learn from it to see how DAX syntax works.

DAX Syntax Fundamentals

To learn the basics of DAX syntax, we're going to start with a simple calculation using an `AVERAGE` function against a single column. We will then add to our simple example a use of the `CALCULATE` function and that will look like line 7 from Figure 5-9. Let's look at Figure 5-10 to get a look at our simplified DAX average.

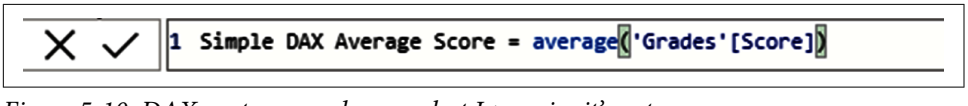


Figure 5-10. DAX syntax sounds scary, but I promise it's not

Here, from left to right, we first have the title of our measure, in this case "Simple DAX Average Score." The equals sign sets the title apart from the actual calculation that is to follow. Average is our function. The function then accepts certain criteria, in our case, a column reference.

The first parenthesis sets the function apart from the arguments or criteria it's looking for. Next, we have the table name enclosed in single quotes and column name enclosed in brackets that we are looking to pass to the function.

The second parenthesis identifies that all the arguments for the preceding function are present. Let's put that all together and make it sound a little more like English.

I have a DAX measure called Simple DAX Average Score. That DAX measure is defined as the Average function using the Score column from the Grades table as its parameter to calculate against. In our case, this will return the average score from the Grades table and is open to be modified by any applicable context. For your reference, all table names that have a space are always enclosed in single quotes, and all column names are always enclosed in brackets. As far as best practices when writing your own DAX, I always recommend putting your table names in single quotes regardless of whether they contain spaces.

Looking at this in a more technical way, all the simple aggregations we looked at earlier have the same basic DAX syntax for their function. Sum, Average, Count, DistinctCount, Min, and Max are all the same. First, Last, Earliest, and Latest are just calculations of the Min or Max. That syntax is as follows.

```
FUNCTION('TABLE'[COLUMN])
```

That's it. That will get you a simple explicit measure that will be filtered by all other context in the visual and any applicable slicers on your worksheet. With this basic context understood, let's go one step up from here, get back to the full version of line 7 from Figure 5-9, and talk about `CALCULATE`.

CALCULATE

The `CALCULATE` function is, in many ways, the Swiss army knife of DAX functions. Like many things in life, 80% of DAX problems can be solved with 20% mastery. If you can master `CALCULATE`, you will be well on your way to that early level of mastery.

The `CALCULATE` function is very simple. It is a wrapper that evaluates an expression in a modified filter context. What does that mean? You can evaluate functions and then preset filter contexts.

Think about being able to use a `WHERE` clause in SQL. You want to limit results to where X = Y or Z > 100, for instance. `CALCULATE` allows you to pass these `WHERE` clause–type parameters into your DAX formula in an explicit way, which means that they will always apply, regardless of any other context. You can probably think of tons of use cases where this would be helpful.

Want to compare this year's sales to date to the sales year-to-date of the previous year? `CALCULATE` can help you do that. Maybe you need to see how another product's sales count compares to a different set of products? You can do that. Do you want to provide a dynamic calculation that passes filter context based on the results of another calculation, like yesterday's date? You can do that.

So, let's review line 7 of Figure 5-9 and discuss the DAX that Power BI put together when it created our implicit measure:

```
"AverageScore" = CALCULATE(AVERAGE('Grades'[Score]))
```

`AverageScore` is the name of the implicit measure. We know how to read the Average function from the previous section. `CALCULATE` wraps that function into a larger function. That's what the parenthesis in front of `AVERAGE` and on the other side of the first right parenthesis are doing.

Let's say we want to compare our students' average scores, but want to compare them to another group result quickly. A great example of this is to take a category and then see how people did against others in that category. Let's look at the average score of

students who have a self-described intermediate level of proficiency in Excel, and see how each of those students performed against their cohort's average.

As we have seen, getting everyone's individual average in a visual isn't hard, but let's say we want to compare that value to the average of a specific category. For instance, is the average score higher or lower than the average score of those people with intermediate Excel proficiency? The CALCULATE function helps us with this by allowing us to define the filter context. Let's look at the code for our new example in Figure 5-11 and break it down.

```
1  Intermediate Excel Average Score =
2  CALCULATE (
3      AVERAGE ( 'Grades'[Score] ),
4      'Survey Data'[ExcelSelfDescribedProficiency] = "Intermediate"
5  )
```

Figure 5-11. Ah, the beauty of properly formatted DAX

As we are going to break down a more complicated DAX statement, I wanted to make sure that the code was formatted to be easier to read. Several DAX formatting options are available online and through the previously mentioned DAX Studio. Let's go through this line by line.

In line 1, we have the name of our measure, in this case Intermediate Excel Average Score.

In line 2, we have established our CALCULATE wrapper and put down the first parenthesis of the CALCULATE function to identify that what comes next is the function that will be called.

In line 3, we call the AVERAGE function, as we did previously in our simple example. Again, note inside the parenthesis of the AVERAGE function, we identify the table name with the single quotes and the column name in regular brackets. Then, at the end of line 3, we have our first new wrinkle, and that's the comma after the right parenthesis.

Now we can look at the syntax for the CALCULATE function to understand what is about to happen. CALCULATE's syntax always follows the following format:

```
CALCULATE (Function(), Filter Statement 1, Filter Statement 2, ...,
  Filter Statement N)
```

Notice that the first comma separates the function from the first filter statement, and then commas are used to separate each filter statement that comes after the first from the last. Yes, that's right, CALCULATE can pass multiple filter conditions. But now that we understand what that comma is doing in line 3, separating the wrapped function from the filter condition that is about to come after, we can move to line 4.

In line 4, we have a very simple true/false, or Boolean, statement. In the Survey Data table, we have a column called ExcelSelfDescribedProficiency. We want to calculate the average score for only the people who have a self-described intermediate level of proficiency, so after the comma in line 3, we identify a table name and a column name and set it to be equal to a value. Notice that `Intermediate` is wrapped in double quotes. Text must always be wrapped in those double quotes, and if it is wrapped in those double quotes, Power BI will treat the value as though it were text. We will come back to this issue in a little bit.

Finally, in line 5 we have the last right parenthesis, which identifies to the `CALCULATE` function that everything is now wrapped and ready to go. Now let's look at Figure 5-12 to see what that looks like in a table with our students, their level of proficiency, and the average score.

LastName	ExcelSelfDescribedProficiency	Average Score	Intermediate Excel Average Score
Avina	None	66.93	
Bainter	Intermediate	81.71	81.71
Bones	None	76.71	
Boomhower	Intermediate	87.57	87.57
Cavin	Intermediate	74.43	74.43
Damato	Beginner	73.43	
Dezzutti	Beginner	81.00	
Dismukes	Advanced	74.00	
Farquharson	Beginner	80.29	
Lucia	Beginner	75.64	
Miyamoto	Beginner	75.93	
Montegalegre	Intermediate	92.50	92.50
Monteiro	Advanced	79.50	
Newlon	None	69.14	
Piatt	None	66.00	
Russell	Beginner	76.57	
Schmaltz	None	77.50	
Schmitz	Advanced	85.36	
Shumway	None	70.57	
Smullen	Beginner	76.64	
Total		**77.07**	**84.05**

Figure 5-12. `CALCULATE` can enforce its own filter context

When we look at this simple table, we can see the average score we've seen multiple times before, but notice that our new Intermediate Excel Average Score measure shows values for only the people who have intermediate self-described proficiency! This is a great example of basic DAX wrapping in `CALCULATE` to show you how that works.

However, what if we wanted to show in this table the total Intermediate Excel Average Score for everyone, so we could quickly see how each person did compared to that 84.05 number, regardless of their proficiency?

We Heard You Like DAX, So We Put Some DAX in Your DAX

As mentioned before, the CALCULATE function can take multiple filter context conditions. However, those filter conditions can themselves also be DAX functions. In Figure 5-12, we saw that we could use CALCULATE to get the specific average for our intermediate Excel users, but we didn't quite get all the way there to make it nice and easy to compare those users.

What I really want to do is compare everyone to the 84.05 value, which is the average score of everyone who had intermediate Excel proficiency. What we need is a calculation that takes the average score of those intermediate Excel users and ignores all the other context or filters. We can do this with the ALL statement.

ALL is an operator that returns all the records, ignoring any filters that might have been applied. ALL comes in a couple of flavors. We will use the simplest one for our example, but the ALL statement can accept a table value or column value to target a specific context to remove filters from. You can also pass no value in the ALL statement to remove all of the filter context. As we did in Figure 5-11, let's take a look at Figure 5-13 to see how we can modify CALCULATE with a second filter function using another DAX statement as the filter condition.

```
Intermediate Excel Average Score with ALL =
CALCULATE (
    AVERAGE ( 'Grades'[Score] ),
    ALL (),
    'Survey Data'[ExcelSelfDescribedProficiency] = "Intermediate"
)
```

Figure 5-13. Just one step down the DAX rabbit hole

You may notice Figure 5-13 doesn't look that different from Figure 5-11. We really added only one line, but remember to put it into the context of how CALCULATE works: `CALCULATE( Function (), Filter 1, Filter 2, ..., Filter N)`.

What we are doing now is adding a filter, in this case, replacing filter 1 and making what was formerly filter 1, now filter 2. For the example provided in Figure 5-13, the order of the filters doesn't matter, but, as a warning, it might in more complicated examples. The ALL function now serves as filter 1, and when the ALL function is followed by nothing within parentheses, it means to remove all filter context for the result.

Think of the DAX statement in normal terms like this. I am going to calculate the average score of intermediate Excel users. When I display that value, I want it to display the average of all intermediate Excel users, regardless of any other context that

exists in the visual or any other slicers or filters that might normally apply. To see how this result is different, look at Figure 5-14.

LastName	ExcelSelfDescribedProficiency	Average Score	Intermediate Excel Average Score	Intermediate Excel Average Score with ALL
Avina	None	66.93		84.05
Bainter	Intermediate	81.71	81.71	84.05
Bones	None	76.71		84.05
Boomhower	Intermediate	87.57	87.57	84.05
Cavin	Intermediate	74.43	74.43	84.05
Damato	Beginner	73.43		84.05
Dezzutti	Beginner	81.00		84.05
Dismukes	Advanced	74.00		84.05
Farquharson	Beginner	80.29		84.05
Lucia	Beginner	75.64		84.05
Miyamoto	Beginner	75.93		84.05
Montegalegre	Intermediate	92.50	92.50	84.05
Monteiro	Advanced	79.50		84.05
Newlon	None	69.14		84.05
Piatt	None	66.00		84.05
Russell	Beginner	76.57		84.05
Schmaltz	None	77.50		84.05
Schmitz	Advanced	85.36		84.05
Shumway	None	70.57		84.05
Smullen	Beginner	76.64		84.05
Total		**77.07**	**84.05**	**84.05**

Figure 5-14. Take a look at ALL the 84.05s

What is our new measure doing? It's calculating the average score of everyone with an intermediate Excel proficiency and then applying that value to every data combination in the visual, regardless of its filter context. When we look at the Intermediate Excel Average Score that we put together for Figure 5-12, we can see it did not return results for users who were not of intermediate proficiency. That would make sense. The calculation is filtered by the visual's context.

Likewise, while we see the total Average Score in Figure 5-12, everyone who is an intermediate user returned their individual average, and we can see their individual average was the same as their average. That doesn't help us compare the result, though.

However, with this consistent value in place, I could do something very simple like turn this into a line and clustered column chart to quickly see which of my students are above or below this new average line. We can see an example of this in Figure 5-15, along with a slicer that would allow us to look at different groupings to see how they might compare.

In this case, we will look at the students who claimed advanced Excel proficiency and see how they compare to the intermediate average. Notice in Figure 5-15 that our 84.05 line is not affected by the slicer being set to Advanced because, with the `ALL` statement inside our `CALCULATE` filter, it's ignoring that filter context.

LastName	ExcelSelfDescribedProficiency	Average Score	Intermediate Excel Average Score	Intermediate Excel Average Score with ALL
Avina	None	66.93		84.05
Bainter	Intermediate	81.71	81.71	84.05
Bones	None	76.71		84.05
Boomhower	Intermediate	87.57	87.57	84.05
Cavin	Intermediate	74.43	74.43	84.05
Damato	Beginner	73.43		84.05
Dezzutti	Beginner	81.00		84.05
Dismukes	Advanced	74.00		84.05
Farquharson	Beginner	80.29		84.05
Lucia	Beginner	75.64		84.05
Miyamoto	Beginner	75.93		84.05
Montegalegre	Intermediate	92.50	92.50	84.05
Monteiro	Advanced	79.50		84.05
Newlon	None	69.14		84.05
Piatt	None	66.00		84.05
Russell	Beginner	76.57		84.05
Schmaltz	None	77.50		84.05
Schmitz	Advanced	85.36		84.05
Shumway	None	70.57		84.05
Smullen	Beginner	76.64		84.05
Total		**77.07**	**84.05**	**84.05**

Figure 5-15. It's ALL about the filter context

Row and Filter Context

The most important lesson that you will learn about DAX as you develop your skills will be to understand row context and filter context. In many ways, this is the least intuitive but most important lesson about DAX you can learn, which will take your mastery of DAX to the next level.

DAX is a language that queries columns. Analysis Services Tabular and Power BI store their data in columnar data store databases. DAX statements query columns to get results for measures or reference other columns when building calculated columns.

When we look at our data in the Data view, we see that the data is still a collection of rows and columns, and when we look at the table visuals we've built to showcase our DAX examples, they're tables with rows and columns. Those row values impact our measure results.

Going back to Figure 5-12, our intermediate Excel average score showed results only where the row contained a record indicating a user's intermediate level of Excel proficiency. This would still be true even if we removed the specific field regarding proficiency from the visual; it's because the LastName field comes from the same table and implicitly identifies their Excel proficiency status, being just a different field in the same table.

This brings us to row context. *Row context* occurs anytime a table is iterated on, or said another way, anytime a formula calls for going over a table row by row. This can happen both explicitly, as seen in Figure 5-12, or implicitly, as we described in the

previous scenario. Row context always applies when we create calculated columns using DAX because the results of a given record for a calculated column are always calculated at the row level.

Certain DAX functions always iterate over a table. These functions can, therefore, be useful when you want to do more than get a simple aggregation for a column because what you really want is an aggregation based on some combination of data for each row of data. You want to return a value that is an expression for each row in a table. I like to call these functions the *X functions* `SUMX`, `AVERAGEX`, `COUNTX`, `MINX`, `MAXX`, and `PRODUCTX`.

You can imagine these X functions as making implicit calculated columns and then taking the desired aggregation of those calculated columns. A classic example of when you might use a function like this is for a sales table with price and quantity sold. If you try to take the sum of the quantity times the sum of the prices, you're going to get a result that doesn't make a ton of sense.

What you really want is something more like the sum of each record's price multiplied by quantity. That's what `SUMX` does, and it does this with row context. Row context is often seen at the visual level, but always happens at the data storage level. Just because Power BI stores its data as columns and computes its data as columns doesn't mean that rows and row context don't matter!

With row context out of the way, we can talk about *filter context*. The first thing to note is that while we discuss filter context second, computationally, it happens first. Filters are applied to the data before any DAX gets computed. This has the benefit of getting to run a calculation against a smaller amount of data instead of over the entirety of the column each time. It's easier to filter out 50 of 100 records and then add the 50 records than it is to add the 100 records, then pick out each record that isn't relevant, and then subtract those records from the total.

Filters on tables apply to all rows of the table that meet the filter condition. From our instance in Figure 5-12, the calculation says to calculate the average score for people with intermediate proficiency. It first filters the table to only those people who have intermediate proficiency and then runs the result. If there were no other columns but LastName and that measure, we would see only the last names that would return values because the table gets filtered first and then passes that filter along its relationship to the other table.

If more than one filter is in place, only the records that meet all the filter criteria are shown. If you want to think of it as a Venn diagram with filter A and filter B, if both filters were on, you would get only the result that would meet both, or the overlapping part of that diagram. In SQL terms, you could think of it as an `INNER JOIN`, in which only the records where both conditions were true would be shown. Remember, filters always get applied first and do not interact with row context.

One Final DAX Example

With these things in mind, let's try our hand at creating one more DAX measure to go a couple of levels up in difficulty from what we've done previously. We are going to start with the measure we made for Figure 5-13 and build on it from there. This example uses some unique DAX functions, and I don't want you to worry about those specifically, but see how the context comes together with the syntax to make a readable DAX statement.

In this example, we want to expand our analysis. We don't want to compare everyone to the intermediate cohort. We want to compare everyone to their own cohort. However, to do that, we need to find a way to pass a specific value—in our case, someone's level of Excel proficiency—through the `CALCULATE` function.

The next problem is, there are four possible values, and we want to make sure that each is called correctly, but we also want the function to work if no value is selected. There are certainly a couple of ways to tackle this problem. However, I intentionally tried to find the most obnoxious one so I could demonstrate how context and syntax come together to make the DAX statement understandable. Let's look at that example in Figure 5-16.

```
1  Filtered Excel Proficiency Average Score =
2  IF (
3      HASONEVALUE ( 'Survey Data'[ExcelSelfDescribedProficiency] ) = TRUE (),
4      CALCULATE (
5          AVERAGE ( 'Grades'[Score] ),
6          ALL (),
7          'Survey Data'[ExcelSelfDescribedProficiency]
8              = SELECTEDVALUE ( 'Survey Data'[ExcelSelfDescribedProficiency] )
9      ),
10     CALCULATE ( AVERAGE ( 'Grades'[Score] ), ALL () )
11 )
```

Figure 5-16. It's not as bad as it looks, I promise!

So, the first thing we have here is going to be familiar to our Excel users. In line 2, we have an `IF` statement. `IF` statements in DAX are similar to the way they function in Excel:

```
IF (Conditional Statement, Conditional Statement is True result,
Conditional Statement is False result).
```

Immediately, I know I'm looking to see what the conditional statement is and what the results are based on whether the conditional statement is true or false. Let's go to line 3.

Our conditional statement here is to say that if the column of ExcelSelfDescribedProficiency is returning one result, for whatever reason, then do the first thing; otherwise, do the second thing. A conditional statement must have a condition to be met. So, in this case, the `HASONEVALUE` statement is testing whether the column has more than one value and then returning a `TRUE` or `FALSE` statement.

Lines 4 through 9 detail what should happen if the statement is true. In this case, we have the first couple of lines we've seen before until we get to line 7. Here we are adding another filter condition to the `CALCULATE` wrapper and saying that the function should also have a filter for the column that is the actual selected value from that column. Why does this work? Remember, filter context is figured out first, before row context!

If I'm using a slicer to determine which value to choose or my visual has that field in its results, it must pass that filter condition to the function and, at that point for that specific version of the calculation, we are returning one specific value.

If for some reason we are in a situation where we are not looking at the average score by Excel proficiency or by a field in the same table as Excel proficiency from which filter context could be derived (say, for the total row), we then go to the conditional formula for when it's not true. To do that, you use a simple `CALCULATE` function of the average, removing all filter conditions with the `ALL` function.

If you were to look at this DAX statement in Power BI or another DAX editing tool, there is a feature called intellisense that we could use to identify what each parenthesis groups together for a given DAX statement. But this statement isn't too far removed from what we have discussed so far. If you can do that, you can figure out how to solve most other DAX problems. With the preceding DAX statement, we can get to a result like we see on the far right column of the table in Figure 5-17.

LastName	ExcelSelfDescribedProficiency	Average Score	Complex Filtered Excel Proficiency Average Score
Dismukes	Advanced	74.00	79.62
Monteiro	Advanced	79.50	79.62
Schmitz	Advanced	85.36	79.62
Damato	Beginner	73.43	77.07
Dezzutti	Beginner	81.00	77.07
Farquharson	Beginner	80.29	77.07
Lucia	Beginner	75.64	77.07
Miyamoto	Beginner	75.93	77.07
Russell	Beginner	76.57	77.07
Smullen	Beginner	76.64	77.07
Bainter	Intermediate	81.71	84.34
Boomhower	Intermediate	87.57	84.34
Cavin	Intermediate	75.57	84.34
Montegalegre	Intermediate	92.50	84.34
Avina	None	66.93	71.14
Bones	None	76.71	71.14
Newlon	None	69.14	71.14
Piatt	None	66.00	71.14
Schmaltz	None	77.50	71.14
Shumway	None	70.57	71.14
Total		**77.13**	**77.13**

Figure 5-17. See!? We figured it out.

With what you've learned here, you can create a measure or calculated column that gets you what you need for your analysis. Just remember, any DAX used to create a calculated column will always be row-context dependent because you're adding data to your data model. Now we're ready for some real data analysis.

Conclusion

At this point, we've got the data into the data model, we've built the relationships, we have the visuals we need, and finally we have enough DAX to create the explicit measures we want when an implicit measure won't do the job.

In the next chapter, we are going to put everything we've discussed together into a real-world workflow using our dataset. We will append data for an extra course into the data model using Power Query, do some cleanup transformations, build some measures, and learn a little bit more about Cool School University.

CHAPTER 6

Putting the Puzzle Pieces Together: From Raw Data to Report

In the first five chapters of this book, we laid a foundation for the use of Power BI. In this chapter, you'll learn how to go from raw data in Excel to a Power BI report.

To facilitate that, we'll bring in the Cool School University data that we've already worked with so far and add data from a second class's grades using Power Query to wrangle our data into the desired form. Then we'll build out the relationships we need so that we can get the data to fit together. After that, we'll build some measures to help us get deeper insights.

Finally, we'll build our first report page with some easy, out-of-the-box visuals that will help us learn a little more about our students' performance. This first, simple report should allow our users to gain valuable insights about our classes that they didn't have before, and that will help us tell a story that will inform our future decision making.

Your First Data Import

Let's begin by importing the data you need. First locate the six Excel files within the ZIP file associated with this text. We'll initially focus on three files, ignoring the other three whose names have "Chapter6Addition" at the end. Don't worry, we'll get to them in the next section.

Before we start, if you want to take time to familiarize yourself with all of the data, feel free to open the files and look around. I recommend saving copies of the files so that you can try different things with the data in Excel and, on your own, try to get those same answers out of Power BI. I also highly encourage you to change some of the data in those files to see how that might impact some of the results after you feel

comfortable with the process that will be laid out through this chapter. Taking that step will help you get more familiar with the functionality and might just make you a Cool School star.

So, ignoring the Chapter 6–specific additions, we're left with three files:

- *CoolSchoolUniversityGradesPowerBIVersion.xlsx*
- *CoolSchoolUniversityInstructorGatheredInformation.xlsx*
- *CoolSchoolUniveristySchoolSuppliedDataClassStart.xlsx*

Choose and Transform the Data When You Import

Let's bring these into Power BI. We'll go through the files one at a time, but remember to not just choose to import the data, but to transform it too, even if we don't necessarily have transformations to make immediately. This is the same process that was discussed in Chapter 3: Get data → Excel workbook → Navigate to the file we want to import → select file → choose "Transform data" in the Navigator window.

To do this, click the "Excel workbook" button on the Home ribbon to first take a look at our school-supplied data. It's the beginning of the semester, and the university provides us a specific set of data about our students for the course.

In the Explorer window that appears (Figure 6-1) you'll see the Navigator menu, discussed previously. For an Excel workbook, each worksheet appears as its own item, as do any named tables.

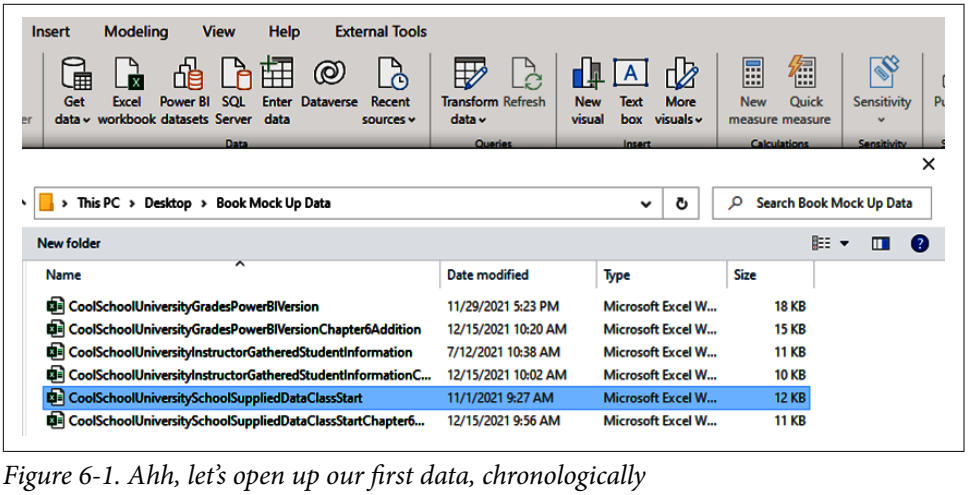
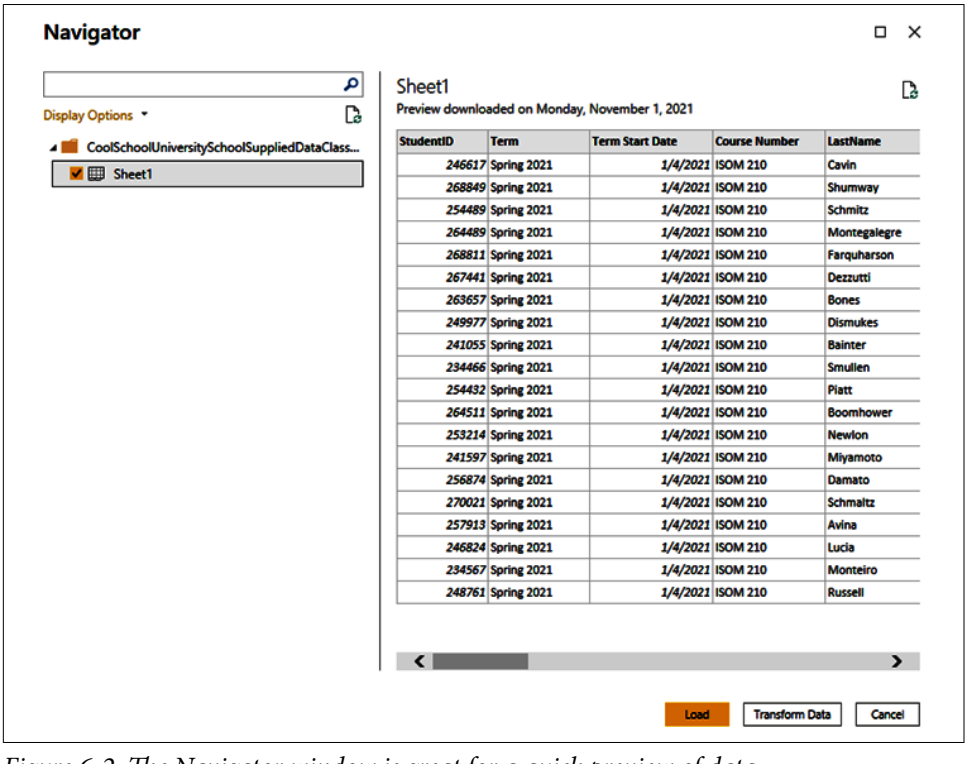


Figure 6-1. Ahh, let's open up our first data, chronologically

Now select the file called *CoolSchoolUniversitySchoolSuppliedDataClassStart*, which has only one Excel worksheet named Sheet1. Then choose "Transform data" and take

a look at Figure 6-2, which shows what you should now see—a preview of the data in the file.



StudentID	Term	Term Start Date	Course Number	LastName
246617	Spring 2021	1/4/2021	ISOM 210	Cavin
268849	Spring 2021	1/4/2021	ISOM 210	Shumway
254489	Spring 2021	1/4/2021	ISOM 210	Schmitz
264489	Spring 2021	1/4/2021	ISOM 210	Montegalegre
268811	Spring 2021	1/4/2021	ISOM 210	Farquharson
267441	Spring 2021	1/4/2021	ISOM 210	Dezzutti
263657	Spring 2021	1/4/2021	ISOM 210	Bones
249977	Spring 2021	1/4/2021	ISOM 210	Dismukes
241055	Spring 2021	1/4/2021	ISOM 210	Bainter
234466	Spring 2021	1/4/2021	ISOM 210	Smullen
254432	Spring 2021	1/4/2021	ISOM 210	Platt
264511	Spring 2021	1/4/2021	ISOM 210	Boomhower
253214	Spring 2021	1/4/2021	ISOM 210	Newlon
241597	Spring 2021	1/4/2021	ISOM 210	Miyamoto
256874	Spring 2021	1/4/2021	ISOM 210	Damato
270021	Spring 2021	1/4/2021	ISOM 210	Schmaltz
257913	Spring 2021	1/4/2021	ISOM 210	Avina
246824	Spring 2021	1/4/2021	ISOM 210	Lucia
234567	Spring 2021	1/4/2021	ISOM 210	Monteiro
248761	Spring 2021	1/4/2021	ISOM 210	Russell

Figure 6-2. The Navigator window is great for a quick preview of data

Transformations in Power Query

After selecting "Transform data," we are brought into Power Query. We can see in Figure 6-3 that Power Query has taken the liberty of applying some basic transformations to help accelerate our development—in this case, the steps of Source, Navigation, Promoted Headers, and Changed Type. You'll notice that Power Query by default will show you the view of the data as of the final transformation, and you'll see that Changed Type is now highlighted in the Applied Steps window on the right.

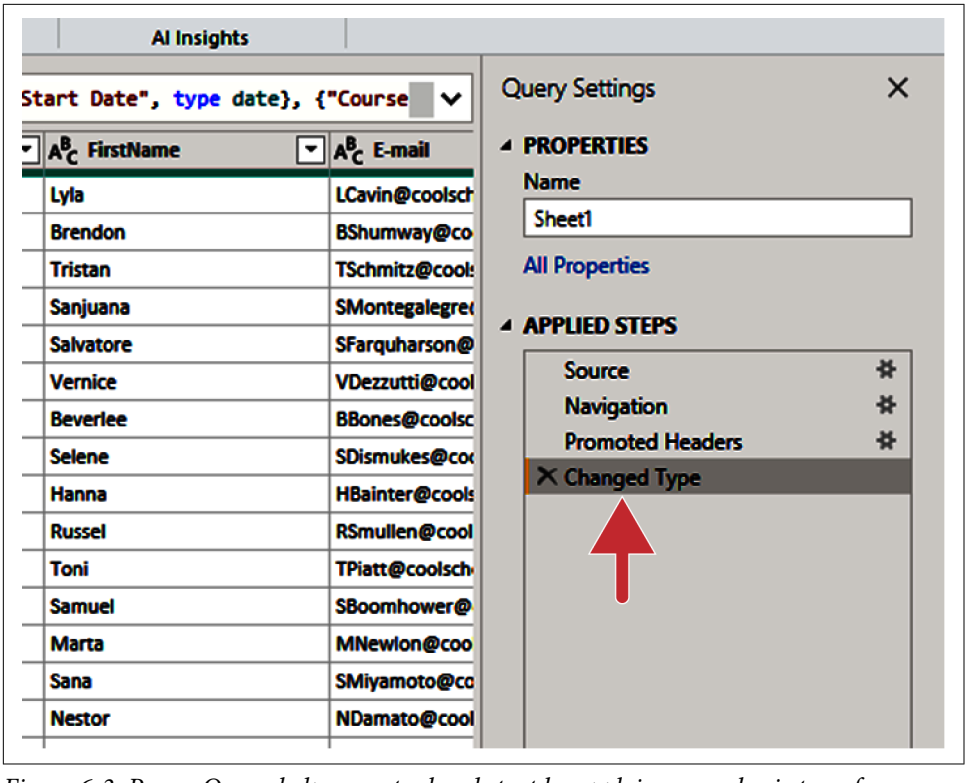


Figure 6-3. Power Query helps us get a head start by applying some basic transformations for us to see

Under Applied Steps on the right, the Source is almost universal for any type of data. This is what Power BI uses to identify the data source so that it knows how to access the data. For an Excel workbook, this will look like a list of worksheet names and table names from the workbook we are looking at. In a database source, it will look like a list of tables and views you have access to.

When using the Navigator window, what we are doing is walking through the first step of Source and the second step of Navigation. This is how Power Query builds a type of map that will allow it to remember what data to get and where in that dataset the specific information we are looking for is located. In a database, the source would be a given database, but the navigation would lead us to a specific table of data. From Excel, the source identifies which Excel file it is, but navigation identifies what worksheet or named table range the data we are looking for is in.

Speaking of Navigation, this is the first view of the data that Power Query gets. If you look at the Power Query window with Navigation selected, you'll notice that the data

doesn't look very clean at all. You can see in Figure 6-4 that the column names aren't there, and the data itself isn't well defined, as each column has a data type of Any.

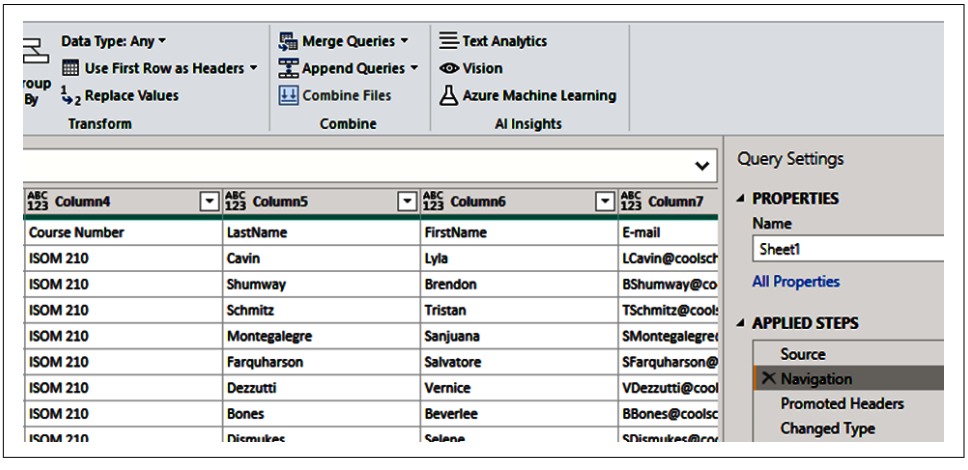


Figure 6-4. The Navigation step is only the beginning, as it's your first view of the data in an unclean format

However, Power Query is helpful here and intuits that the first row should, in fact, be column headers. Power Query automatically changes the data types to fit based on a review of the data in the columns themselves. That's why Promoted Headers and Changed Type appear under Applied Steps in Figure 6-4.

While Power Query's accuracy with these steps is incredibly high, that doesn't mean it's perfect. Therefore, I always like to take a cursory glance at these steps when they're applied to confirm that's indeed the behavior I want.

Also, sometimes if Power Query can't intuit these steps for whatever reason, these steps might not appear. If that happens, you can apply these steps manually from Power Query as discussed in Chapter 3.

There will also be data for which the Promoted Headers applied step won't be necessary because the data source provides that metadata detail in advance. This is true most often with database data sources, but it can also be true of other data sources, such as named Excel tables.

If you'd like, you could certainly review the Advanced Editor to look at the M that is generated by Power Query, but I think the last thing to do here is to change the name of the table to something more meaningful. Sheet1 just doesn't have a great ring to it. You can name the table whatever you like, but I'll keep things simple and call it "UniversitySuppliedData." Note that if your naming conventions are not the same as mine, you'll need to adjust whatever DAX is used in this chapter accordingly.

You could insert spaces in that name, as well, but I'm not a fan of putting spaces into table names. From a metadata perspective, it's generally not a database best practice. Also in my experience, DAX IntelliSense tends to get weird when dealing with table names that include spaces. So that's why I removed the spaces and used capital letters at the beginning of each word to help readers identify how to read the table name. It's a stylistic choice more than technical impact, but in my opinion it does help.

With that, we have our first piece of data in Power BI! Congratulations!

Now let's go get the other two files and look at some specific cases where the process might differ from what we did. In fact, we can add more data from within Power Query by using the New Source button, so let's use that. Remember, the button's drop-down arrow makes a shorter list of most used data sources, and Excel is the first on that list.

Next, chronologically, would be our student survey data from the beginning of the term. This is the file within our file list called *CoolSchoolUniversityInstructorGatheredStudentInformation.xlsx*. This is another single-sheet Excel workbook, so the Applied Steps are going to look identical to the first worksheet we imported. Let's rename this table "StudentSurveyData" and move on to our last initial data import.

Finally, we get our grades sheet at the end of the term that we've theoretically been updating throughout the year. You'll notice that *CoolSchoolUniversityGradesPowerBIVersion.xlsx* has two worksheets: AssignmentDIM and GradeScores. We want both of them, so in the Navigator window select Both.

If you're doing this from outside Power Query, remember to choose "Transform data" and remember that is the default behavior inside Power Query. Thankfully, as these sheets are named inside Excel, Power Query makes those sheet names the default table names, which in our case is perfect. First data import complete! So now we have four tables. Next, we need to bring in our second semester's worth of data.

Second Data Import and Wrangling

Our second set of data importing starts very much like the first. We have three files that we are going to bring in for this portion, and the first part of it is the same as what we just did—except we're importing the files with the Chapter6Addition filenames.

When you import those four sources exactly as we did before, your query list should look like Figure 6-5. You'll notice I didn't make any modifications or any other edits to these tables yet. I just imported them. When something is imported that would have the same name as a query that already exists, it will have a number (*N*) automatically added to it, where *N* is the number of items with the same name.