The CAPED Framework

Characterizing User **Skills** in Chart Authoring through the Lens of **Tasks** and **Tools**





Chenglong Wang
Bongshin Lee
John Thompson
Leo Zhicheng Liu

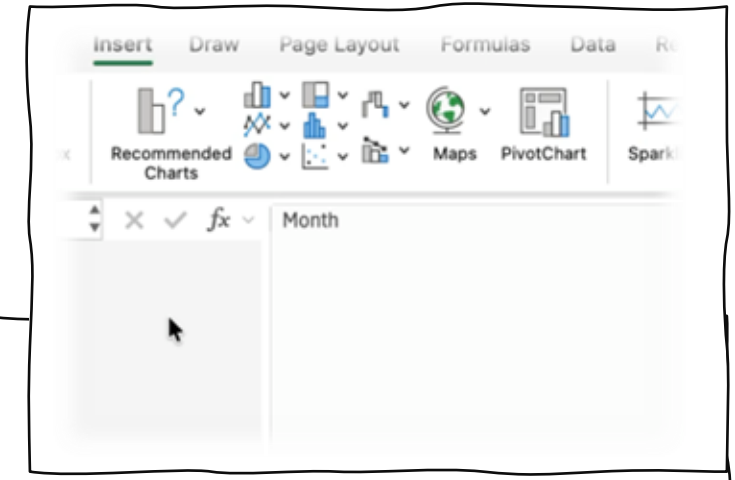
Compare Monthly Profits

I need to visualize profit changes month to month for our company.



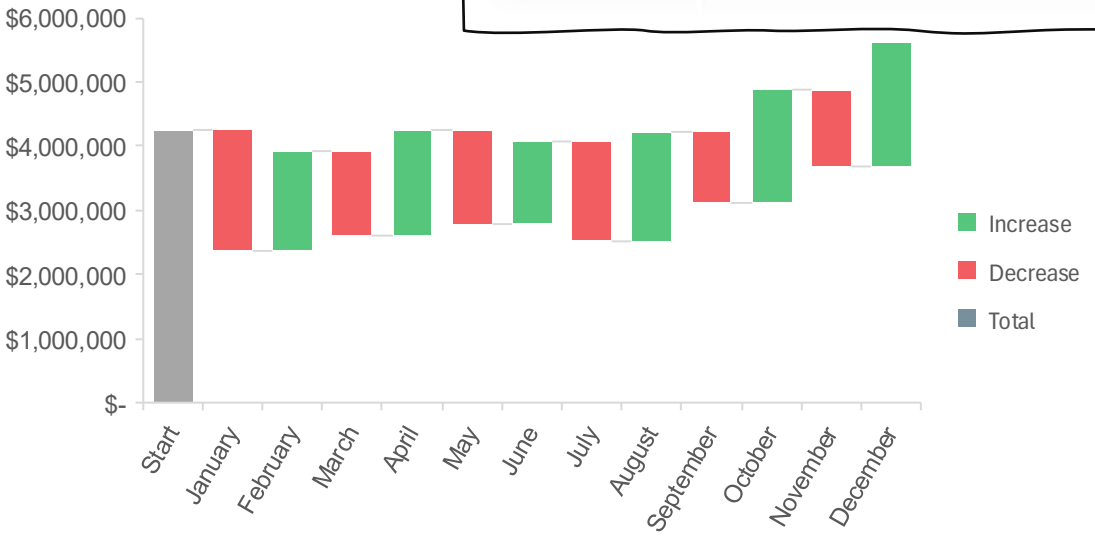
Month	Profit	Difference
Jan	$4.25M	-
Feb	$2.38M	($1.87M)
…	…	…
…	…	
Nov	$3.68M	($1.19M)
Dec	$5.62M	$1.94M

Compare Monthly Profits



Creating a waterfall chart is wicked easy!





Evaluate Regional Sales

I need to compare target vs gross sales by territory.



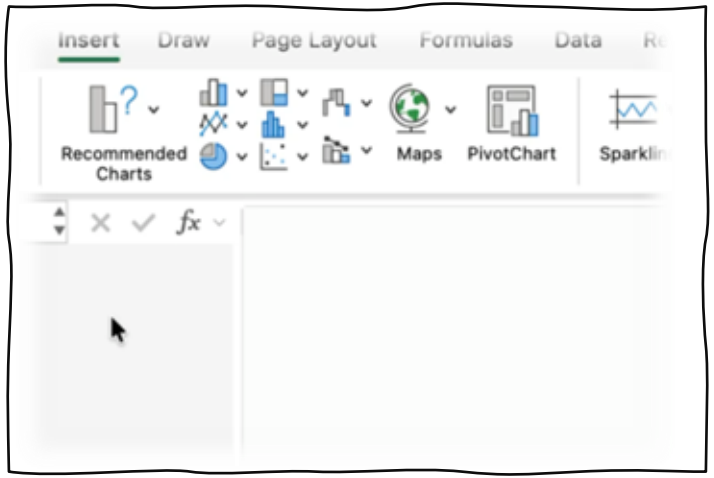
Territory	Sales	Target
California	$875k	$825k
Texas	$819k	$755k
…	…	…
…	…	
Chihuahua	$537k	$495k
Jalisco	$669k	$731k

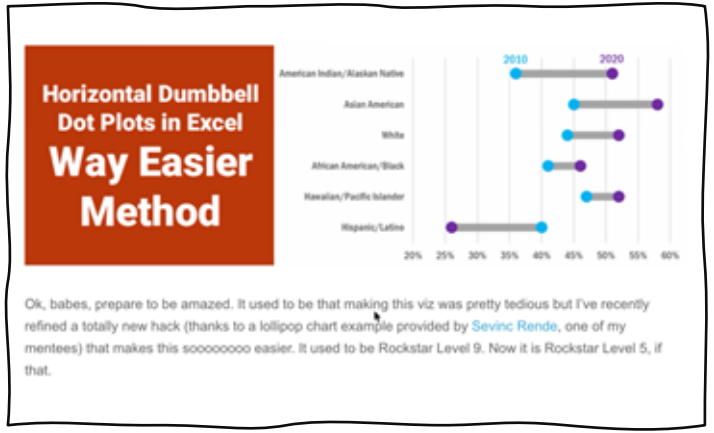
Evaluate Regional Sales

I need to compare target vs gross sales by territory.

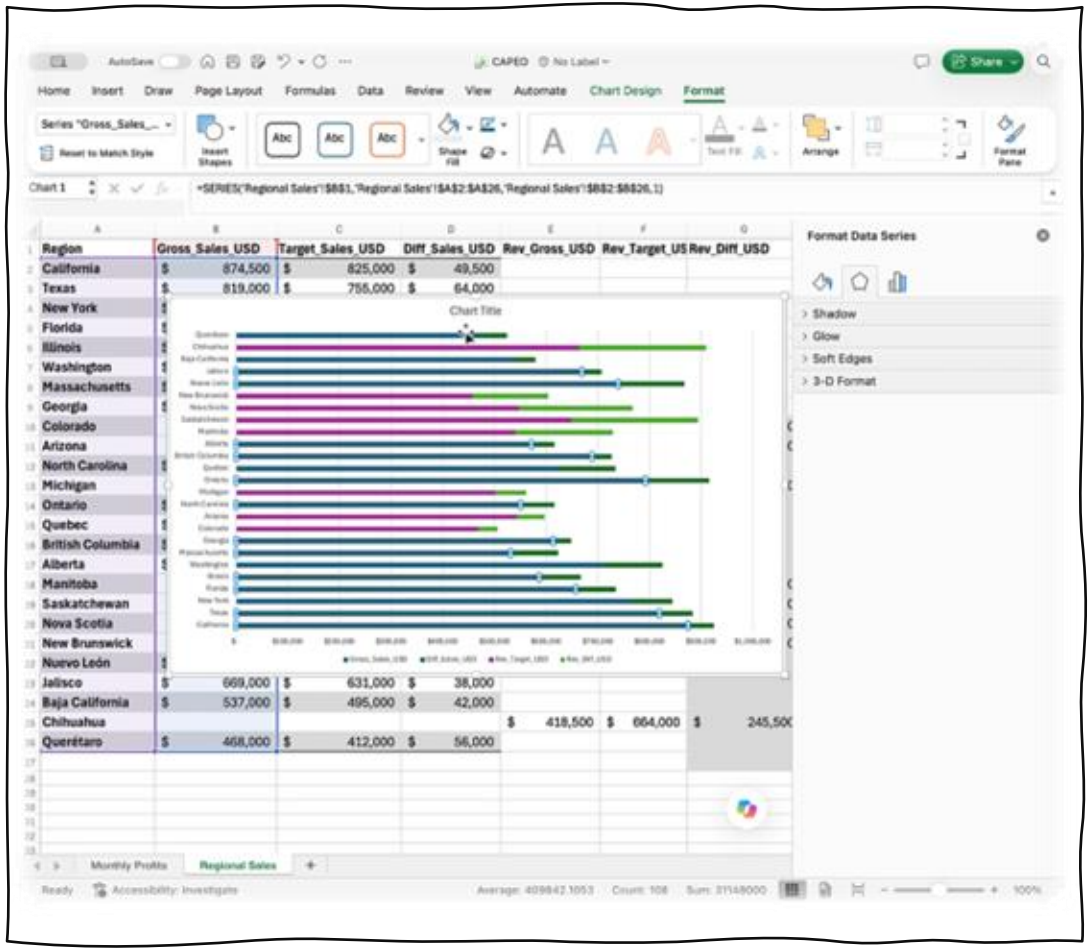


A dumbbell plot!

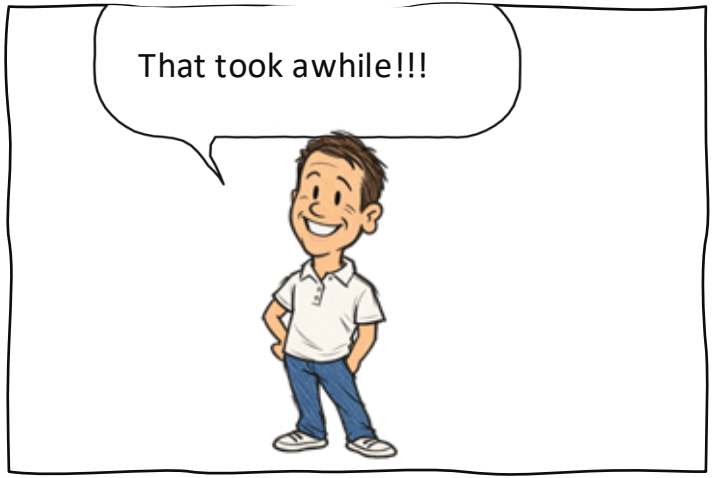


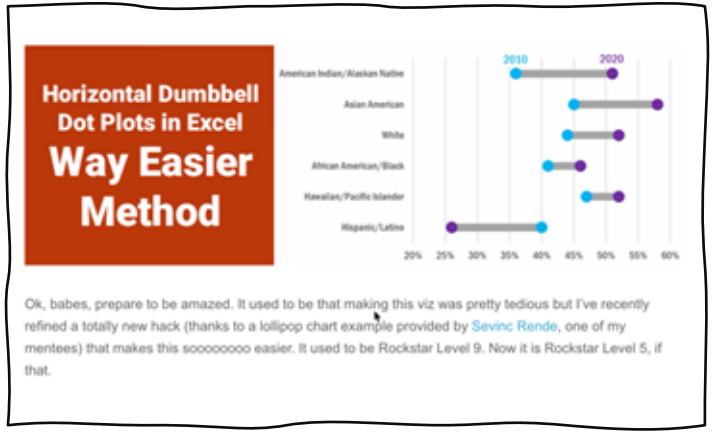


https://stephanieevergreen.com/horizontal-dumbbell-dot-plots-easier/



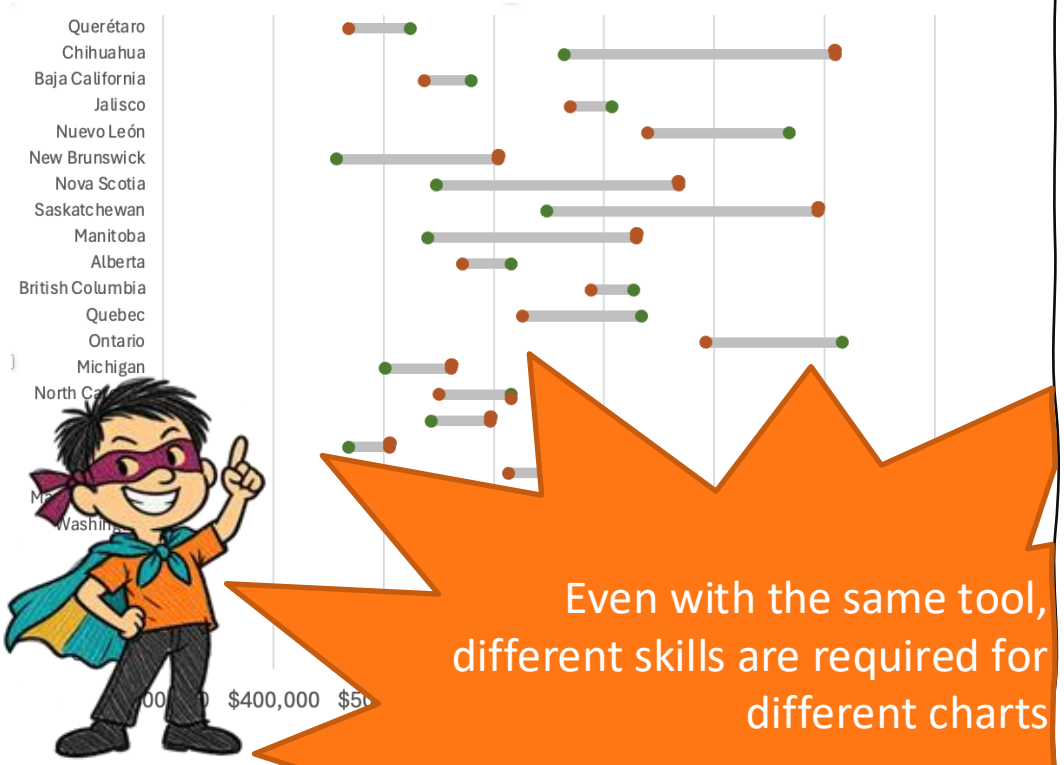
Region	Gross_Sales_USD	Target_Sales_USD	Diff_Sales_USD	Rev_Gross_USD	Rev_Target_US	Rev_Diff_USD
California	$ 874,500	$ 825,000	$ 49,500			
Texas	$ 819,000	$ 755,000	$ 64,000			
New York						
Florida						
Illinois						
Washington						
Massachusetts						
Georgia						
Colorado						
Arizona						
North Carolina						
Michigan						
Ontario						
Quebec						
British Columbia						
Alberta						
Manitoba						
Saskatchewan						
Nova Scotia						
New Brunswick						
Nuevo León						
Jalisco	$ 669,000	$ 631,000	$ 38,000			
Baja California	$ 537,000	$ 495,000	$ 42,000			
Chihuahua				$ 418,500	$ 664,000	$ 245,50
Querétaro	$ 468,000	$ 412,000	$ 56,000			





https://stephanieevergreen.com/horizontal-dumbbell-dot-plots-easier/

CAPED Co. Territory Sales Performance



Even with the same tool, different skills are required for different charts

That took awhile!!!





Ok, babes, prepare to be amazed. It used to be that making this viz was pretty tedious but I've recently refined a totally new hack (thanks to a lollipop chart example provided by Sevinc Rende, one of my mentees) that makes this soooooooo easier. It used to be Rockstar Level 9. Now it is Rockstar Level 5, if that.

https://stephanieevergreen.com/horizontal-dumbbell-dot-plots-easier/

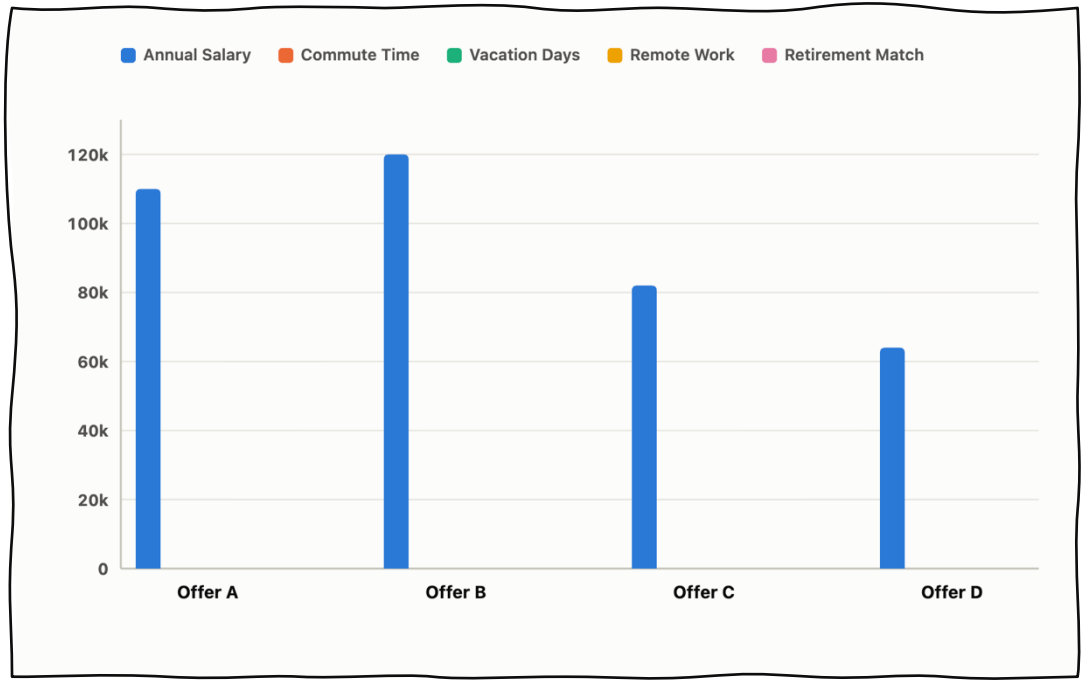
Compare Job Offers

I'm on the job market and considering job offers. This is a big decision – I'll ask ChatGPT.



Create a chart to compare the jobs in terms of salary, commute time, and all other data attributes.

Compare Job Offers

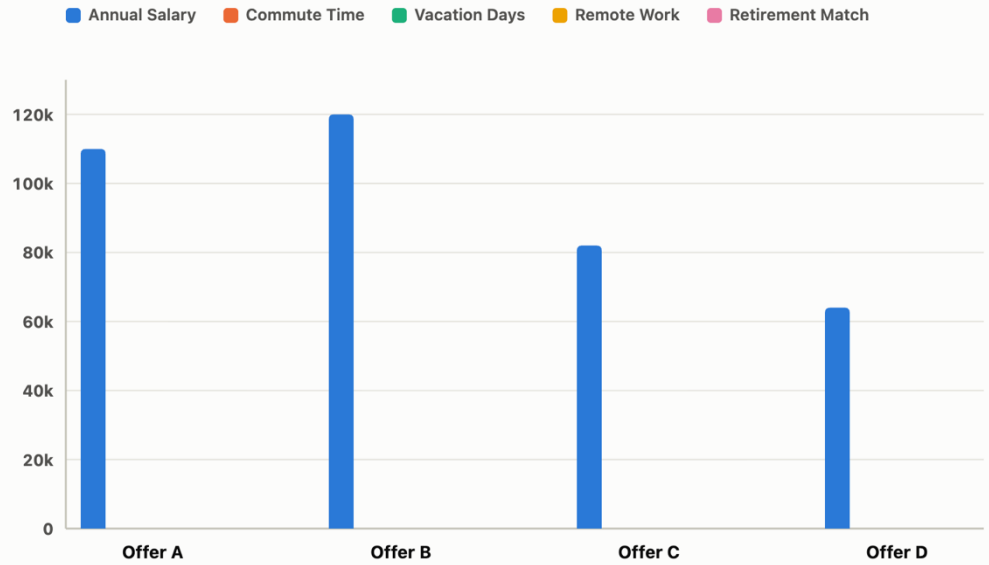


Create a chart to compare the jobs in terms of salary, commute time, and all other data attributes.

I created a grouped bar chart to visualize all data attributes. Offer B pays the most.



Compare Job Offers



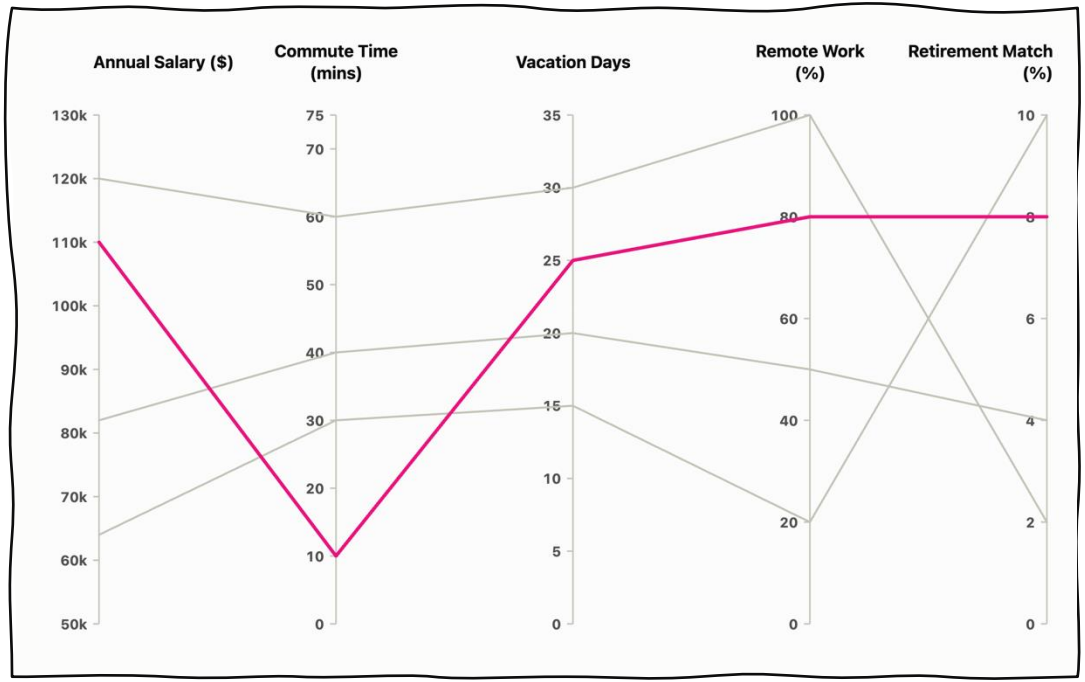
Create a chart to compare the jobs in terms of salary, commute time, and all other data attributes.

I created a grouped bar chart to visualize all data attributes. Offer B pays the most.

Show me the code.



Compare Job Offers



visualize all data attributes. Offer B pays the most.

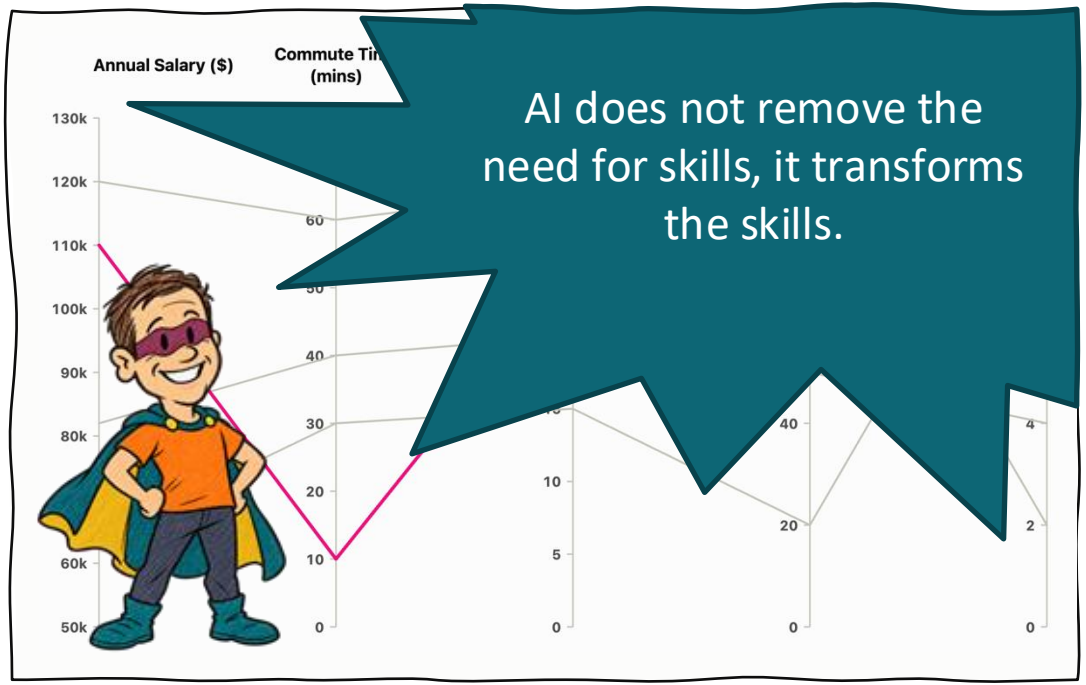
Show me the code.

Create a parallel coordinate chart.

Great idea! I created a parallel coordinate chart. With each data attribute as a normalized axis.



Compare Job Offers



visualize all data attributes. Offer B pays the most.

Show me the code.

Create a parallel coordinate chart.

Great idea! I created a parallel coordinate chart. With each data attribute as a normalized axis.



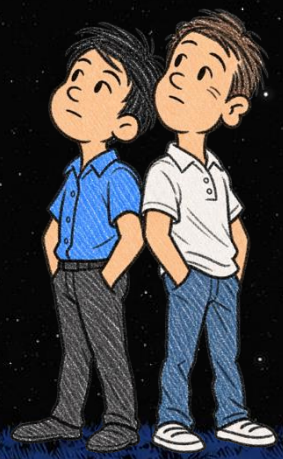
There are so many chart authoring tools…

But how do we describe:

Existing skills?

Skills yet to learn?

Skill relevance to tools?



How do other disciplines describe skill?

LEARNING SCIENCES

1990

What Is Skill?

PAUL ATTEWELL
City University of New York

The concept of skill is important in many areas of sociology, from studies of income inequality to debates on whether capitalism is deskilling work to issues of comparable worth. Underlying all of these topics is the apparently simple idea of "skill." But like so many common-

SOCIOLOGY

2005

What Is Competence?

FRANÇOISE DELAMARE LE DEIST & JONATHAN WINTERTON
Toulouse Business School, France

ABSTRACT *This paper explores the definitions and usage of competence, especially in the context of training and development initiatives in the USA, UK, France and Germany, seeking to clarify the concept by incorporating knowledge, skills and competences within a holistic*

PSYCHOLOGY

1990

Skill

MEANINGS, METHODS, AND MEASURES

KENNETH I. SPENNER
Duke University

Over the past 20 years, a renaissance of research has used the concept of skill in a variety of contexts. These include studies of technological change, the labor process, overeducation-underemployment, job redesign,

ECONOMICS

2011

What is Skill?

An Inter-Disciplinary Synthesis

Francis Green
Institute of Education, University of London

When economists, sociologists and psychologists discuss skill they often appear to be talking about different things, even though they each ascribe high importance to it. To make progress and to facilitate inter-disciplinary communication it would be better to be sure what we mean by skill. I propose a simple functional concept that

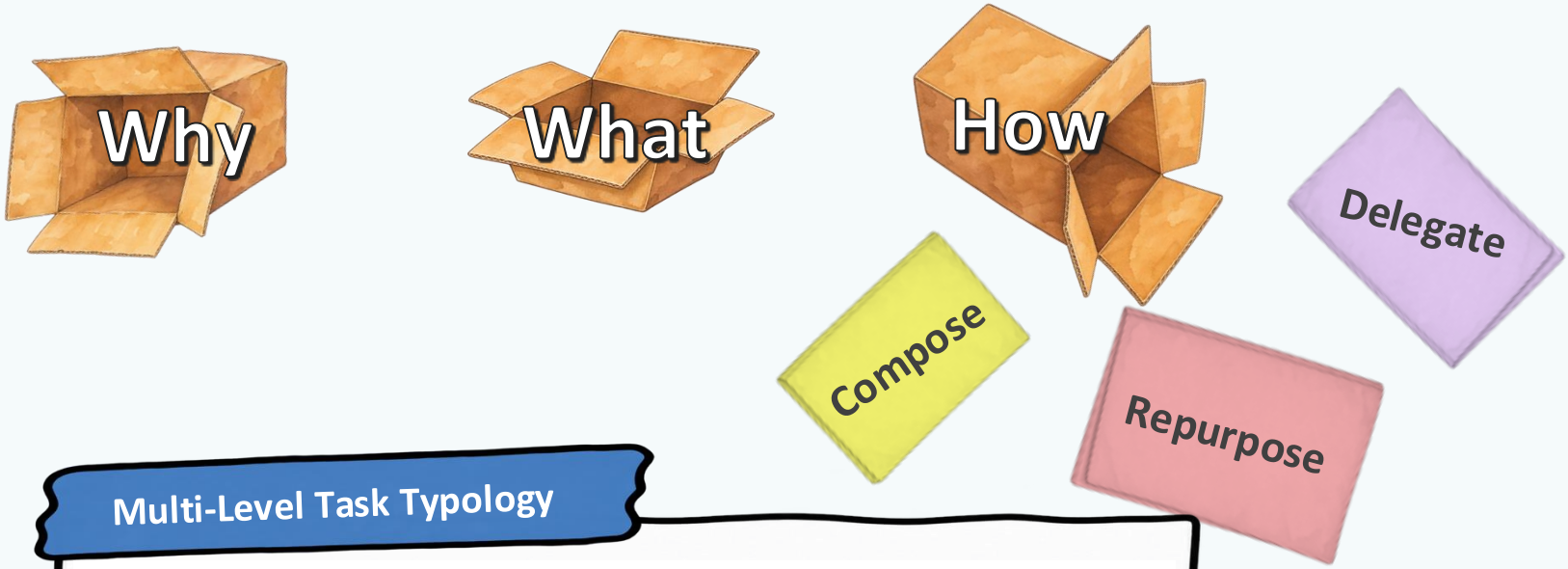
Skill

is the ability and knowledge

to accomplish a task



Task Characterization: High-Level



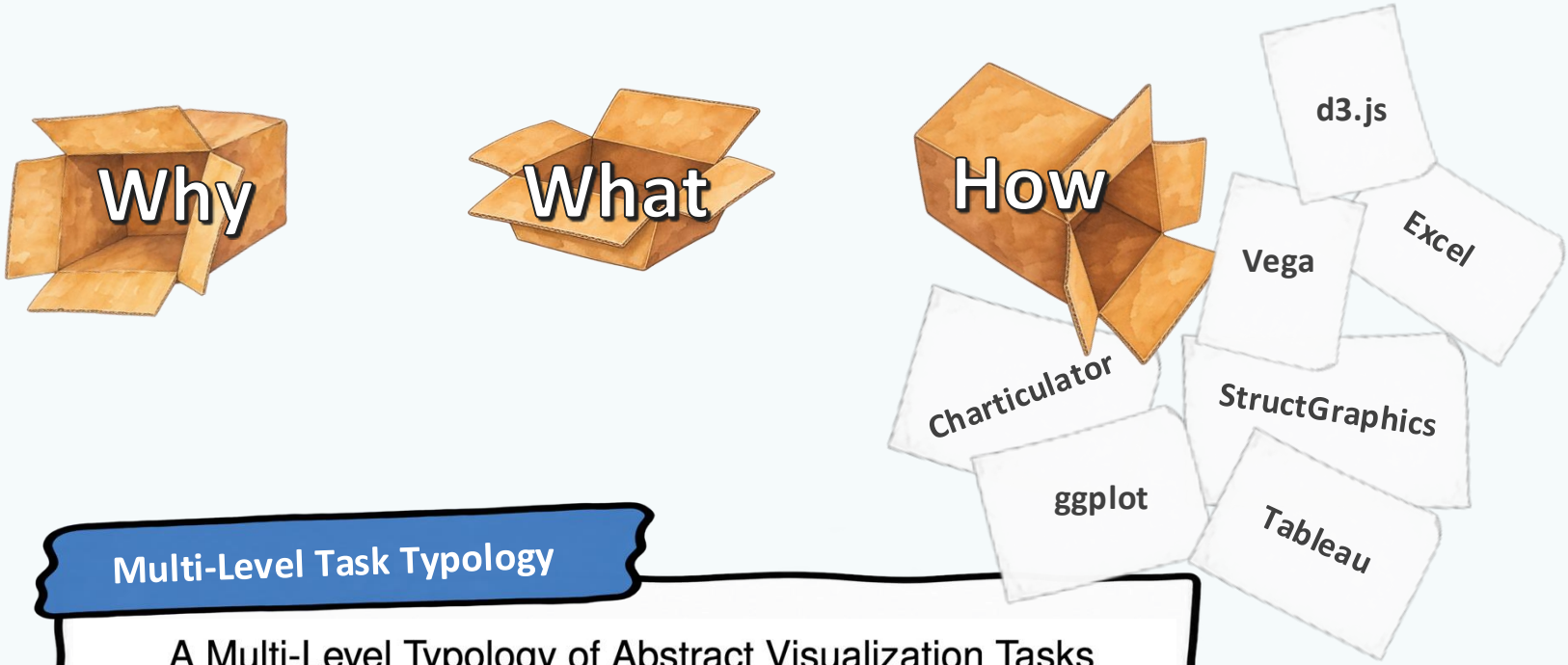
Multi-Level Task Typology

A Multi-Level Typology of Abstract Visualization Tasks

Matthew Brehmer and Tamara Munzner, *Member, IEEE*

Abstract—The considerable previous work characterizing visualization usage has focused on low-level tasks or interactions and high-level tasks, leaving a gap between them that is not addressed. This gap leads to a lack of distinction between the ends and means of a task, limiting the potential for rigorous analysis. We contribute a multi-level typology of visualization tasks to address this gap, distinguishing *why* and *how* a visualization task is performed, as well as *what* the task inputs and outputs are. Our typology allows complex tasks to be expressed as sequences of interdependent simpler tasks, resulting in concise and flexible descriptions for tasks

Task Characterization: Lower-Levels



Multi-Level Task Typology

A Multi-Level Typology of Abstract Visualization Tasks

Matthew Brehmer and Tamara Munzner, *Member, IEEE*

Abstract—The considerable previous work characterizing visualization usage has focused on low-level tasks or interactions and high-level tasks, leaving a gap between them that is not addressed. This gap leads to a lack of distinction between the ends and means of a task, limiting the potential for rigorous analysis. We contribute a multi-level typology of visualization tasks to address this gap, distinguishing *why* and *how* a visualization task is performed, as well as *what* the task inputs and outputs are. Our typology allows complex tasks to be expressed as sequences of interdependent simpler tasks, resulting in concise and flexible descriptions for tasks

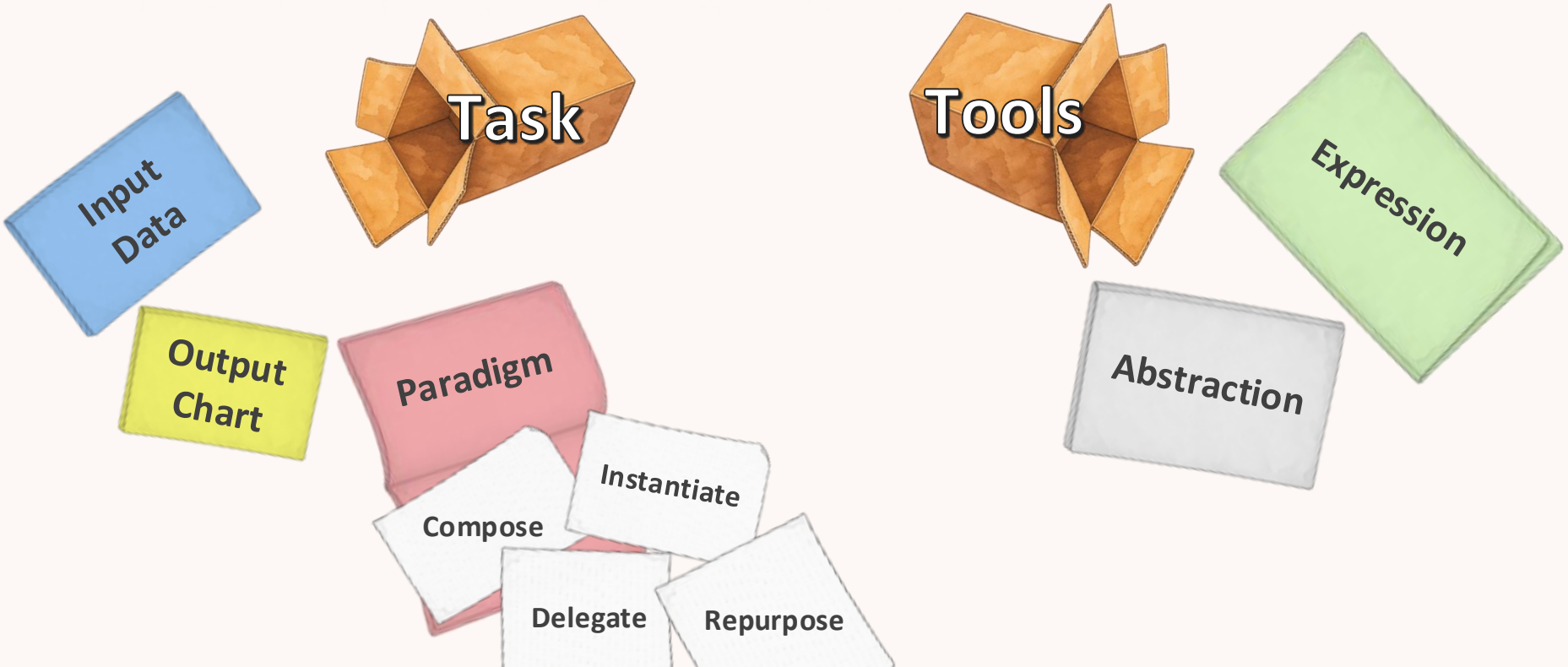
The CAPED Framework



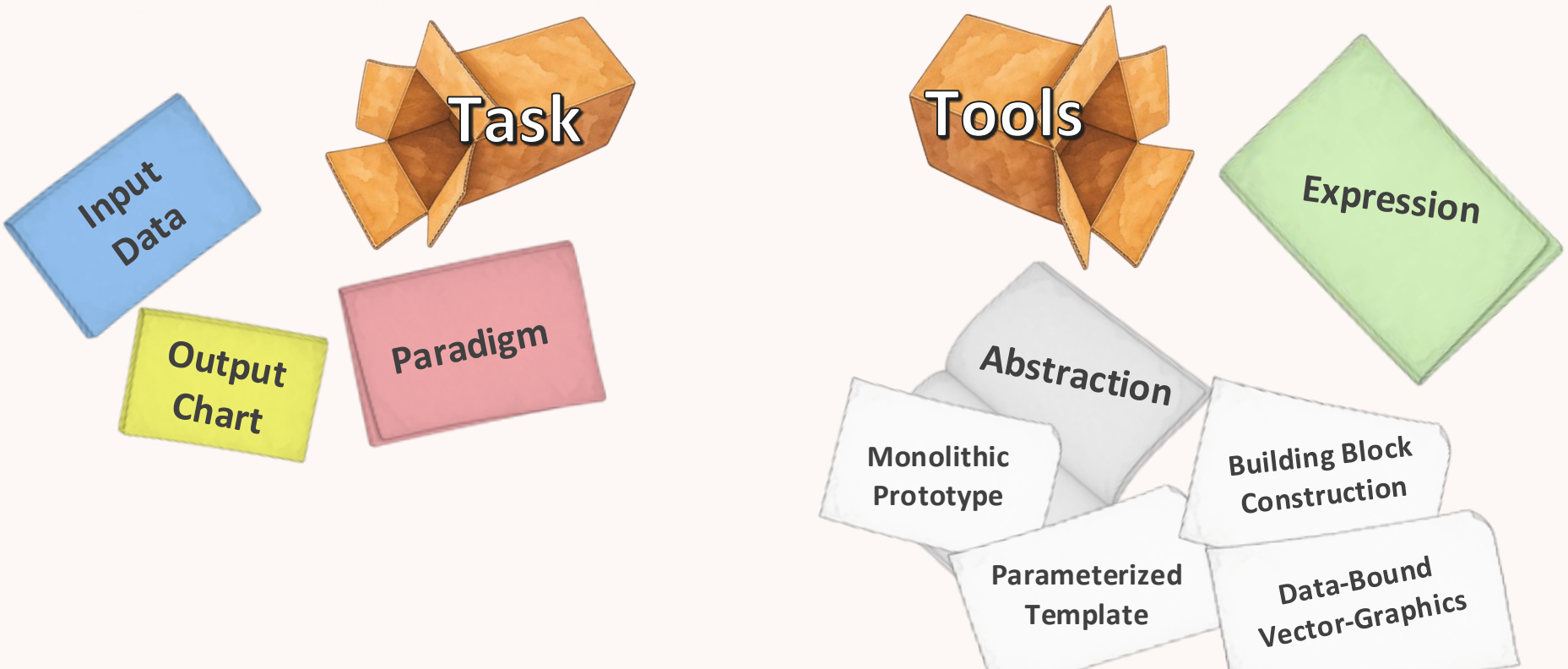
The CAPED Framework



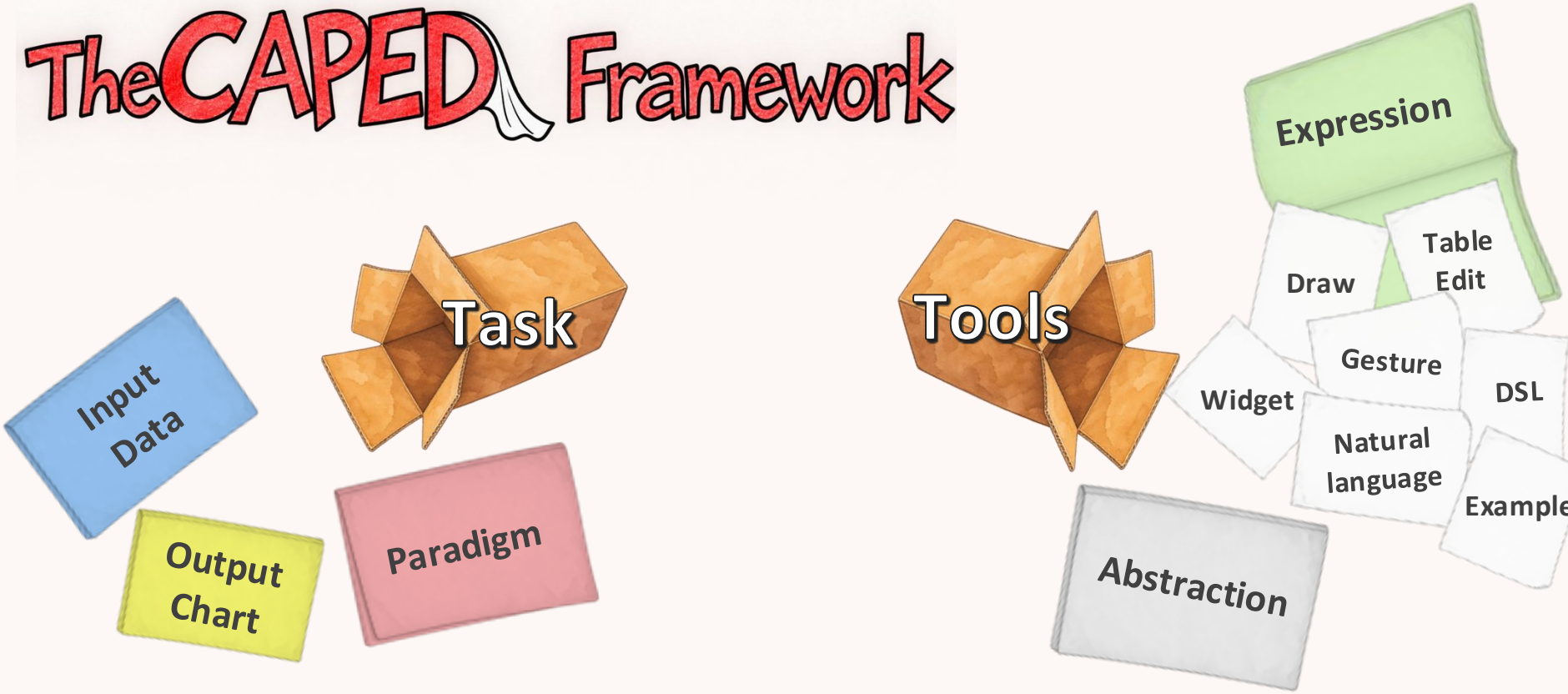
The CAPED Framework



The CAPED Framework



The CAPED Framework



CAPED



Applying CAPED

Input Data

Tool compatible

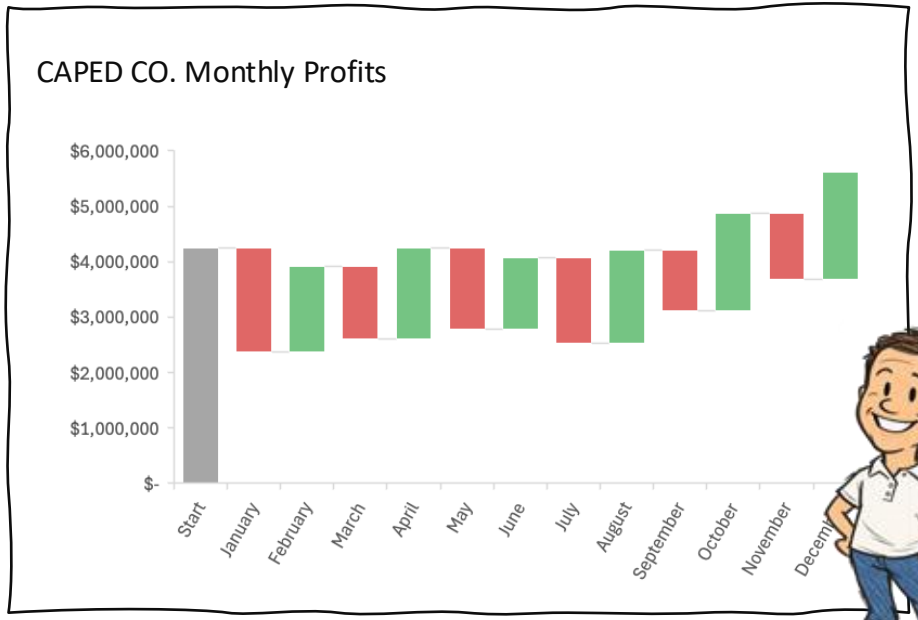
Paradigm

Instantiate

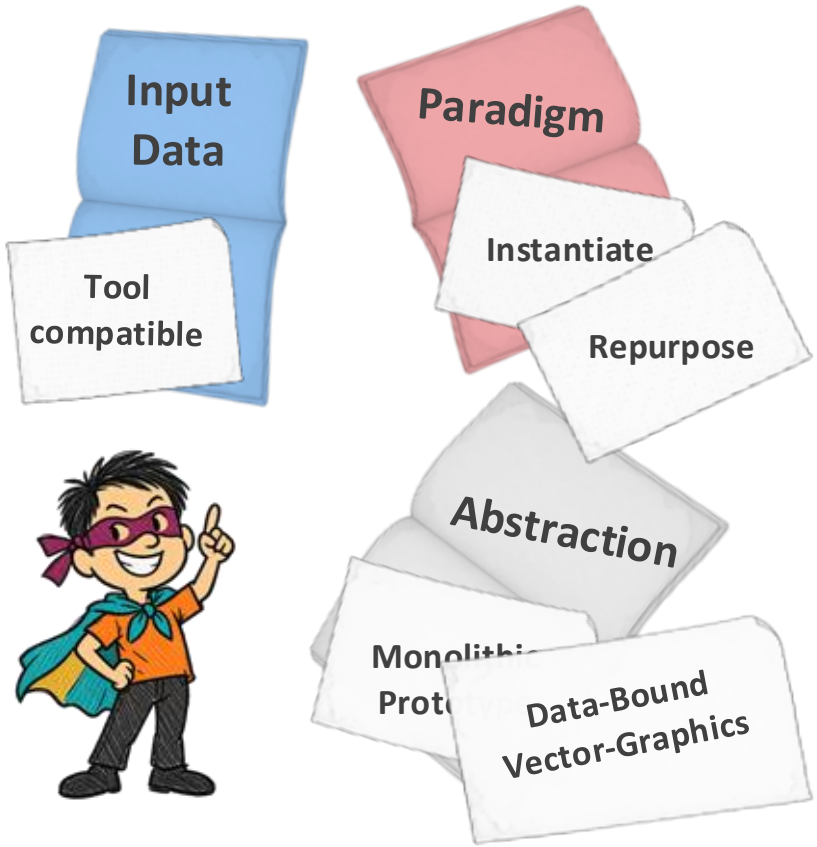
Abstraction

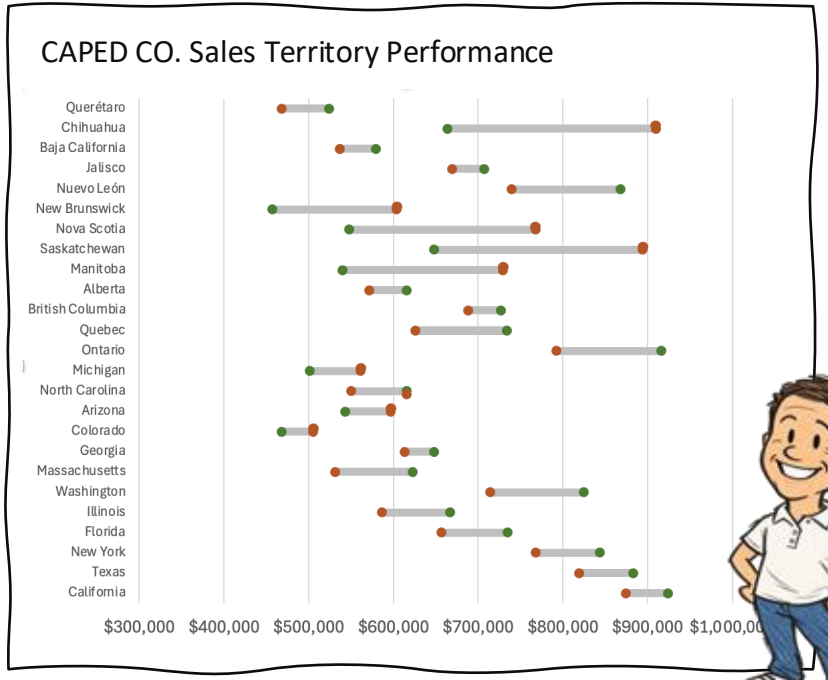
Monolithic Prototype



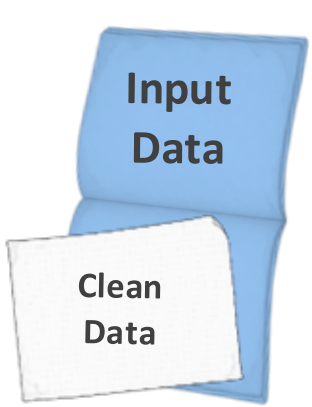


Applying CAPED





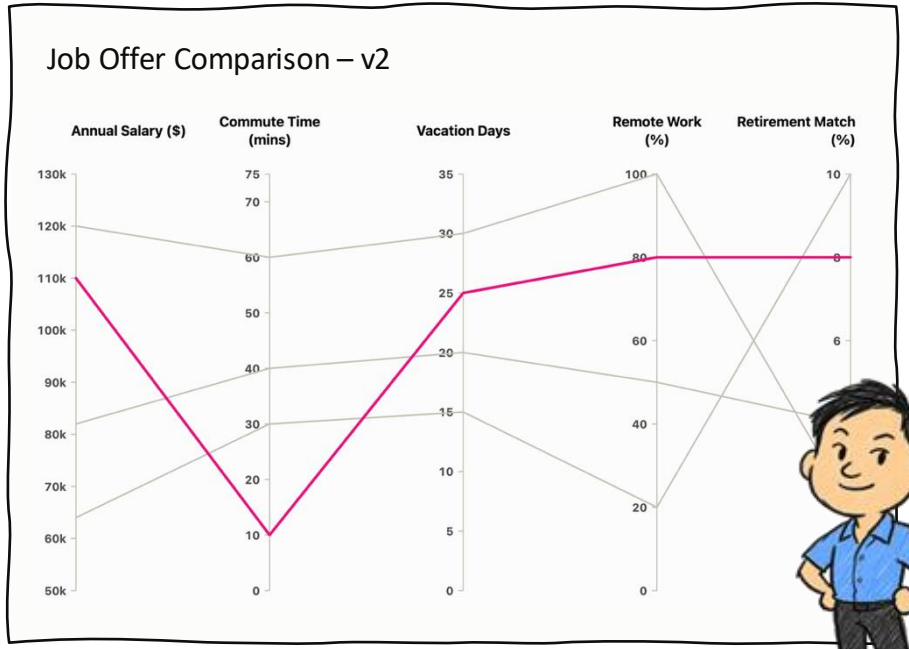
Applying CAPED











Applying CAPED

Input Data

Clean Data

Paradigm

Delegate

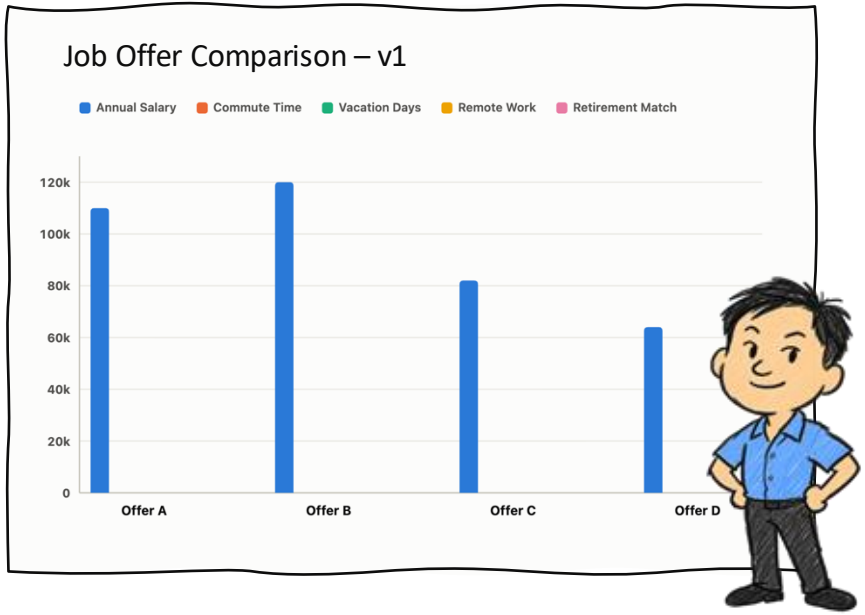
Compose



Abstraction

Monolithic Prototype

Building Block Construction

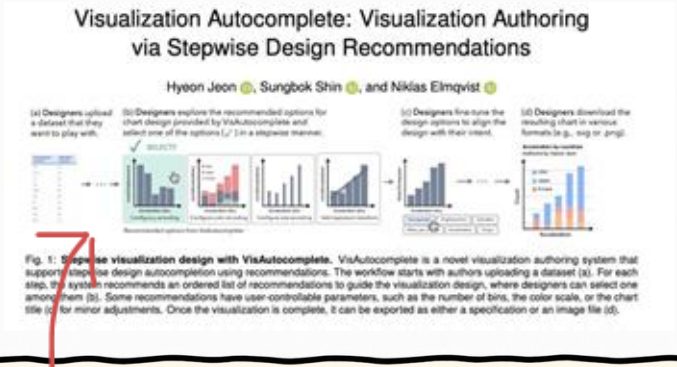


Opportunities



Support transitions between authoring paradigms.

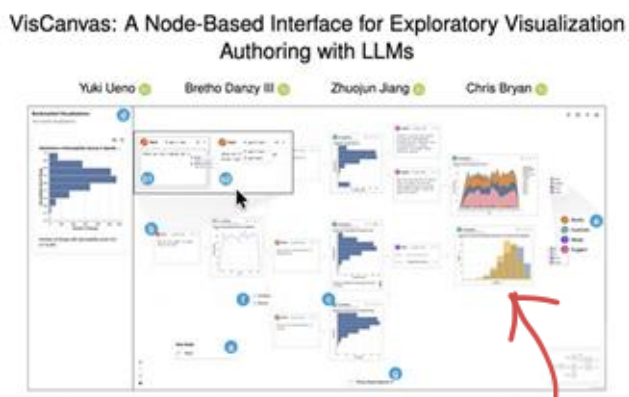
Visualization Autocomplete


Visualization Autocomplete: Visualization Authoring via Stepwise Design Recommendations

Hyeon Jeon, Sungbok Shin, and Niklas Elmqvist

compose,
delegate

VisCanvas

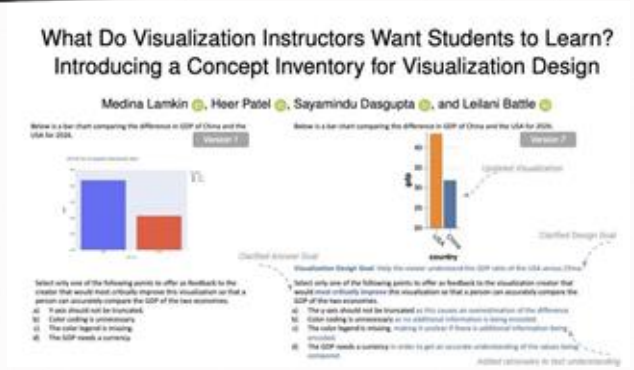

VisCanvas: A Node-Based Interface for Exploratory Visualization Authoring with LLMs

Yuki Ueno, Bretho Danzy III, Zhuojun Jiang, Chris Bryan

Instantiate,
repurpose

Tailor specific learning goals to people and tools.

Concept Inventory



What Do Visualization Instructors Want Students to Learn?
Introducing a Concept Inventory for Visualization Design

Medina Lamkin, Heer Patel, Sayamindu Dasgupta, and Leilani Battle

Designing Cognitive Friction



What Should the Agent Withhold? Designing Cognitive Friction Against Over-Reliance in Visualization Design Learning

Jing Lu[1*] Yuheng Zhao[1,2] Cagatay Turkay[3] Siming Chen[1]

[1]Fudan University, [2]Aalto University, [3]University of Warwick

Figure 1: Cognitive friction intervenes at three points in the learner–agent loop during visualization design: before the agent generates output, before the learner accepts it, and after adoption. Each position requires a different agent capability to deliver, shown below the corresponding position. The example prompts are adapted from the case study in Section 5. Rationale checking can also gate pre-acceptance (see Table 2).

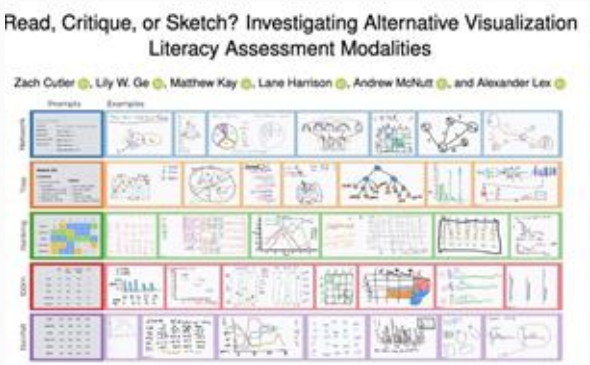
Tailor specific learning goals to people and tools.

	Compose	Instantiate	Delegate	Repurpose
Conceptual Knowledge (examples)	For the data: Understand the data requirements of the tool and the visualization to be created.			
	Understand the meaning, application, and relationship of primitives.	Understand the meaning of the desired template and its availability.	Assess the delegate tool's capability, results, and output quality.	Understand the underlying frameworks for the source and the target.
Procedural Knowledge (examples)	For the data: Prepare the data in the required input format.			
	Conduct the required steps to construct a chart with primitives.	Identify and instantiate the appropriate template.	Specify the chart with valid semantics and syntax for the given language.	Convert the source chart using the target data.
Meta-cognitive Knowledge (examples)	Know the capabilities and limitations of the tool and choose an appropriate tool. Understand the strengths and weaknesses of different authoring strategies and choose an appropriate one. Decide to switch to a different tool for a better outcome or adapt to different strategies for error recovery.			

Provides educators with a vocabulary for reasoning about learning objectives

Better integrate expressions with authoring intent

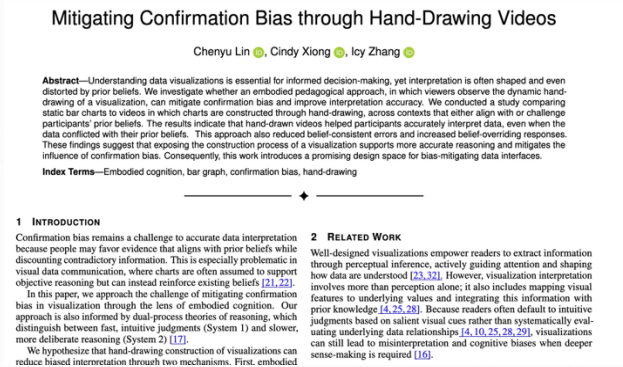
Read, Critique, or Sketch?



Read, Critique, or Sketch? Investigating Alternative Visualization Literacy Assessment Modalities

Zach Cutler, Lily W. Ge, Matthew Kay, Lane Harrison, Andrew McNutt, and Alexander Lex

Hand-Drawing Videos



Mitigating Confirmation Bias through Hand-Drawing Videos

Chenyu Lin, Cindy Xiong, Icy Zhang

Abstract—Understanding data visualizations is essential for informed decision-making, yet interpretation is often shaped and even distorted by prior beliefs. We investigate whether an embodied pedagogical approach, in which viewers observe the dynamic hand-drawing of a visualization, can mitigate confirmation bias and improve interpretation accuracy. We conducted a study comparing static bar charts to videos in which charts are constructed through hand-drawing, across contexts that either align with or challenge participants' prior beliefs. The results indicate that hand-drawn videos helped participants accurately interpret data, even when the data conflicted with their prior beliefs. This approach also reduced belief-consistent errors and increased belief-overriding responses. These findings suggest that exposing the construction process of a visualization supports more accurate reasoning and mitigates the influence of confirmation bias. Consequently, this work introduces a promising design space for bias-mitigating data interfaces.

Index Terms—Embodied cognition, bar graph, confirmation bias, hand-drawing

1 Introduction

Confirmation bias remains a challenge to accurate data interpretation because people may favor evidence that aligns with prior beliefs while discounting contradictory information. This is especially problematic in visual data communication, where charts are often assumed to support objective reasoning but can instead reinforce existing beliefs [21, 22].

In this paper, we approach the challenge of mitigating confirmation bias in visualization through the lens of embodied cognition. Our approach is also informed by dual-process theories of reasoning, which distinguish between fast, intuitive judgments (System 1) and slower, more deliberate reasoning (System 2) [17].

We hypothesize that hand-drawing construction of visualizations can reduce biased interpretation through two mechanisms. First, embodied

2 Related Work

Well-designed visualizations empower readers to extract information through perceptual inference, actively guiding attention and shaping how data are understood [23, 32]. However, visualization interpretation involves more than perception alone; it also includes mapping visual features to underlying values and integrating this information with prior knowledge [4, 25, 28]. Because readers often default to intuitive judgments based on salient visual cues rather than systematically evaluating underlying data relationships [4, 10, 25, 28, 29], visualizations can still lead to misinterpretation and cognitive biases when deeper sense-making is required [16].

The CAPED Framework



Supplemental Website



The CAPED Framework: Characterizing User Skills in Chart Authoring through the Lens of Tasks and Tools

Bongshin Lee, Zhicheng Liu, John Thompson, Chenglong Wang

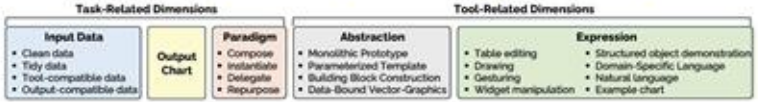
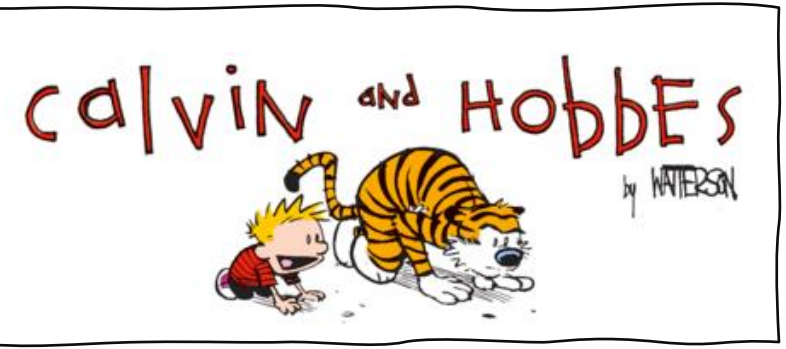


Fig. 1: The CAPED framework enables the characterization of user skills in chart authoring using five dimensions: Input Data, Output Chart, Paradigm, Abstraction, and Expression.

Abstract—In this paper, we introduce a new framework for characterizing the user skills required for chart authoring. Despite growing attention to authoring systems, we lack a conceptual framework that characterizes the diverse and multifaceted skills involved and helps identify opportunities for system design and development. Our initial investigation revealed that skill is a complex and elusive concept, and that existing theories on skills from other disciplines are too high-level to capture the importance of tasks and tools in data visualizations. To address this gap, we formulate the CAPED framework that characterizes skill as the ability to create a chart involving five dimensions pertinent to tasks and tools: input data, output chart, paradigm, abstraction, and expression. We demonstrate







Images Created with:

GPT-6 Luna & GPT Image 2.5 Sunburst

Art Inspired by:

Bill Watterson, Calvin and Hobbes