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A Visualization Creativity Workshop Framework: Workshop Process, Practical Considerations, and Pitfalls

Ethan Kerzner, Sarah Goodwin, Sara Jones, Jason Dykes, and Miriah Meyer

Abstract— Creativity workshops are a valuable method for visualization designers. Through the use of structured methods that foster creative thinking, they enable designers and collaborators to explore the problem and solution spaces of a design study. We have used 11 creativity workshops in 8 visualization projects, often sharing practices and guidelines through informal discussions as there are no formal guidelines nor frameworks for applying creativity workshops. Based on analysis of our experiences, we propose a visualization creativity workshop framework. This framework unpacks the nuanced definition of visualization creativity workshops, connects workshops to existing visualization and creativity theory, defines a process model for using workshops, and identifies both guidelines and pitfalls for future workshops. We also use this framework to evaluate the effectiveness of past workshops and to provide three example workshop templates that can be tailored for future projects.

Index Terms—Creativity workshops, design study, user-centered design

1 Introduction

Creativity workshops are a useful method for applied visualization research. Through the use of structured *creativity methods*, workshops help researchers and collaborators to establish rapport, to characterize domain problems, to understand specific analysis tasks, to broadly explore the solution space for a given problem, and to evaluate potential solutions. Reflecting their use of creativity workshops, Goodwin et al. [12] conclude that the *"deliberate use of techniques to enhance creativity early in the visualization design process can contribute to success in terms of process and outcomes."*

Existing creativity workshop literature generally focuses on workshops for creative problem solving, often in a business setting [46]. While creative problem solving encourages participants to formulate problems and to explore solutions for those problems, visualization creativity workshops often emphasize communication between visualization researchers and domain collaborators. Software requirements engineers use creativity workshops to understand the needs of diverse stakeholders in complex software systems [24]. But these workshops mention data only implicitly and do not account for the nuances of visualization design, including: the critical role of data early in the design process [43]. the use of specialized process models [62], the sharing of knowledge between designers and analysts [65], the fuzzy nature of visualization software requirements [54], and the evolution of data and tasks that occurs throughout the project [39].

This paper explores the concept of **visualization creativity workshops** — creativity workshops tailored to the needs of applied visualization researchers. It results from a collaboration between visualization researchers to answer a seemingly simple question about two creativity workshops used in design studies [12, 27]: *what could we do better next time?* Informal discussions about this question revealed that answering it required a vocabulary to describe workshops and appropriate constructs to evaluate their effectiveness. Our initial discussions expanded to analysis focused on answering this question: *what do we know about visualization creativity workshops?*

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We have explored answers to this question using a methodology resembling *critically reflective practice* [61] to propose insights by synthesizing existing theory with careful analysis of our experiences. In our reflection, we reviewed literature spanning both the theoretical and practical aspects of creativity workshops [4, 7, 8, 9, 17, 59, 38, 44, 46, 51, 51, 57, 63, 63]. We conducted additional workshops and analyzed our past experiences, having conducted a total of 12 visualization creativity workshops in 8 research projects [10, 12, 13, 27, 30, 45, 48, 64]. And we draw on the experience of a researcher (who is also a co-author) who pioneered the use of creativity workshops in software requirements engineering [20, 24, 25, 34, 36].

The reflection identified constructs for analyzing workshops and describing our knowledge: the workshop purpose, process and practical considerations. The *workshop purpose* connects workshops to specific roles in existing visualization process and decision models. The *workshop process* describes the steps of using a workshop in applied visualization research. *Practical considerations* distill our experiential knowledge into recommendations and pitfalls for future workshops. Examining our experiences revealed that 8 of our 12 workshops focused on the early stages of applied research related to domain problem characterization and understanding user needs in terms of data and tasks. Although we believe the workshop process applies to any visualization workshop, we focused on specific practical guidance for workshops used early in the design process.

This paper's primary contribution synthesizes the workshop process, purpose, and practical considerations into a **visualization creativity workshop framework** with four aims: 1) it defines four workshop types based on their purpose; 2) it proposes a six stage process model with practical considerations for designing, running and analyzing workshops focused on workshops early in the design process; 3) it provides example workshops that can be tailored to specific domain collaborations; and 4) it identifies a set of pitfalls to avoid in all visualization workshops. While many resources exist that describe how to run a creativity workshop, this actionable framework is the first to provide theoretical and practical guidance that accounts for specialized challenges faced by applied visualization researchers.

As we conduct applied research in an uncontrolled setting, we intend for the framework to describe our experiences and prescribe practical considerations based on the analysis of our actions in the context of existing theory. The framework emphasizes description, ecological validity, and transferability over prediction and generalization. Overall, we hope that it provides guidance to visualization researchers for using, analyzing, and documenting creativity workshops in future projects.

In the remainder of this paper, Section 2 summarizes background of creativity workshops. Section 3 describes our workshop experiences and analysis methods. Section 4 defines four workshop types to char-

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acterize the workshop purpose. Section 5 proposes the process model for using workshops along with practical considerations. Example workshops and our discussion are in Sections 6 and 7 respectively.

2 Background

In this section, we adopt a vocabulary for discussing creativity, examine the role of creativity workshops in visualization design, and summarize the origins of creativity workshops for problem solving and software engineering. However, creativity research spans many domains, including philosophy [2], psychology [52], biology [37] , and human-computer interaction [56]. While a full summary of creativity research is outside the scope of this paper, two excellent resources that explore the diverse perspectives of creativity have been written by Sternberg [60] and Sawyer [52].

2.1 Workshop Definitions

Creativity is defined as the generation of ideas that are new and useful in a specific context, such as to an individual, a group, or all of humanity [38]. Creative ideas commonly involve solving problems through new insights, (re)formulating problems, or creating new associations from existing concepts [52]. Group creativity refers to the emergent creativity from interactions between members of a group, such as in a workshop setting [51]. A **creative process** is one that encourages divergent thinking to explore many ideas followed by convergent thinking to select the most promising ones [32, 46]. Visualization design is a creative process that requires exploring a broad consideration space winnowed to a narrow proposal space [54].

Methods are the repeatable procedures that describe the actions of designers [6], though they are sometimes called techniques [49, 50]. Creativity methods are methods used in creative processes — every method used in design is a creativity method to some extent [1]. Creativity methods can be classified by attributes, including whether they are generative, evaluative, or their role in the design process [1, 15, 40]. The structured use of methods to achieve a goal is a **workshops** [4]. Creativity workshops are workshops that encourage creativity through a creative process, though the distinction between workshops and creativity workshops is often based on intent rather than observable differences [17].

2.2 Creativity research

Researching creativity is challenging as it is hard to quantify the novelty and usefulness of an idea [44]. But, there is agreement on the characteristics of creative work and a vocabulary to describe creative thought processes. Researchers agree that creativity results from individuals and organizations who exhibit expertise in their domain, hard work, and open communication [38, 44, 52]. And creative insights are usually the results of many smaller but interconnected mini-insights [52].

Many models exist for creativity [2], but the two common models emphasize the importance of *thinking* and *doing* in creative endeavors: the four stage model and the action theory of creativity. The *four stage model* defines a linear sequence of creative thoughts as *preparation, incubation, insight*, and *elaboration* [16]. This model, however, oversimplifies human thought and understates the role of action in creativity [52]. The *action theory of creativity* emphasizes the importance of action in a feedback loop: as creators express an idea, the world reacts to that expression, and this reaction influences the creator, changing their idea and leading to new ones [11]. These two models provide a useful vocabulary to describe creativity methods and workshops. [52]. <E: If we do not ever use vocab from these models, then we should condense this paragraph. Revisit it later.>

2.3 Creativity workshops for problem solving and software requirements engineering

Creative problem solving practitioners are credited as the first individuals to create methods and workshops that harnessed creativity for a specific purpose [44]. Creative problem solving ranges from recommendations for creativity methods, such as brainstorming [46], to methodologies, such as Creative Problem Solving [5] and Synectics [14]. Principles of these methods and methodologies include:

Year(s)	Workshops	Analysis
2004 - '09	Creativity workshops invented for software req. engineering	
2009	EDINA workshop	
2010 - '13	E.ON workshop and HTVA workshop	Applied software req. workshops to visualization
2015	Graffinity workshop in design study CP workshop in design study	Reconcile differences of workshops Speculate on guidelines for future workshops Reviewed literature with narrow scope: creativity methods
2016	DiscoveryJam Workshop	Reviewed literature broadly: creativity, creativity support, workshops Detailed analysis of E.ON and Graffinity workshops
2017	UPDB workshop Arbor workshop Lineage workshop	Revisited experiences, interviews on EDINA and HTVA projects Formulated initial process model Reflected, revised, evaluated, and ellaborated process model Articulated results of reflection (wrote this paper)

Fig. 1. Timeline of our workshops and analysis methods. Following *critically reflective practice*, we have used workshops, analyzed the experiences, and changed our actions based on experiences. Insights from earlier workshops, for example, influenced our actions in the Arbor and Lineage workshops. <E: This is a placeholder. Text is too small. Should replace with a timeline.> .

encouraging convergent and divergent thinking [46], fostering a creative atmosphere by suspending judgment [7], stimulating creativity through analogy [14], gaining new perspectives on a problem [63], and using both analytically and intuitive mindsets [42]. These useful guidelines do not directly apply to visualization, in part, because creativity for problem solving assumes that workshop participants have the necessary knowledge to solve their own problems. In contrast, visualization research emphasizes the importance of sharing knowledge between domain collaborators and visualization researchers to reach a solution [65].

Software requirements engineers recognize that generating requirements requires creativity [47] and researchers have tailored tailored existing creativity methods and methodologies, such as Creative Problem Solving, to their field [33]. This includes creativity workshops to engage project stakeholders and to elicit requirements for complex systems [23, 34, 36, 35]. Common parameters of these workshops include a length of 0.5 to 2 days, 18 - 24 participants, and hundreds of ideas generated per workshop [25]. These ideas generated were integrated into requirements engineering processes [24] or more modern agile processes [19]. Although these workshops also provide useful guidelines for visualization workshops, they mention data only implicitly [22], in contrast to the important role of data early in the visualization design process [31]. There is also no clear relationship between the use of workshops and existing visualization design processes.

2.4 Creativity workshops in visualization

Using structured workshops has evolved in visualization from origins in human-computer interaction and geographic information systems [10]. Koh et al. [28] describe a process where two workshops demonstrate visualizations to collaborators: *visualization awareness workshops* show collaborators generic visualizations to elicit requirements by example and *domain visualization workshop* demonstrate visualization prototypes with collaborators' real data. Similarly, Slingsby et al. [58] describe a process of focused short term collaboration involving participatory methods for understanding current practices, designing, prototyping, and evaluating prototypes. These processes show that workshops are useful in applied visualization research, but fall short of prescribing guidelines or specific methods.

Workshops in visualization design also evolved from the fields of software engineering and creative problem solving as Goodwin et al [12] used three workshops in a design study with energy analysts. This work inspired our use of creativity workshops in a variety of projects [13, 27, 26, 30, 45, 48] which we describe in more detail as our experiences in the next section.

3 Workshop Experience, Data, and Analysis

This section describes our experiences using 12 visualization creativity workshops in 9 applied research projects and the relevant multiform data collected from those workshops. It also summarizes the collaborative methods that we used to analyze our experiences, relevant data, and existing literature.

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Project name	Author	Domain	Collaborators	Project goal	Num workshops	Reference	Result
EDINA	Dykes	GIS	Industry	*"reimagine the legend in the context of visualization"*	1	[10]	InfoVis paper
E. ON	Goodwin	Energy	Industry	Deliver insights into the role of Smarthomes and new business potenital	3	[12]	InfoVis paper
HTVA	Walker	Human terrain	Defense	*"develop [visualization] techniques that are meaningful in HTA"*	2	[64]	InfoVis paper
CP	Goodwin	Constraint programming	Academic	Design performance profiling methods for constraint programmers	1	[13]	VAST paper
DiscoveryJam	Rogers	Hydrology	Industry	Promote collaboration between visualization researchers and domain scientists	2 (in parallel)	[48]	Vis Workshop
Graffinity	Kerzner	Neuroscience	Academic	Create novel visualization techniques for multivariate graphs	1	[27]	EuroVis paper
Lineage	Nobre	Psychiatry	Academic	Create visualization tools to analyze determining or associated factors of suicide	1	[45]	TVCG paper
UPDB	Kerzner	Genealogy	Academic	Create visualizations to support geneology analysis	1	[26]	—
Arbor	Lisle	Biology	Academic	Create visualization software for phylogenetic analysis	1	[30]	NSF grant application

Table 1. A summary of projects where we have used creativity workshops. We have been involved with 12 workshops in 8 projects, spanning a variety of domains and collaborators from different organizations. With the exception of DiscoveryJam, all workshops were used in design studies. The details of project workshops are shown in Table 2.

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Project name	Workshop goal	Participants	Duration (days)	Workshop type
EDINA	Explore possibilities for enhancing legends with visualization	7 employees of EDINA GeoSpatial Services	1	Requirements
E. ON	Identify ways of utilising Smart Home data/technologies	5 employees of Forward Thinking Tech. Team	1	Requirements
	Develop concepts from requirements workshop in an agile approach	7 visualization designers	0.5 x 2	Design
	Elicit feedback on prototypes from experts	8 analysts total, 4 from previous workshops	1	Evaluation
HTVA	Establish current practice and perceived needs	4 analysts, 8 visualization designers	1	Requirements
	Aacquire feedback on progress and additional requirements	4 defense analysts (?)	1	Evaluation
CP	Identify data analysis and visualization opportunities	10 analysts	1	Requirements
DiscoveryJam	*A game jam for science*	20 - 40 attendees of IEEE Vis.	0.5	Design
Graffinity	Find opportunities for visualization in retinal connectomics and identify shared user needs	9 analysts and support staff	1	Requirements
Lineage	Understand the main domain tasks of collaborators	6 genealogy psychiatric analysts	0.5	Requirements
UPDB	Find opportunities for a design study with genealogy researchers	7 analysts and 3 vis designers	0.5	Domain characterization
Arbor	Find opportunities for funded collaboration between visualization designers and biologists	10 biologists, 2 visualization designers	2	Domain characterization

Table 2. An overview of the 12 total workshops grouped by their project. Workshops generally spanned 0.5 - 2 days in length. With the exception of DiscoveryJam, all workshops had less than 20 participants. Here, we analyzed the workshop goal and participants to propose the concept of a workshop type, defined in Table 3.

Workshop type	Description	Design activities	Nested model	Ideal participants
Domain characterization	Provides broad characterization of domain problem space.	Understand (generative)	Problem characterization	Domain collaborators
Requirements	Identifies specific analysis needs suitable for a design study	Understand and ideate (generative)	Data/operation abstraction	Frontline analysts
Design	Explores the solution space for specific problems.	Ideate and make (generative)	Encoding/interaction technique	Visualization designers
Evaluation	Evaluates visualization solutions with collaborators.	Deploy and understand (evaluative)	Downstream validation	Domain collaborators

Table 3. Four types of visualization creativity workshops: domain characterization, requirements, design and feedback. These types map to activities of the design activity framework [40] and levels of the nested model for visualization design [43].

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3.1 Experience and data

The visualization creativity workshop framework is based on analysis of our experience using workshops in a variety of projects, summarized in Table 1. These projects span a variety of domains, from biology, to constraint programming, and geographic information systems (GIS). The projects span different types of collaborator organizations, including industry, defense, and academic. Of the 9 projects, 6 resulted in publications at major visualization venues, 1 was a workshop at IEEE Vis, 1 resulted in a grant application, and 1 project was a failure that we have abandoned.

A summary of the 12 workshops is shown in Table 2. Workshops have 4 - 12 participants including domain collaborators and visualization designers. Their duration ranges from 0.5 - 2 days. We categorize workshops based on their role in the design process, from problem characterization, to requirements, design, and evaluation. Section 4 provides a more complete definition of the workshop type.

Workshops generate tremendous amounts of quantitative and qualitative data throughout the process of using them, from planning a workshop to analyzing the output. The data includes the workshop participants, anticipated outcomes, preparation efforts, methods, materials, venue description, notes and transcripts, method artifacts, participant feedback, and facilitator reflections. It also includes the insights gleaned from analyzing workshop output and the impact of those insights on the design process. As our workshops were conducted over a period of 10 years, the data are missing or incomplete in some places. In those cases, we have supplemented the data with interviews of individuals involved in the project.

3.2 Analysis methodology and methods

The visualization creativity workshop framework results from the careful analysis of our experiences using workshops combined with existing theory. We have developed it using a methodology resembling *critically reflective practice* [3, 53, 61]. It is characterized by describing and analyzing our experiences in the context of existing knowledge, proposing insights based on that analysis, and acting on insights to test our understanding while generating more experiences for reflection.

The specific analysis methods evolved through our two year collaboration, shown in Figure 1. Workshop analysis started with informal discussions to reconcile differences between three workshop experiences in E. ON, CP, Graffinity. In these discussions, we proposed guidelines for future workshops. But the proposed guidelines were speculation based on limited experience. Yet these discussions were fruitful in that they revealed a lack of constructs for describing and analyzing visualization creativity workshops. We struggled to understand our experiences because we did not have the language to describe important aspects of workshops, including the process and purpose.

A majority of our analysis, conducted over the past year, consisted of a broad literature review and detailed reflection on our actions and experiences using workshops. The broad literature review established constructs for creativity workshops in general domains. Through a process of informal discussions, collaborative reflection, and iterative improvement, we have adapted existing constructs to the domain of visualization. We performed this improvement by reconciling our understanding of workshops with our experiences of past workshops (e.g., HTVA and EDINA). We also explored limitations of existing frameworks with respect to visualization.

Writing this paper is an important part of our analysis. Through our writing, we have articulated the tacit knowledge developed through our experiences using creativity workshops and reached consensus between the co-authors with diverse perspectives and experiences. The resulting visualization creativity workshop framework is one of many possible interpretation of our experiences and existing theory. Nevertheless, this subjective interpretation provides valuable guidance for our community on how to both use and understand creativity workshops.

4 Workshop Purpose

Reflecting on our experience reveals that workshops can serve different purposes in the design process. Many aspects of the workshop are dependent on the purpose, such as the participants, methods, and intended output.

We define a **workshop type** based on their intended purpose in the visualization design and process models. The four workshop types are: domain characterization, requirements, design, and evaluation. The workshop types map to *design activities* from the Design Activity Framework [40] as this framework connects the actions of designers to intended outcomes, just as we connect the decision to run workshops to their intended outcomes. Workshop types also correspond to levels of the Nested Model for Visualization Design [43].

Table 3 summarizes each types and its corresponding design activities, and levels of the nested model. First, **domain characterization workshops** generate a broad understanding of domain needs, without necessarily identifying specific analysis tasks. This maps to the understand activity. Output from the workshop influences the domain problem characterization of the nested model. Second, a **requirements workshops** focuses on the needs of specific data analysts. It corresponds to the understand and ideate design activities.Output from these workshops influences decisions at at the problem characterization and data and task analysis levels of the nested model. The domain characterization and requirements workshops are used for exploring the problem Third, **design workshops** involve ideating or creating designs to fulfill the needs of analysts. This fulfills the ideate and make design activities, and the interaction, encoding, and implementation levels of the nest model. Fourth, **evaluation workshops** focus on evaluating, validating, and eliciting feedback on visualization solutions for a given domain. This corresponds to the make and deploy design activities and produces data used in downstream evaluation of the nested model. <E: Split this paragraph somehow>

Table 2 identifies the workshop types for our experience. This paper focuses on domain characterization and requirements workshops because this where we have the most experience as 8 of our 12 workshops fulfill this type.

However, workshop types are an abstraction of the *intended* outcome from complex human activity and interaction. It is impossible to perfectly describe the outcome of a workshop. One benefit of workshops is the serendipitous and unpredictable results. Workshop types also oversimplify the continuum of cyclical design activities [62] by representing discrete points. Nevertheless, workshop types provide an important vocabulary for characterizing and describing workshops.

5 Workshop Process

This section describes a process model for applying visualization creativity workshops to a design study. The process consists of six stages conducted in a forward linear motion. Each stage has a defined purpose, input, and output. Figure 2 shows the stages: **decide** to use a workshop, **design** the workshop, **perform** the workshop, **analyze** the workshop output, **act** on analysis, and **reflect** on workshop efficacy. The stages are cascading as decisions in one stage impact others downstream. For example, the factors influencing the decision to run a workshop will influence the insights that we can glean from workshop output. The process model provides constructs for describing and analyzing our workshop experiences. For each stage, we identify important aspects from our experiences, and identify pitfalls to avoid in future projects.

5.1 Decide to run the workshop

In the first stage, we decide whether a workshop would benefit a design study while identifying the workshop's goals, contributors, and constraints. Input to this stage is an in-progress design study. As a result of this stage, there should be a workshop leader who has selected an appropriate workshop type, created a workshop goal, selected workshop contributors, and identified workshop constraints.

Workshop leader: the **workshop leader** is a critical role as they will use the insights from the workshop in their applied visualization research project. Without a clearly defined leader, the workshop output will go unused. In our failed project where we used a creativity workshop, we had no leader to use workshop results (pitfall *PF. 1*). Generally, the workshop leader is also responsible for identifying the workshop type and promising workshop contributors.

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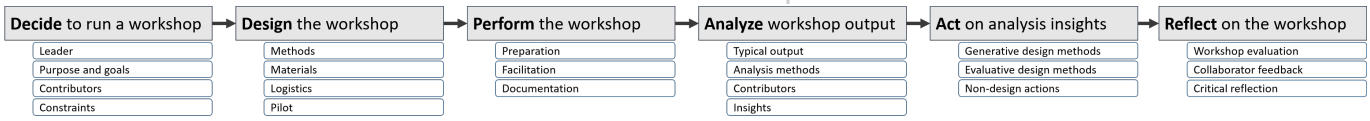

Fig. 2. The process of using a creativity workshop in applied visualization projects defined by six stages (rectangles) and a set of practical considerations for each stage (ovals). Movement through stages is in a forward, linear fashion. Stages are cascading: output from one stage impacts those downstream.

Workshop type: the workshop type summarizes the intended role of the workshop in the design process. The workshop type depends on the leader's domain knowledge. For a problem characterization workshop, the leader needs sufficient vocabulary to discuss the collaborators domain problems. This requires understanding the existing software tools and data, but not necessarily the analysis tasks. For a requirements workshop, leaders should be able to describe the roles of analysts in the organization, though the exact analysis tasks may still be unknown. Insufficient domain knowledge going into a workshop risks ineffective methods and an inability to lead discussions or ask appropriate questions (pitfall *PF. 2*).

Workshop goals: the **workshop goal** is the stated reason for running a workshop. While existing workshop literature emphasizes the workshop goal should fulfill a *client's* needs [17], in applied visualization research an effective goal summarizes the objectives of all stakeholders — visualization designers and collaborators. For example, in the requirements workshop with constraint programmers, the workshop goal, *"to identify data analysis and visualization opportunities for more effective profiling techniques for (complex) constraint programs,"* reinforced the mutually beneficial relationship between everyone involved. The workshop goal is useful for identifying and recruiting the workshop contributors.

Workshop contributors: deciding to run a workshop involves identifying the workshop contributors, individuals who will be involved with it. Workshop contributors fit roughly into three categories: participants, facilitators and scribes. As the name suggests, **participants** will participate in the workshop. For characterization and requirements workshops the ideal participants tend to be domain collaborators and frontline analysts. Visualization researchers may also be useful participants, if they have the required knowledge. **Facilitators** lead and instruct the workshop participants through the methods. Workshop facilitators should be comfortable running workshops and have sufficient knowledge to lead discussions about the domain. The **scribes** aid in recording the workshop output. <E: So what about scribes?>

Workshop constraints: identifying the workshop constraints can be used to decide if a workshop is feasible, and will help with designing it. Two important constraints are the location and length. The location is the general area where the workshop will occur, though not necessarily the exact venue. All workshop contributors should be in the same location for it as remote involvement detracts from the experience due to latency and the inability to share physical artifacts (pitfall *PF. 3*). The workshop length depends on the time that contributors can commit to a workshop. We have used workshops ranging in length from half a day to two days.

5.2 Design the workshop

In the design stage, we create a workshop of the desired type that fulfills the stated goals. The output of this stage is a workshop plan that is ready to be run. The plan consists of identifying the workshop methods, the materials, and venue. Designing a workshop is an iterative process that involves selecting or inventing methods, tailoring those methods to the specific workshop, testing the methods in a pilot workshop, and assembling a final workshop plan. The output from this stage is a workshop that is ready to run. The workshop is described by a workshop plan. The plan includes a description of all the workshop methods, and the materials needed to fulfill those methods. The plan should also define the roles of facilitators and scribes. The facilitators and scribes should

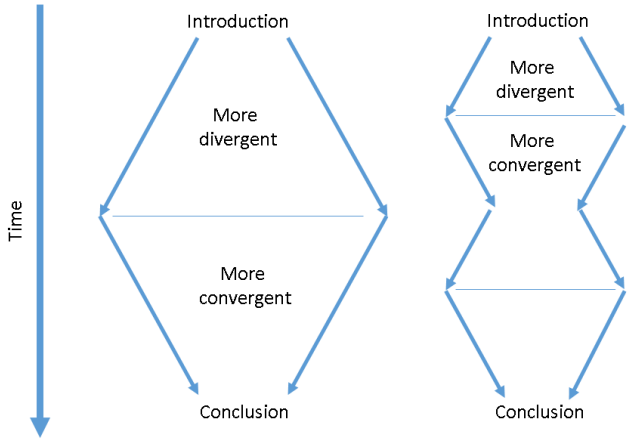

Fig. 3. A structure of workshop methods. Workshops generally follow a pattern of divergent methods to explore an idea space, followed by convergent methods to select the most promising ideas. Here, we show two ways of thinking about workshop methods: as one diverge-converge cycle throughout the entire workshop or as a series of diverge and converge cycles applied sequentially. These structures are end points of a spectrum and effective workshops occur somewhere between them. <E: Placeholder to be replaced with higher quality image.>

be ready to run the workshop, based on their experience piloting. Here, we describe aspects of selecting methods including methods that prime participants and establish a creative atmosphere, selecting methods that allow for broad exploration and narrow consideration spaces, tailoring methods to specific domains, resources for selecting methods, visualization specific methods, and framing methods as creativity support tools.

Priming methods: In our experience and workshop literature, it is recommended that workshops start with an introduction to establish buy-in from participants and foster a creative atmosphere. Establishing buy-in from participants involves communicating the the mutually beneficial workshop goal and sharing an agenda that will be used to acheive that goal. While workshop methods sometimes appear chaotic, we have received positive feedback from participants who appreciated structure of an agenda. But, spending too much time on the roadmap may detract from the workshop experience as it sets an atmosphere similar to a lecture with one person speaking in front of the participants. In the DiscoveryJam workshop, we used around 30 minutes of introductory minutes which we were told in feedback that it was too long. Around 10 minutes for setting the workshop goals seems appropriate.

Another goal of priming methods is to establish a creative atmosphere. The characteristics of a creative atmosphere include supporting open communication and suspending judgment. A particularly effective method for establishing a creative atmosphere is to use introductions that force people to share ideas that they might not otherwise be comfortable with. For example, many of our workshops have used *Introduction by analogy* where we ask participants: *Introduce yourself as a*

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food. This type of activity fosters interpersonal leveling — everyone in the workshop has to participate. It also leads to individuals more comfortable to share ideas.

Structure of divergence and convergence: tere is a strong convention from researchers and practitioners that methods follow a pattern of divergent thinking followed by convergent thinking [12, 14, 17, 24, 46]. Framed in a visualization vocabulary, workshops employ cycles of *generative* methods to expand the idea space, followed by *evaluative methods* to winnow the idea space [40]. An example generative method is *brainstorming ideas* which may be followed by an evaluative method, *selecting the most promising ideas*. We have applied diverge-converge cycles with different periods in our experiences. For example, full day requirements workshops [12, 13, 27] followed a cycle that lasted the entire day. In contrast, we used a domain characterization workshop that employed four cycles of diverge-converge over the span of two days [30].

Domain-specific methods: workshop methods should be customized for the domain and workshop type. In a common generative called *Wishful thinking*, we ask participants to record aspirations about what they would like to know, what they would like to see, or what they would like to do on post-it notes. These aspirations are often focused on a specific problem. For example, in our neuroscience workshop, we used broad prompt: "*While working with connectome data, what would you like to know? ...*". We used a more narrowly scoped prompt in the workshop for constraint programmers: "*Your program does not execute as expected...what would you like to know?...*" Broad prompts will result in higher-level ideas about the goals of a domain, suitable for domain characterization workshops. Narrower prompts focus discussion on specific analysis challenges and may be more suitable for requirements workshops. Another important aspect of customizing methods is the language that they use. For example, one method that we have used in previous workshops is called Constraint Removal. But when working with constraint programmers, we were careful to avoid using the term *constraint* because of the domain-specific connotations (pitfall *PF. 8*).

Method duration: there are many factors to consider in selecting the duration of methods, and the exact duration will depend on how the method is received and performed by the participants during the workshop. But we have generally used methods that range in length from 1 - 2 hours, allowing ample time for breaks between methods. This is a generally accepted practice in workshops run in other domains as well [17].

Resources for selecting methods: In addition to the example workshop provided in this paper, we recommend useful compendiums of methods. These include books of creativity methods focused on general product development (e.g., [18, 41, 55]), software engineering and design method catalogs (e.g., [15, 29]), and visualization specific methods (e.g., [40]). Although these are thorough descriptions of individual methods, they do not address the coherency of stitching together methods, nor do they all address visualization-specific considerations.

In selecting methods, it is important to remember that a workshop is more than just a collection of methods — it is an arrangement of methods that work in concert to achieve a desired goal. And so, it it useful to consider how methods relate to one another. We have had success with methods that encourage participants to generate ideas, and then use those ideas to explore topics in more depth. For example, in our domain requirements workshop, we used the wishful thinking activity followed by a clustering exercise where participants had to categorize their ideas and select the most pressing categories. These high-priority categorized were explored in subsequent workshop methods. This is similar to the springboard methods invented for Synectics [14].

Workshop methods and *creativity support tools* [56] both aim to foster creative output from the participants (or users). We have found useful criteria for selecting methods to be provided in the literature for creativity support tools. These criteria include: *low thresholds, high ceilings, and wide walls*; *supporting many paths and many styles*; and *encouraging collaboration*<E: cite Resnick2005 - add to mendeley> .

In one of our projects [27], we had less success with a method of Storyboarding where users had to draw their interaction with future software tools. The facilitator who used this method has avoided using it since then. In retrospect, the criteria of creativity support tools would have identified that this method may be less successful as it violated the principle of low thresholds as it required participants have some ability to draw.

Visualization-specific methods: <E: Need to fill this in with visualization awareness.>

Workshop materials: the workshop materials are critically important for the success of workshop methods. Materials allow for the smooth execution of methods. In visualization workshops, methods often involving demonstrating visualizations for ideation or feedback. These methods require high resolution and high contrast projectors (pitfall *PF. 5*.)

Another important factor of materials is the format that they afford. A surprisingly common mistake is to use post-it notes that are too large. Often, methods require recording one idea per post-it note to allow for rearrangement and linking of concepts. This has limited the effectiveness of one workshop that we have run [27] and more than one workshop that we have participated in. Another mistake is to use materials that do not afford the desired outcome (pitfall *PF. 7*). For example, if a method is trying to elicit high level ideas, a thicker tipped pen can prevent participants from trying to draw highly detailed images. <E: Cite? Buxton book> One way to ensure that materials are appropriate for the intended methods is to try them out. This leads to the next question about designing workshops.

Workshop venue: this is where the workshop will be run. The venue should also include considerations of food, transportation, lodging, and activities for rest. We have used a variety of workshop venues, ranging from conference rooms at our collaborators' organization to neutral off-site locations. Although it is difficult to prove with controlled experiments, the creativity literature generally recommends that venues be well-lit, have adequate space, and separate participants from their daily work [21].

Pilot workshops: from our experiences, we recommend approaching pilot workshops as dress rehearsals for the proper workshop. They should use all of the actual materials that will be used in the workshop itself. This includes everything from method prompts, to the writing utensils, to the output materials. We have used abridged workshops, often shortening the methods from the hour or two of a planned workshop to 10 - 15 minutes for a pilot. In addition to piloting the workshop, we have also tested individual methods, though this is largely an informal process.

In many of our experiences, pilot workshops helped us refine materials, finding typos or ambiguous directions. We have also used pilot workshops to brief co-facilitators on the desired outcomes of activities which has helped them answer questions during the workshop. Although we have run workshops without pilots, these workshops anecdotally tend to have more mistakes in the prompts which leads to more distraction of participants. We cannot stress this enough: workshop pilots are critical and important part of visualization creativity workshops (pitfall *PF. 7*).

5.3 Perform the workshop

In the perform stage we execute the workshop plan. We use the term perform because running a workshop is like a performance that involves all the contributors carrying out the planned methods, often acting in concert to achieve the desired workshop goal. This section is a visualization specific supplement to existing resources that have detailed descriptions about effectively running workshops in general, e.g., [4, 17]). We focus on important aspects of performing workshops, including preparing participants, learning from methods, moving through the methods with flexibility, collecting artifacts, and gathering feedback.

Participant preparation: preparing participants for the workshop includes giving and receiving information about the workshop from the participants. This includes surveys and specific methods, e.g., homework. Surveys yield mixed results. Surveys of biologists in the Arbor project received less than 25% response rate when sent through email, but the CP workshop used surveys to identify all of the participants<E: is that true?> . We have had limited success with pre-workshop methods, such as in the E.ON project where participants

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ignored pre-workshop directions. <E: Needs details. what were the directions? do we have a quote about it?> Overall, we have had general success asking participants to attend the workshop well rested and ready to be fully engaged in the workshop.

Minimize distractions: creativity workshops provide an opportunity for focused work. Technology, such as cell phones and laptops, introduces distractions to the workshop. We strongly discourage the use of laptops and phones during the workshop. This should apply to everyone in the room where the workshop is happening. In the Graffinity workshop, a facilitator taking out their laptop caused a ripple through the room. some participants saw the laptop as a cue that it was acceptable for them to take out their computers. We have seen similar effects when a workshop scribe used a laptop to record notes in the Arbor workshop.

In addition to technology, workshop observers can also distract participants, facilitators, and scribes. In the Graffinity workshop, observers entering and exiting the workshop distracted the facilitators from the flow of methods. Existing workshop literature also emphasizes that observers can detract from the creative atmosphere as they are isolated from the participants [17].

Learn from participants: domain characterization and requirements workshops emphasize the transfer of knowledge between participants and facilitators. It is useful for facilitators to learn from participants, especially during methods where participants are working individually or in small groups. We have found it useful to walk around talking and listening to participants. However, facilitators who get drawn into group discussions need to beware of the time and the workshop plan.

Keep moving through methods: there are many discussion topics that can derail carefully planned methods and stall the workshop. We recommend avoiding the explicit discussion of visual representations and implementation details. The goal of characterization and requirements workshops is to understand the correct problem solve. The focus should be on the problem space as opposed to the solution space. <E: SG's story about constraint programmers can go here.>

Be flexible: <E: JD's story about analysts taking over the workshop [64]> .

Generate, collect, and preserve artifacts: workshop methods generate artifacts, the tangible output often on post-it notes, paper, or other materials. Artifacts are invaluable for the visualization design process, but workshops generate hundreds of artifacts. It can be overwhelming to organize the artifacts to enables transporting them from the workshop venue to a regular work place, and to support reviewing them later. Workshop methods that encourage organizing artifacts, such as clustering ideas recorded on post-it notes, make it easier to transport and review artifacts after the workshop (pitfall *PF. 12*).

Record useful output: it is useful to capture data about the workshop not represented in artifacts, such as the discussion topics. In our half-day workshops, we found it useful to record audio of both small groups and large group discussions. This audio was useful for identifying themes not identified in the workshop output, but transcribing audio is time consuming [31] and we would not recommend it for longer workshops. Scribes can help by recording discussion points, however, scribes often record output that is redundant with the artifacts generated by methods (pitfall *PF. 11*). In future workshops, we plan to have scribes document the ideas that are *not* already captured by method artifacts.

Gather feedback: feedback from participants provides valuable information about the workshop and the facilitators. For example, feedback from the Graffinity workshop critisized the storyboarding method, and we have since discouraged its use in repeated workshops. Feedback can also be used to evaluate facilitation, such as, for example, whether the methods were used effectively. Gathering feedback can be challenging though. The E.On requirements workshops attempted to use post cards to gather feedback, but received only one reply<E: Need to cite GD's paper for justificaiton.> E-mail surveys sent immediately after the workshop seem to have the highest response rates.

Reflect immediately: we have found it useful to spend time immediately after the workshop to reflect on the workshop. Reflection can involve identifying key themes that were discussed or opportunities for improvement. These reflections can be used to make sense of the workshop output and improve future workshops. <E: So what? Why?>

5.4 Analyze workshop output

Analyzing the workshop output is an iterative and labor intensive process that transforms the workshop output into actionable knowledge. The workshop output can contain hundreds of artifacts, recordings, transcripts, and notes. The result of analyzing output depends on the project, but can include broad themes for research projects, and specific opportunities, constraints and considerations for visualization development. The *leader* should conduct most of the analysis as they will integrate the insights from analysis into a research project. This section describes considerations of analysis including a description of typical output, methods for analyzing output, recommendations on involving workshop contributors in analysis, and sample insights generated from analysis.

Typical output: workshops generate a tremendous amount of output. Although it varies with the methods used and the number of participants, workshops typically generate on the order of hundreds of ideas recorded on artifacts in addition to documentation and recordings of the day. As noted in the previous two stages, using methods that introduce meaningful organization may help analyzing output. In the Graffinity workshop, for instance, we used methods that generated relatively unorganized artifacts, while the Arbor workshop used methods where participants clustered artifacts into meaningful categories. This clustering proved valuable in our analysis methods.

Insights from analysis: the goal of analyzing output of characterization and requirements workshops is to generate insights that inform the design process. The insights have generally taken two forms: insights as themes and insights as requirements. <E: Don't really understand this yet.>

Analysis methods: The workshop output is mostly qualitative data as the artifacts generally represent aspirations, ideas, or concepts. It follows that qualitative methods are most appropriate for analyzing results. We have used open coding, thematic analysis, and mind maps to generate these categories. However, these methods are more effective when followed informally: data (and not the methods) should drive the analysis of workshop output. <E: Needs evidence or better explanation.>

A pitfall to avoid in analysis is quantification of workshop output (pitfall *PF. 13*). In the Graffinity project, we attempted quantification of the workshop output, but found that counting output misrepresents important aspects of the data. For example, more important themes from the day were discussed often, but only appeared in a small fraction of the workshop artifacts.

Contributors in analysis: workshop facilitators and scribes may be helpful in analyzing workshop output as they can provide contextual details or elaboration of certain artifacts. Involving workshop participants in the analysis is a delicate question: workshop participants may be too constrained by the conventions of a domain to identify abstract relationships between artifacts, just as too much domain knowledge can restrict the ability of visualization designers. Identifying a participants who is also a *translator* [54] can help with analyzing somewhat cryptic workshop output, but we have generally not involved contributors into the analysis of workshops. Participants, however, have been involved in the actions that we take based on the output of analysis.

5.5 Act on the analysis insights

In this stage, visualization researchers act on the analysis from workshop output. Acting on workshop output typically influences the *understand*, *ideate*, and *make* design activities [40]. More concretely, acting on analysis is where the results of the workshop influence the results of the applied research project. We describe these actions in the text of generative design methods, evaluative design methods, and non-design methods.

Generative design methods: workshop output can be used as opportunities for generative design methods. For example, the E. ON project used output from their requirements workshop as input to a *design*

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workshop where visualization designers explored the design space of prototypes. The Graffinity project used output from the workshop into parallel sketching and prototyping methods.

Evaluative design methods: Constraints and considerations are useful for evaluative methods they provide criteria to measure the projects success. They also provide important restrictions for designers. Evaluation referred back to this feedback as well as original requirements. The participants really liked that we linked everything back to each stage and they could see the path of the design [Goodwin 2012].Throughout the design and development process the development integrations were focused back to the requirements. We tried to ensure each prototype met a set of different requirements with limited overlap to help reduce scope, allow us to prioritise quickly and to increase the potential for new insight. [Goodwin 2012]

Non-design actions: The output can also be used to help the domain - e.g., SGs example of possible directions for future work in the field that were beyond the scope of her vis project.

5.6 Reflect on the workshop

<E: I don't really have anything to say here, yet.>

6 Example Workshops

In this section we describe the example workshops which are included as supplemental material.

7 Discussion

Here, we summarize pitfalls to avoid in using visualization creativity workshops. We also identify limitations of our approach in using qualitative data analysis to make sense of visualization creativity workshops.

7.1 Pitfalls

PF. 1 No workshop leader
PF. 2 Insufficient domain knowledge
PF. 3 Participants not local
PF. 4 Collaborators cannot commit time
PF. 5 Projector insufficient for vis
PF. 6 Materials have wrong affordances
PF. 7 Failure to pilot workshop methods
PF. 8 Failure to account for collaborators' language
PF. 9 Venue furniture not conducive to creativity
PF. 10 Co-facilitators and scribes not prepared
PF. 11 Scribes record redundant data
PF. 12 Methods generate unorganized artifacts
PF. 13 Analyze artifacts as quantitative data

<E: Need to move these into a table or float.>

7.2 Comparison to other methods

7.3 Limitations and future work

Although practitioners claim creativity workshops stimulate creative thinking, creativity researchers have found no clear evidence of this. Surveys of the field reveal that researchers *"disagree on which [creativity methods] are best, whether any of them work at all, and how we should test their effectiveness"* [52].

8 Conclusion

Acknowledgments

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