Reflections on Creativity Workshops
in Applied Visualization Research

Abstract— Creativity workshops are a valuable method that help visualization researchers to establish rapport with project stakeholders, to understand domain problems, and to explore solutions to those problems. They have been used successfully in a variety of recent projects, but there are no established practices for what exactly are creativity workshops or how to use them effectively in visualization. Through a methodology of critically reflective practice, we have analyzed our use of 17 creativity workshops in various applied visualization contexts. This paper contributes the results of our analysis: a framework that describes the process and design considerations of visualization creativity workshops. We support the framework with a validated example workshop and 22 actionable recommendations for future workshops. We intend for this paper to provide thinking tools for planning, executing, and reflecting on visualization creativity workshops.

Index Terms—User-centered visualization design, design studies, creativity.

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1 INTRODUCTION

The early, formative stages of visualization design work focus on identifying interesting visualization opportunities within a domain [50]. Typically, these stages rely on many hours of repeated interviews and observations with a set of stakeholders in order to discover and codify a set of common needs [26]. A number of design studies, however, report on the use of *creativity workshops* – a structured participatory method that deliberately and explicitly fosters creative thinking in the early stages of visualization design work – as an alternative method for discovering visualization opportunities [10, 11, 12, 23, 39, 57]. These workshops bring together a small group of visualization designers and domain experts for a day of focused work to explore opportunities by establishing open communication, building trust, and encouraging deep thinking. The workshops greatly reduce the time and effort of discovering cross-cutting needs, as noted by one participant: *"the interpersonal leveling and intense revisiting of concepts made more team progress in a day than we make in a year of lab meetings ... [the workshop] created consensus by exposing shared user needs"* [23].

Despite the documented success of creativity workshops in the visualization design process, there is little existing guidance about what exactly creativity workshops are, why they are useful, how to effectively use them, or how to evaluate and report them. For example, Kerzner et al. [23] summarize their use of a workshop in a single sentence, while the rich description provided by Goodwin et al. [11] focuses on their experience *using* a workshop. Furthermore, structured guidance from other domains that use creativity workshops, such as creative problem solving [5, 6, 15] and software engineering [19, 20, 21], do not account for the nuances of visualization design. These nuances include: the critical role of data early in the design process [37, 42]; the use of specialized process models [35, 50, 55]; the sharing of knowledge between visualization researchers and collaborators [58]; the fuzzy nature of visualization software requirements [50]; the evolution of data and tasks that occur throughout a project [33]; and the importance of

evaluating and validating design decisions [26].

This paper fills the gap by providing guidance on how to design, execute, and analyze creativity workshops while accounting for the nuances of visualization design. The guidance in this paper results from a research methodology of *critically reflective practice* [3]. Our reflection includes analysis of our collective experience conducting 17 creativity workshops in 10 different applied visualization contexts [10, 12, 11, 22, 23, 27, 39, 45, 46, 57], as well as a review of creativity workshop literature from the domains of design [1, 7, 8, 25, 47], software engineering [17, 19, 20, 21, 29, 30, 32] and creative problem solving [6, 13, 15, 36, 41].

Two primary contributions arise from this analysis. The first contribution is a framework for using creativity workshops in the visualization design process, which consists of: 1) a cascading process model describing how to initialize, design, execute, analyze, and reflect on workshops; and 2) thinking tools to navigate the workshop design space, including a general workshop structure, a validated example workshop, and workshop design considerations. The second contribution is a series of <**REVISE ME:** 15(?) > actionable recommendations for applying workshops to visualization design projects.

2 BACKGROUND AND RELATED WORK

This section provides a background on creativity workshops in applied visualization research, describing the diverse uses of workshops and summarizing the origin of creativity workshops in the fields of software requirements engineering and applied creativity. It concludes with a summary of where workshops have been used in recent visualization research.

Although the term *workshop* is overloaded in visualization, we are focused on workshops used as a method in the design process. Workshops are structured, participatory methods to achieve a goal [4]. Examples of workshops in visualization include the *visualization awareness workshops* and *domain visualization workshops*, generative design methods, where researchers present either visualizations of general data or domain-specific data respectively [24]. These workshops can be used as part of design processes that encourage short-term intensive collaboration for understanding current practices, creating visualization prototypes, and evaluating designs [52]. This process is exemplified in the three imagination exercises used by Dykes et al. [10] to understand the needs of geographic information systems (GIS) researchers, to create visualization designs, and to evaluate those designs.

The term *creativity workshop*, a workshop that deliberately and explicitly encourages creative thinking, was first used in visualization by

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Goodwin et al. [11], who describe a process with three types of workshops: *creativity requirements workshops* to understand the needs of energy analysts, *design concepts workshops* to create visualizations relevant to those needs, and *evaluation workshops* to demonstrate prototypes and evaluate their efficacy.

The creativity requirements workshop was inspired by workshops documented in the fields of software requirements engineering and creative problem solving. In software engineering, creativity requirements workshops provide opportunities for project stakeholders to collaborate and invent software requirements [19, 30, 32, 31]. These workshops range in duration from 0.5 to 2 days, engage 18 - 24 participants, and generate hundreds of ideas [21]. Workshop results have been integrated into requirements engineering processes [20], such as agile development [16]. Software requirements workshops were based in the field of applied creativity, where practitioners use workshops to deliberately and explicitly harness collective creativity to solve problems, often in a business setting [40]. While there are many competing methodologies for general creativity workshops (e.g., Creative Problem Solving [5], Lateral Thinking [6], and Synectics [13]), research surveys reveal common themes in these approaches, including: encouraging open communication, providing time for focused work, fostering divergent and convergent thinking, supporting iteration of ideas, and emphasizing problem finding and problem solving [38].

Workshop descriptions and principles from software engineering and applied creativity are useful for visualization researchers but do not explicitly address the challenges of visualization research. These workshops mention data only implicitly, in contrast to the important role of data early in the visualization design process [28]. Work from outside of visualization also does not account for the evolution of data abstractions and task analysis that occurs throughout a project. Nor does it incorporate the critical role of validation and evaluation familiar to visualization researchers [37].

Nevertheless, creativity requirements workshops have been used successfully in recent visualization research. Walker et al. [57] describe a process of three workshops to understand the needs of defense analysts, create visualizations, and evaluate the designs. Kerzner et al. [23] applied a workshop to understand the needs of neuroscientists. Recently, Goodwin et al. [12] used a requirements workshop to understand the needs of constraint programmers. Similarly, Nobre et al [39] used a two hour workshop to understand how genealogists could use their visualization software. And Lisle et al. [27] used a two day creativity workshop to find opportunities for a collaboration between visualization designers and evolutionary biologists.

Despite these repeated success, understanding how to use creativity workshops requires designers to piece together disparate information from the literature of visualization, software engineering, problem solving, and psychology. Experiential knowledge about how to run workshops has been developed through trial and error or communicated through informal discussions. This paper is the first comprehensive analysis of creativity workshops in applied visualization research. It describes a framework and recommendations based on knowledge gained from careful analysis of our experience, described next.

3 EXPERIENCE AND RESEARCH PROCESS

This section describes our collective experience using creativity workshops in applied visualization research. It also summarizes the research methods of critically reflective practice.

3.1 Workshop Experience

Our understanding of workshops evolved through 10 years of using creativity workshops in a variety of domains. Tab. 1 summarizes our 8 research projects and Tab. 2 summarizes workshops in each projects. We refer to projects by unique IDs (e.g., [P1 – P8]) and workshops by unique IDs within a project (e.g., [P1.R]).

We initially described workshops as *imagination exercises* in a design study with geographic information system (GIS) developers [P1]. Although they were not called creativity workshops, we deliberately fostered creativity in structured workshops for requirements [P1.R], design [P1.D], and evaluation [P1.E].

A similar pattern was used in the project that introduced the term *creativity workshop* to visualization. In a design study with energy analysts [P2], we worked closely with software requirements engineers to deliberately and explicitly foster creativity in requirements gathering [P2.R], design with researchers [P2.D1], design with collaborators [P2.D2], and evaluation [P2.E].

This inspired the use of creativity requirements workshops in a variety of projects, including design studies with constraint programmers [P4], neuroscientists [P5], psychiatrists [P6], genealogists [P7], and biologists [P8]. In these projects, the workshop output was used in traditional user-centered design processes, such as parallel prototyping, instead of being input to additional workshops.

As every domain collaboration has specific challenges, the diversity of projects in terms of their context, collaboration, and results increases the potential usefulness of our reflection. Overall, we have used creativity workshops in different types of organizations: industry companies [P1, P2], a defense agency [P3], and academic labs [P4 – P8]. We had a variety of outcomes, including visualization publications [P1 – P6], a grant application [P8], and one failure [P7].

We also draw on experience using workshops outside the context of applied visualization research. We designed and facilitated two conference-based workshops at IEEE Vis [45, 46]. Aimed at exploring visualization approaches to domain-specific data, these workshops are not included in our experience above as they were not part of a larger collaboration. Also, one co-author has extensive research applying creativity workshops to software requirements engineering [7, 8, 17, 19, 20, 21, 30, 31, 32]. Although these experiences were not part of visualization research projects, they provide important details about aspects of involving data in workshops.

3.2 Research Process

The results presented in this paper were developed using *reflection* — the analysis of experiences to generate insights [2]. More specifically, we applied *critically reflective practice* [3], a methodology of *"synthesizing experience, reflection, self-awareness and critical thinking to modify or change approaches to practice"* [54]. This reflective analysis was performed through a two year collaboration of the authors of this paper that intertwined analysis and action. Our understanding of workshops evolved and solidified throughout this time period.

More specifically, our collaborative, reflective analysis made use of group discussions, individual synthesis, writing, and running workshops. Throughout the two years, discussions involved reflecting on our experiences running creativity workshops, as well as on our review of literature about creativity and workshops. We attempted to codify the outcomes of our thinking many times throughout this period, sometimes individually and sometimes collaboratively, in both narrative and diagram form. Writing often identified shortcomings in our thinking as well as useful refinements to the workshop framework. We tested our evolving ideas by both running new workshops as well as by reflecting back on previous workshops. The result of our reflective analysis are the contributions presented in this paper, as well as a rich set of collected documentation captured throughout the two years. A detailed description of significant reflective events can be found in the Supplemental Material, along with an audit trail of documents that were produced throughout.

4 PROCESS OVERVIEW

We propose a six stage process model for creativity requirements workshops in applied visualization research projects, as shown in Fig. 1. The process starts with *initialization* where we decide to use a workshop. Next, we *design* the workshop by selecting appropriate

ID	Domain	Collab.	Purpose	Workshops	Result	Ref.
P1	Cartography	Industry	*"Reimagining the legend as an exploratory visualization interface"*	3	InfoVis paper	[10]
P2	Smarthome	Industry	Deliver insights into the role of Smarthomes and new business potential	4	InfoVis paper	[11]
P3	Human terrain	Defense	*"develop [visualization] techniques that are meaningful in HTA"*	3	InfoVis paper	[57]
P4	Constraint prog.	Academic	Design performance profiling methods for constraint programmers	1	VAST paper	[12]
P5	Neuroscience	Academic	Create novel visualization techniques for multivariate graphs	1	EuroVis paper	[23]
P6	Psychiatry	Academic	Create visualization tools to analyze determining or associated factors of suicide	1	TVCG paper	[39]
P7	Genealogy	Academic	Create visualizations to support genealogy analysis	1	None	[22]
P8	Biology	Academic	Create visualization software for phylogenetic analysis	1	Grant app.	[27]

Table 1. We have used creativity workshops in 8 applied research projects—6 of projects resulted in publications [P1, P2, P3, P4, P5, P6], 1 resulted in a grant application [P8] and 1 was abandoned as a failure [P7]. We refer to projects by their ID because this work contains details about the workshops that did not appear in their corresponding publications. These projects have been intertwined with our analysis. For more details on the individual workshops, please refer to Tab. 2.

ID	Focus	Goal	Length (hrs)	Team	Partic. (collab)	Partic. (vis)
P1.R	Req.	Explore possibilities for enhancing legends with visualizations	6	1	7	3
P1.D	Des.	Candidate solutions identified and considered in light of identified requirements	6	1	—	3
P1.E	Eval.	Presentation and evaluation of deliverables	4	1	3?	3
P2.R	Req.	Identify future opportunities for utilising smarthome data/technologies	6	3	5	0
P2.D1	Des.	Develop concepts from req. workshop in an agile approach	4	2	0	6
P2.D2	Des.	Elicit feedback from prototypes and prioritize design improvements	3	2	7	0
P2.E	Eval.	Evaluate final prototypes	3	2	5	0
P3.R	Req.	Identify novel visual approaches most suitable for HTA	9	2	6	7
P3.D	Des.	To further establish requirements ... to acquire feedback on initial designs	7	1	3	6
P3.E	Eval.	Structured evaluation against scenarios	4	1	3	6
P4.R	Req.	Identify analysis and visualization opportunities for improved profiling of cons. prog.	2	7	10	0
P5.R	Req.	Find opportunities for visualization in retinal connectomics and identify shared user needs	7	4	9	0
P6.R	Req.	Understand the main tasks of psychiatric researchers	3	2	6	1
P7.R	Req.	Find opportunities for a design study with genealogists	3	1	7	3
P8.R	Req.	Find opportunities for funded collaboration between vis. and bio.	7 x 2	2	10	2

Table 2. Our workshop experience includes 15 workshops in a variety of projects. Common characteristics of workshops include number of participants ranging from 3 to 10 and duration ranging from 3 to 9 hours. While our analysis draws on all workshop experience, this paper focuses on workshops for requirements.

methods. Design is followed by *execution*, performing the workshop and collecting artifacts. Next, during *analysis*, we make sense of the workshop outputs, creating knowledge. This knowledge is integrated into the project through *action*. Permeating the process is *reflection*, as we review our experiences to generate insights. Stages of the process are completed in a cascading, linear fashion. Decisions from upstream stages cascade to downstream stages. For example, the reason for initializing a workshop influences the appropriate design. As the model represents complex and messy actions of researchers, it also describes the cyclical influence between stages. For example, designing a workshop can reveal valuable insights on why a workshop is being run. Similarly, acting on the workshop results can generate new knowledge that influences how workshop results are analyzed. The model is also nested as it is carried out by researchers who learn from the experiences and actions. This section summarizes each stage of our workshop process.

Workshop *initialization* encompasses the decision to run a workshop. Researchers identify the workshop purpose — such as establishing an understanding of broad domain goals or specific analysis needs. The purpose for running a workshop is usually articulated in a concise workshop goal that identifies mutually beneficial outcomes of the workshop, providing a reason for stakeholders to participate or help facilitate the workshop. Initialization also serves as a precursor to workshop design, identifying workshop constraints and logistics. We refer to the output of workshop initialization broadly as the *workshop context*, it includes the workshop purpose, relevant constraints, participants, and team members.

Next, workshop *design* is about creating a flexible workshop plan that identifies methods to be used during the workshop tailored to the appropriate context. We emphasize that design creates a flexible plan because the output of methods ultimately depends on how they are received by the participants during execution. We describe the details of workshop design in Sec. 5.

After design, the workshop is run during *execution*. Execution is a performance: the workshop team continuously adapts to the feedback from workshop participants. Execution requires deviating from the plan in ways that are both profound and subtle. It results in a plethora of workshop artifacts and documentation, tangible results created through the workshop methods or recorded by the workshop team.

We make sense of the workshop results during *analysis*. Performed by the workshop team, it involves identifying insights in the form of themes, patterns, key concepts, or outliers from the workshop artifacts.

The knowledge gleaned from workshop analysis influences the workshop *action*, where we continue the collaboration. This includes the action of visualization researchers as the workshop provides new information valuable for generative and evaluative design methods. It also includes the workshop participants as they may approach existing problems or practices in a new way.

Permeating the process is *reflection*, where we generate knowledge from experience. We reflect on our experience executing the workshop, on the effectiveness of workshop design, on the influence of workshop results on the projects outcomes, and on the use of workshops in different projects and contexts.

Although this model simplifies the complex actions of researchers, it provides a consistent vocabulary for us to connect our actions with their intended outcome across diverse projects. This model serves as a roadmap for researchers to apply workshops in their own project. We augment this roadmap with a series of actionable recommendations (see Sec. 6). Next, we describe a set of thinking tools for navigating the possible design space of workshops.

5 WORKSHOP DESIGN

This section unpacks workshop design concepts. It describes a general structure of workshop methods and illustrates this structure with a validated example workshop. It concludes with workshop design
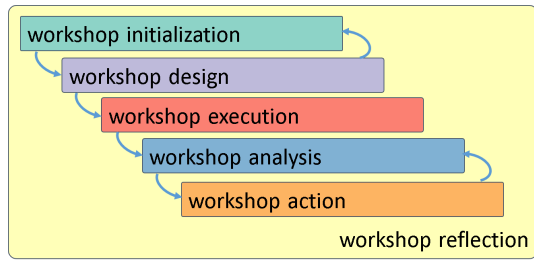
Fig. 1. A process model for creativity requirements workshops. The model identifies cascading stages of initialization, de-sign, execution, analysis, and reflection. The model is cascading as decisions of upstream stages influence downstream stages, e.g., the workshop initialization defines a context that influences the workshop design.
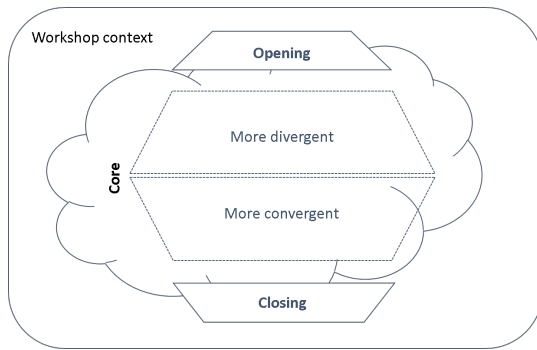

Fig. 2. Workshop structure. Workshops are designed in the context of applied visualization. The workshop opening communicates its intent and purpose. The core supports ideation and exploration, often in cycles of divergent and convergent thinking. The nebulous shape of the core represents the emergent and unpredictable collective creativity. The closing concludes the workshop, establishing next steps for action.

considerations on tailoring workshops to specific projects and creating entirely new workshops.

5.1 Workshop Structure

The workshop structure, shown in Fig 2, describes the intent of methods used in a workshop. Workshops start with an *opening* to establish intent, to prepare participants for productivity and creativity, and to promote trust and agency. Next, the workshop *core* encourages participants to think deeply and creatively about specific ideas — often in cycles of generating ideas followed by evaluating ideas. Lastly, the workshop *closing* brings the workshop to an end, validating the time and energy that participants invested in it. The workshop structure is based on existing workshop models that identify differences between the beginning, the middle, and the end of workshops [4, 5, 13, 14, 15]. It is broad enough to encompass every workshop we have run, but specific enough to yield actionable guidance. More specifically, each phase of the workshop has specific characteristics that can be connected to the methods used.

5.1.1 Workshop Opening

The workshop opening prepares participants for a productive and creative experience. Effective openings establish an atmosphere conducive to creativity by communicating the workshop purpose, providing agency, and supporting trust.

Purpose. All of our workshops have started with a short (¡5min) presentation to explain why participants are attending the workshop and what we hope the workshop will create. The opening encourages

creativity by encouraging participants to suspend judgment [41], to commit to the entire workshop [15], and to think deeply about concepts [49]. Yet, telling participants to be creative may not be enough. The workshop opening also relies on methods to engage participants by providing agency and trust.

Agency. Effective workshop openings encourage agency, a feeling of ownership, responsibility, and ability to act. Methods that promote agency exhibit multidirectional communication and provide an opportunity for self-expression [4]. Methods that encourage the one way communication, such as lectures, hinder agency and disengage participants [28]. Yet, this is a mistake we made in two workshops.

Trust. Workshops encourage group creativity, the emergent creativity that results from cross-pollination of ideas. Open communication is critically for group creativity and it relies on trust, the confidence that participants place in each other and in the workshop team [48]. Methods that encourage trust show an intent to listen and demonstrate vulnerability [4].

5.1.2 Workshop Core

After the opening is the workshop core where participants generate, explore, and evaluate a variety of ideas. While there are practically infinite possibilities for the workshop core, reflection on our experience illuminates common concepts that we have found useful for designing workshops: the ideaspace; the visualization, data, analysis and automation context; externalization; connection; and incubation.

Ideaspace. Methods are characterized by their influence on an ideaspace, the abstract set of all ideas being considered [1, 35, 41]. Divergent methods generate ideas and expand the ideaspace. Convergent methods evaluate ideas and winnow the ideaspace. Workshops consist of repeated diverge-converge cycles, exploring a broad space of possible ideas before selecting the more promising ones [5, 41]. Diverge-converge cycles occur between methods as workshops start with divergent methods, such as brainstorming to generate ideas followed by grouping those ideas into meaningful clusters [P8.R]. Diverge-converge cycles also occur within methods such as workshops brainstorming to generate ideas and then asking participants to highlight the more interesting or important ideas [P1.R].

Externalization. Methods are also characterized by the physical artifacts that they produce, in other words, how they encourage or support externalization. This is important to foster creativity as creating a physical representation of an idea starts a feedback loop that forces the idea to evolve [49]. It is also important for workshop analysis as visualization researchers will eventually make sense of the workshop output. Effective externalization create physical representations of ideas, such as post-it notes, sketches, or other physical representations. Methods without useful artifacts include unstructured group discussion. The externalization also allows methods to be connected into a coherent workshop.

Connection. Related to externalization is connection, the way in which methods are connected to form a coherent workshop. Connection promotes revisiting of concepts to discover emergent ideas. Externalization can support connection as output from one method is input to another. For example, by generating ideas on post-it notes and then clustering or ordering those post-it notes. Methods can also be connected implicitly, for example, by asking participants to create new ideas based on previous discussions.

Incubation. Providing downtime in a workshop can promote the generation of ideas. More specifically, providing time for ideas to incubate, both through conscious and unconscious thought, is a critical for creativity [49] and should be integrated into workshops. Incubation is supported through passive methods that provide breaks or time to listen without necessarily generating ideas. In shorter workshops, unstructured breaks between methods provide brief periods of incubation [P6.R]. In longer workshops, breaks for lunch [P2.R ,P5.R, P4.R] encourage incubation. Reflecting on the impact of incubation on one workshop [P2.R], the a workshop team member described the discussions afforded unstructured lunch: *"Conversation just flowed well!*

The morning had prompted a lot of ideas and there was a really interesting and diverse discussion over lunch about the subject and possibilities in the area. I expect this was partly also due to the fact that everyone was forced to eat at the neutral venue - lunch was served in a really nice dining area, no decisions had to be made ... There were no distractions. So we just continued to discuss the topic."

5.1.3 Workshop Closing

After the core, the workshop closing concludes the workshop, providing participants with a sense of closure through reflection on their experience and validation of their efforts. The workshop closing is also an effective time to gather feedback from participants.

Reflection. Reflective methods ask participants to analyze their experience in the workshop. A common example is to ask participants about interesting ideas from the day. Reflection provides information for the workshop team about what participants found more interesting, guiding the analysis of workshop results. The reflection also demonstrates to participants that their time was used effectively as ideas have often evolved throughout the day.

Validation. The workshop closing is an opportunity to provide participants with a sense of validation. This includes thanking participants for their participation in the workshop. It is also important to communicate the next steps of the project, to validate that participants energy will influence the direction of the collaboration [15].

Feedback. The closing is also a time to ask for feedback on the workshop. This includes communicating surveys to participants to asking for feedback through other methods.

Following the workshop, ideas and artifacts from it are analyzed. The analysis drives forward the visualization project by identifying areas for future work, exposing shared user needs, and establishing criteria for evaluating ideas.

5.2 Illustrative Example Workshop

We illustrate the workshop structure with a full day workshop, shown in Fig. 3, that has been validated in design studies with energy analysts [P2.R], constraint programmers [P4.R], and neuroscientists [P5.R]. This subsection examines the intent of methods used during the opening, the core, and closing at a high level of abstraction. The next subsection unpacks the nuanced differences between the projects where we used this workshop. Together, they provides a starting point for future workshops. But ultimately, this is one sample of a practically infinite workshop design space.

5.2.1 Workshop Opening

The workshop opening consists of a short presentation and introduction method. The presentation communicates the purpose of the workshop and articulates how the researcher will use the workshop outputs to guide the collaboration. The presentation also establishes guidelines for encouraging group creativity. Example guidelines used in a previous workshop [P2.R] are:

- all ideas are valid — record them;
- let everyone have their say;
- be supportive of others;
- instead of criticizing, create additional ideas;
- think 'possibility' not implementation;
- speak in headlines and follow-up with detail; and
- switch off all electronic devices.

Next, an *Analogy Introduction* asks the workshop team and participants introduce themselves through analogy, such as *"What animal are you today?"* This method provides agency through self-expression. It promotes trust by encouraging the display of vulnerability. Reflection on this experience reveals [P2.R]: *"the animal introductions required some audacity on the part of our facilitator...it seemed useful preparation for future exercises in initially putting all participants on an equal footing."*

5.2.2 Workshop Core

The workshop core starts with a divergent active method *Wishful Thinking*, that elicits participants aspirations for visualization software. Prompted with a scenario in their domain, participants respond to the following three questions on post-it notes: *What would you like to be able to see? What would you like to be able to know? What would you like to be able to do?* Participants share ideas through group discussion before generating more ideas in small groups.

The ideas generated in *Wishful Thinking* cascade through the workshop as they are input to the next divergent, active method *Barrier Removal* that asks participants to identify and record barriers in the way of their aspirations. These barriers are then *'removed'* by imagining what would be possible if the barrier no longer existed. These ideas are recorded on post-it notes, following the same *know/see/do* prompts. This method promotes divergent thinking as participants are asked to generate additional ideas. Next, time for lunch is provided to allow for incubation and unstructured discussion.

After lunch, the participants return to a divergent, passive method, *Visualization Analogies*, where participants are shown a variety of visualizations and record ideas about how the visualization may apply to their domain. This method is similar to visualization awareness workshops [24]. It engages participants, allowing them to specify requirements by example.

After a short break, a convergent method, *Storyboarding*, is used to winnow the ideas into coherent narratives as participants depict 'a day in their life' while imagining the impact of topics from the workshop. *Storyboarding* is implicitly connected to the previous methods.

5.2.3 Workshop Closing

The workshop concludes with a reflective closing method where participants are asked *"what do you know now that you did not know this morning?"* Because this question is intended to start a discussion, it requires participants prioritize their thoughts to talk about the more interesting ideas. Recording this discussion provides important cues for the workshop team to jump-start their analysis.

5.3 Workshop Design Considerations

This section describes differences between the example workshops in action, revealing the subtleties of workshop design and execution. We use these differences as a springboard for examining high-level workshop design considerations.

5.3.1 Example Workshop in Action

The three projects that used the example workshop exhibited differences as we we tailored the workshop to the specific project context, to our experience as visualization researchers, and to our comfort level facilitating workshop discussions.

Context. We adapted the workshop methods to the context and desired outcomes of each project. We tailored the *Wishful Thinking* method by adjusting the prompt for each of our three projects. Our collaboration with energy analysts focused on long term goals for a forward-thinking smarthome program and we asked participants to:

In contrast, working with constraint programmers examined shorter-term goals and con-crete analysis tasks: *Your program does not execute as expected[what would you like to know/see/do]?* A similar concrete aspect was used in the neuroscience workshop: *Suppose you are analyzing a connec-tome, [what would you like to know/see/do?]* This workshop also used screenshots of existing tools to stimulate ideas. Although the dif-ference in wording may be subtle, the connection between methods means that these ideas propagate through the workshop. It is impor-tant to tailor the methods to the appropriate context.

Experience. We adapted the workshop methods to reflect our experience, knowledge, and style. In the *Visualization Analogies* method, we presented different visualizations in each workshop. Reflecting on our experience revealed that we selected visualizations that we could talk about with confidence, to establish trust by demonstrating our
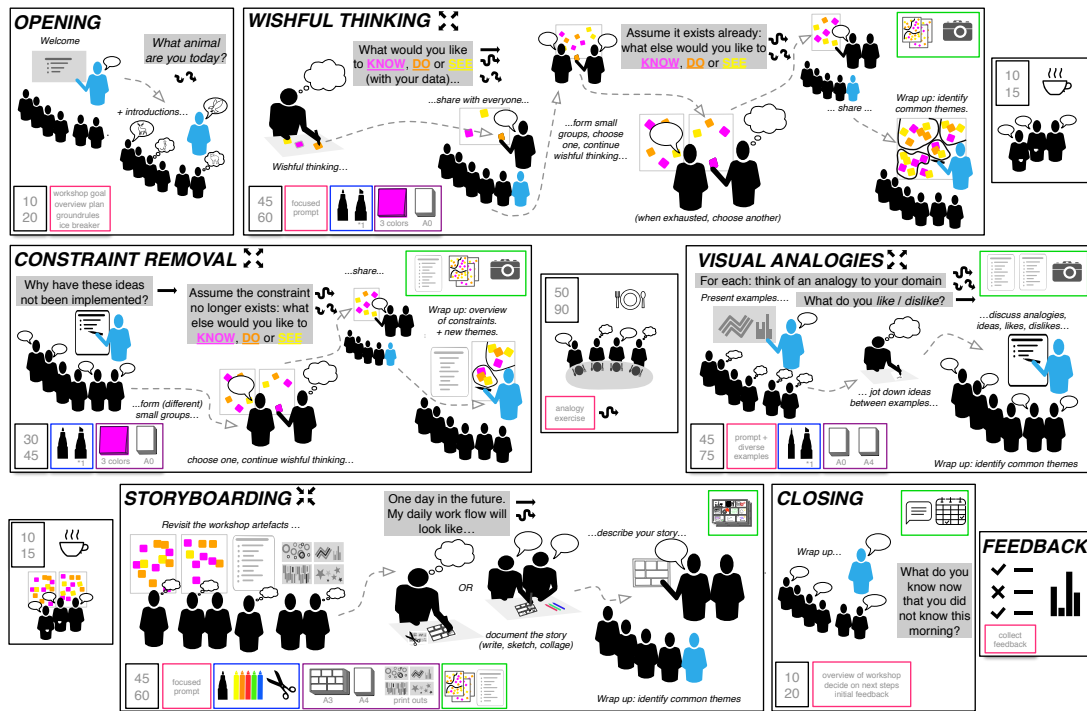
Fig. 3. A validated full day requirements workshop that illustrates the workshop structure and serves as a starting point for future workshops. The opening establishes a creative atmosphere, encouraging trust and agency. The core allows for exploration of ideas. The closing summarizes, validates, and concludes the workshop.

credibility. We also identified common themes of how to select visualizations, including a mix of seemingly unrelated visualizations (to promote divergent thinking), visualizations that you created (to show authority and credibility), visualizations that you did not create (to show knowledge of the field), older visualizations (to show depth of knowledge), and playful visualizations (to support engagement). This method has generated many interesting discussions, such as *"what does it mean for legends to move?"* [P1.R], *"what does it mean for energy to flow?"* [P2.R], and *"what does it mean for neurons to rhyme?"* [P5.R].

Execution. Although workshops can plan to use the same methods, they will follow different execution processes depending on the experience of the workshop team or feedback from the workshop participants. An example of this is how we used the *Wishful Thinking* method with different processes (shown in Fig. 4). One process involved individual ideation, large group discussion, and then small group ideation. The other process relied on hierarchical aggregation of ideas, moving from individual ideation, to small group ideation, to large group discussion. Execution processes can also differ in how participants form small groups for ideation or discussion. We have *shuffled* participants into groups based on a variety of factors, including by their organization (visualization research vs domain specialist), seniority, gender, research focus, or by chance. Although it is impossible to prescribe the most effective course of execution, it is important to recognize that execution will vary between workshops based on many factors.

5.3.2 Design Considerations

We introduced the workshop structure and illustrative example to provide a starting point in the workshop design space. This subsection describes considerations for exploring that design space. It emphasizes that there are limitless workshop possibilities. It identifies criteria for evaluating workshops based on how they support creativity. It summarizes resources that may be useful for selecting methods, and describes how methods can be tailored for visualization workshops.

Limitless Possibilities. The validated example represents a minority of our experience as all other workshops relied on different structure.
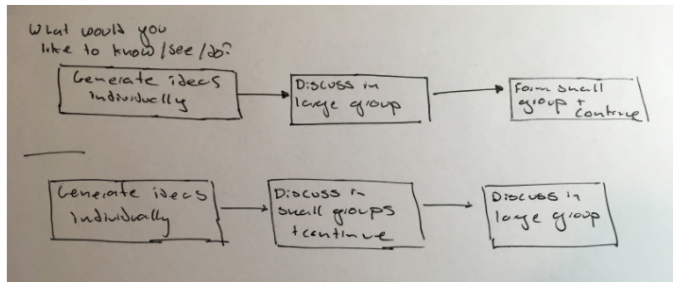

Fig. 4.

Workshops that use the same methods will be executed with different processes, such as the process of *Wishful Thinking* shown here. In one case (top), individual ideation is followed by large group discussion that segues to small group ideation and dis-cussion [P2.R, P4.R]. In the other case (bottom), individual ideation is followed by hierarchical discussion, from small group to large group dis-cussion [P5.R]. We illustrate this difference to encourage thinking about which method may be more appropriate.

True, a set of these workshops were condensed versions of the example [P6.R, P7.R]. But the other workshops used entirely different methods that seemed appropriate for the workshop context. Working with defense analysts, we used methods that identified surrogate data to use in place of classified human terrain reports [P3.R]. Working with biologists, we explored key aims for a grant proposal instead of requirements for visualization software [P8.R]. Working with GIS researchers, we identified key themes to explore the design space of interactive legends through brainstorming and prioritization [P1.R]. A summary of the methods used in each workshop is included in our supplemental material. These differences illustrate that workshops will look different depending on the project and the project goals.

Creativity Support. Framing workshops as *creativity support tools* provides valuable criteria for their design and evaluation. Shneider-

man et al. [51] proposed the following guidelines for creativity support software, but the same principles apply to effective workshops:

- *Support collaboration and communication* — workshops support communication by encouraging group work and explicitly externalizing ideas.
- *Provide low barriers, high ceilings, wide walls* — workshops encourage exploration through easy-to-use methods and undefined stopping conditions.
- *Make it as simple as possible* — workshops focus participant energy on the ideas, instead of understanding the method.
- *Invent things that you want to use yourself* — workshops use methods that are fun and engaging.
- *Support many paths and many styles* — workshops support the different styles and preferences of participants.

Combining these guidelines with the workshop structure provide a foundation for selecting methods for creativity workshops.

Method Resources. Workshop methods can be selected from a plethora of resources. Particularly useful resources that we have used are from the fields of visualization, design, and business. McKenna et al. [35] provide 100 exemplar methods relevant for visualization researchers, but these methods may need to be adapted to a workshop setting. Kumar [25] describes 101 product design methods useful in a business setting. Gray et al. [14] describe *games*, methods that encourage creative thinking and can be chained together into workshops. The seminal work of the Creative Problem Solving Foundation [5, 41], Synectics [13], and Lateral Thinking [6] may also be useful for thinking about workshop design. All but one of these resources were targeted for domains outside of visualization and the methods should be adapted for visualization design.

Method Adaptation. We adapt methods to visualization by injecting vocabulary, prompts, or other materials that explicitly reference domain problems, data analysis, automation, and visualizations. One example of this is the *Wishful Thinking* method. This is a visualization-specific form of *Aspirations Thinking* [34] adapted by prompting participants to think about their data analysis and by using visual language. Another example is the use of *Visualization Analogies*, which resembles analogy-based creativity methods [13] but has been customized to excite participants about visualization while demonstrating the workshop team's breadth of visualization knowledge. We include these examples to inspire the design of more creativity methods that explicitly explore the relevance and role of visualization, data, analysis, or automation.

Mutual Learning. In addition to exploring the importance of data, analysis, and visualization, the workshops of creativity methods should promote mutual learning of visualization researchers and domain collaborators. Examples of this abound in our experience — *Wishful Thinking* creates artifacts that teach visualization researchers about the aspirations of the domain analysts, and *Visualization Awareness* can demonstrate important concepts of visualization design such as multiple linked views, overview-to-details, and specialized visual encodings. Methods can promote mutual learning by exploring the state of the domain, by encouraging collaborators to present scenarios about their domain [P3.R] or asking about current successes and problems of existing tools [P1.R].

Limitations of Design. The concepts in this section are a starting point for designing workshops. They are thinking tools and resources for describing methods, but they do not account for the complexities of human thought [49], the emergent nature of group creativity [48], nor the serendipitous interactions that workshops support [4]. Ultimately workshop design involves working out which of a set of methods we might use and what effect they might have on the workshop. But the workshop execution requires flexibility in terms of execution process and in light of unpredictable reactions that occur during the workshop. Both the design and execution should be considered in the context of the entire applied visualization collaboration. Recommendations for the entire process, from deciding to using a workshop to designing the workshop methods, executing the methods, and analyzing the results are described next.

6 WORKSHOP PROCESS DETAILS AND RECOMMENDATIONS

While the previous section described design considerations, this section proposes recommendations — likely beneficial courses of action for future workshops. We propose <**REVISE ME:** 15? > recommendations, shown in Tab. 3, supported by analysis of our collective experience and research literature. The recommendations are described in the context of the workshop process.

6.1 Initialization

Initialization involves deciding to use a workshop, identifying the workshop purpose, and articulating constraints. Initialization and design are mutually influential, as shown in Fig. 5.

If considering a workshop at the start of a collaboration, *evaluating design study preconditions* [$\mathcal{R}$.1] assesses the project's viability. Time commitment from collaborators is particularly important. In our failed project [P8], our collaborators were too busy to meet with us before the workshop, making it challenging to identify an appropriate workshop context for design.

In deciding to run a workshop, it is important to *articulate the workshop purpose and decide who is going to use the workshop results.* Visualization process models are valuable for identifying the workshop purpose — creativity requirements workshops fulfill the *understand* and *ideate* design activities [35], more specifically they are useful to characterize broad domain challenges (e.g., [P8.R]) and to identify specific analysis needs (e.g., [P6.R]). All but one of our requirements workshops influenced the direction of the research collaboration; the exception was our failed workshop [P7.R]. Retrospectively, another reason for this failure was that we did not identify who would use the workshop results to continue collaboration with domain specialists.

In addition to being valuable for workshop design, articulating the workshop purpose is useful for convincing project stakeholders to commit valuable time and energy to a workshop. This can help *recruit diverse, creative, and engaged participants and team members* who can contribute to the work success [5, 13]. We have (sometimes unintentionally) recruited participants that are diverse in many ways, including: their seniority (e.g., graduate students to senior researchers [P5.R]), technological fluency [P8.R], specialization in the domain (e.g., practitioners, tool-builders, teachers, and students [P4.R]), and place of work (e.g., industry and academia [P4.R, P8.R]). We have also recruited participants for their creativity or openness to new ideas based on survey responses [P4.R]. The team members should be diverse and creative as well. In domains where vocabulary is complex, or time is limited, domain collaborators may make valuable team members as they assist in bridging the language gap between researchers and collaborators [P4, P8]. Professional facilitators may help in designing and executing the workshop (e.g., [P2.R, P3.R]), although a majority of our workshops were facilitate by visualization researchers. All workshop team members and participants should be in the process. Hamilton [15] recommends avoiding *poppers*, participants, team members, or observers who want to *pop in* to the workshop for an hour or *pop out* of the workshop for a phone call. In our experience, poppers distract facilitators and participants from the workshop and should be avoided early on.

The availability of participants and team members is useful for *recognizing workshop constraints* [$\mathcal{R}$.4] — such as the duration, location, logistics and budget. With respect to duration, one day (6 - 8 hours) seems to be sufficient. Our half day workshop [P6.R] felt rushed and did not allow incubation and iteration on ideas, though the results were still valuable. One workshop spanned two days [P8.R] as it required participants to travel from out-of-state, though two working days is a large commitment for collaborators who are not traveling. Constraints also include the venue. Creativity literature expounds the importance of neutral, well-lit venues [5, 18]. We have had success with such venues [P2.R, P3.R] but have also had success hosting workshops in on-site conference rooms chosen in order to meet the project constraints [P4.R, P5.R, P6.R]. The venue affordances, such as the room

ID	Recommendation	Importance
R.1	Evaluate the design study preconditions.	
R.2	Articulate the workshop purpose and decide who will use the results.	
R.3	Recruit diverse, creative, and engaged participants and team members.	
R.4	Recognize workshop constraints such as venue, location, and duration.	
R.5	Design a flexible workshop with analysis in mind.	
R.6	Recognize the value of workshop design.	
R.7	Pilot workshops to test, evaluate, and improve methods.	
R.8	Explore the workshop design space.	
R.9	Prepare for execution internally and externally.	
R.10	Guide the workshop to foster creativity.	
R.11	Embrace flexibility but bemoan distractions.	
R.12	Execute with analysis in mind.	
R.13	Brace for a deluge of data, allocate time, and recruit stakeholders to help with analysis	
R.14	Analyze with creativity in mind	
R.15	Expect messy output that warrant action	
R.16	Use workshop insights for generative design methods.	
R.17	Use workshop insights for evaluative design methods.	
R.18	Complement workshops with investigative methods.	
R.19	Explore additional uses of workshops and their output.	
R.20	Maintain an audit trail of workshop decisions and actions.	
R.21	Use workshops to communicate and explain design decision provenance.	

Table 3. Recommendations for future creativity requirements workshops supported by critical reflection of our experience.
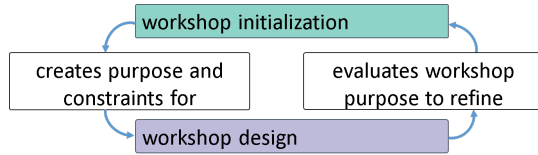

Fig. 5. Workshop initialization and design form a cycle. Initialization decides on the workshop purpose. In designing a workshop, we often revisit that purpose as we better understand the challenges faced by our collaborators.
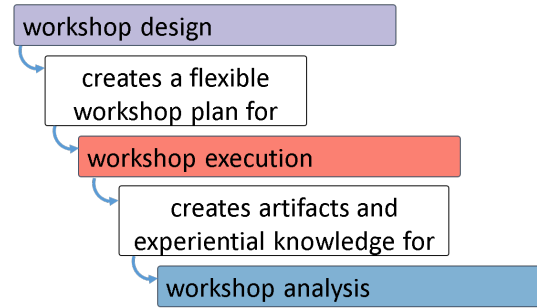

Fig. 6. Workshop design creates a flexible work-shop plan that is followed during the workshop execution. The results of execution include artifacts and experiential knowledge that are then analyzed.

size and physical layout, are important factors in selecting locations. The constraints and the workshop design are mutually influential — constraints help to winnow the space of possible workshops.

The initialization is complete when the workshop context is identified — this includes the purpose for running the workshop, its intended results, the individuals who will be involved with it, and hard constraints. This information provides a foundation for the workshop design.

6.2 Design

Workshop design is an iterative process of proposing methods, testing methods, and improving methods based on the test results. Designing a workshop helps to better understand the purpose of a workshop in a project, as shown in Fig. 5. Designing a workshop is necessary for execution as it creates flexible workshop plan that describes the methods, materials, and other considerations of workshop execution, as shown in Fig. 6.

In our experience, workshop design required varying amounts of time and energy based on the designers facilitation experience, familiarity with the domain, and comfort improvising. But an important similarity is that we *design a flexible workshop with analysis in mind* [*R.*11]. Design describes the methods we *might* use, the effect they *might* have on the workshop, and the output that they *might* produce. The reactions of workshop participants are unpredictable — we have deviated from the plan with successful results. Refer to our design considerations for details on creating a flexible workshop plan.

We increasingly *recognize the value of designing workshops* [*R.*6], as it involves analyzing the state of a project and tailoring workshop methods to that state. This requires an understanding of the domain data, analysis tasks, and visualizations. Thus, designing workshops provides an opportunity to evaluate and validate domain problem characterization and data/task analysis. More specifically, the prompts used to start workshop methods can be tested with domain specialists in pilot workshops.

We strongly encourage researchers to *improve the design with pilot workshops to test and evaluate methods* [*R.*7]. Piloting workshops enables the workshop team to check that methods are easy to understand and that they produce appropriate artifacts. Piloting helps the workshop team understand how methods may be received participants and what they should be doing during execution. It also provides important opportunities to find errors in method prompts and materials, limiting distractions during the workshop [P2.R, P5.R, P6.R, P8.R]. To account for the challenges for designing methods for participants, we include proxy workshop participants, such as visualizations researchers [P2.R] or domain collaborators [P8.R], to evaluate workshop methods. Involving domain collaborators in testing workshop methods provides opportunities to evaluate and validate our understanding of the domain problems and analysis needs.

We emphasize that the workshop design space is unbounded and encourage the visualization community to *explore the workshop design space* [*R.*8], creating new workshop methods and new workshop structures tailored to specific projects.

6.3 Execution

After the workshop is designed, it is performed during the execution. We focus on effective execution to promote creative thinking about domain goals in the context of visualization, to generate useful artifacts and knowledge, and to encourage continued creative collaboration.

Immediately before executing the workshop, we *prepare for execution both internally and externally* [$\mathcal{R}$.9]. Internal, or inward-facing preparation, involves understanding the workshop context (i.e., its purpose) and reviewing effective facilitation guidelines (e.g., [4, 5, 15, 14, 53]). Common principles of facilitation include being energized, providing encouragement, demonstrating acceptance, using humor, being prepared, and being punctual. External, or outward-facing, preparation involves gathering appropriate materials for the workshop and preparing the venue. Careful attention should be paid to the size of materials that will be used for externalization, such as post-it notes. The venue should also be prepared, such as by arranging furniture to promote a feeling of co-ownership, promoting agency and trust. A semi-circle seating arrangement works well [56]. A mistake in one of our workshops was to have the speaker using a podium, which implied a hierarchy between facilitators and participants, hindering communication [45].

During execution the workshop team must *provide guidance to foster creativity* [$\mathcal{R}$.10]. This requires guiding participants through methods, allowing for exploration while moving toward a common goal. Conversations that deviate from the day's focus should be redirected, but this requires careful judgment to determine if a conversation will be fruitful or not. Although it can be intimidating to redirect the conversation, participants will appreciate the focus. When allowed to discuss freely, participants commented *"we had a tendency to get distracted [during discussions]"*[P5.R]. Whereas more active guidance resulted in feedback: *"we were guided and kept from going too far off track despite our tendencies to do so. This was very effective."* [P8.R].

Execution require balance as we *embrace flexibility but bemoan distractions* [$\mathcal{R}$.11]. Deviating from the plan may be effective, such as in one workshop where participants proposed a method that would be more useful for their goals by exploring data analysis scenarios [P3.R]. Embracing flexibility also involves interpreting group dynamics to adapt to the changing situation [4]. But embracing flexibility should be balanced with bemoaning distractions. Distractions include spurious discussions that need to be redirected. Another common distraction is the use of computers and phones for unrelated activities. Restricting the use of devices helps limit distractions.

We *execute with analysis in mind* [$\mathcal{R}$.12], encouraging the creation and preservation of artifacts and knowledge. Workshops produce a tremendous amount of information and discussions are ephemeral: anything not written down will likely be lost. In one case, audio recordings provided valuable information [P6.R], but this workshop was shorter than the others, producing shorter recordings. In general, recording requires a tremendous amount of time to transcribe and analyze after the workshop [28]. Recording may also hinder creativity as participants become self conscious . We make an effort to document all activities in the workshop, by note taking or through methods that create artifacts. The workshop team must know the expectations for note taking, pilot workshops will help with this.

6.4 Analysis

Following execution, we analyze workshop output to generate insights about the collaboration. These insights ultimately influence our actions, but we separate analysis and action for simplicity. We recognize, however, that they are mutually influential, as shown in Fig. 7.

To prepare for analysis, we *brace for a deluge of data by allocating time and recruiting stakeholders to help with analysis* [$\mathcal{R}$.13]. Analyzing the workshop outputs — which typically involve hundreds of post-it notes, posters, sketches, and other tangible artifacts — often requires more time than the workshop itself, tens of hours spread over days or weeks allowing for focused work and periods of incubation. We start analysis by typing or photographing artifacts into documents or spreadsheets. This allows us to become familiar with all ideas in

the artifacts. It also enables sharing the output to enlist diverse stakeholders — such as collaborators or other workshop team members — in making sense of the results and clarifying ambiguous requirements. This is particularly important in domains with complex vocabulary. The challenge of analyzing workshop outputs can be minimized by designing [$\mathcal{R}$.11] and executing the workshop with analysis in mind [$\mathcal{R}$.12]. Also, ensuring that analysis starts early so workshop discussions and (particularly any non-documented) ideas are still fresh in memory.

The workshop output should be *analyzed with creativity in mind* [$\mathcal{R}$.14] to generate new and useful insights about the domain challenges in the context of visualization. Workshop outputs are diverse, descriptive and can often be surprising. We use qualitative analysis methods to make sense of this rich data source. But qualitative analysis is not enough, the analysis should be approached with creativity as generating software requirements is inherently a creative process [44]. Analysis methods vary by researcher, but they rely on some form of aggregation and prioritization. Aggregation involves grouping ideas into common themes or goals, such as identifying broad opportunities for visualization in terms of goals and tasks [P2.R, P5.R, P4.R]. When aggregating results, the sets of ideas and the individual ideas should be considered carefully. Prioritization involves ranking ideas based on some metric — usually perceived impact to the domain or development costs. Having participants prioritize ideas during the workshop can provide valuable guidance to visualization researchers [P1.R, P3.R], but may assume that participants have sufficient knowledge of what is possible with visualization. In some projects, we explicitly avoided direct prioritization because of this limitation [P5.R, P2.R].

Overall, *expect fuzzy outputs from analysis* [$\mathcal{R}$.15] that warrant continued action. Our analysis has created key themes or lists of tasks relevant to the domain. It has also identified opportunities for visualization research. The fuzzy results will need to be investigated through various forms of action.

6.5 Action

Workshops are one piece of an on-going design conversation between researchers and collaborators. The results of analysis should be integrated into that conversation through action. This action, in turn, generates new knowledge valuable to interpreting workshop outputs. Thus, workshop action and analysis occur in a cycle, as shown in Fig. 7. Here, we describe some of the ways to use workshop results for generative and evaluative design methods. We also recognize that workshops complement other user-centered design inquiry methods.

We commonly *used workshop insights for generative design methods* [$\mathcal{R}$.16] that expand the ideaspace of the collaboration. We have used the results of workshop analysis in additional design workshops to create prototypes [P1.R, P2.R, P3.R] or in parallel prototyping [P4.R, P5.R]. Workshop output can be valuable for deciding what features to add to existing software prototypes [P6.R], as one of our collaborators who used the workshop told us *"I personally got a much better understanding of what they were trying to do and what information they needed to do ... which ultimately guided our design decisions."* We have also used workshop output to outline key aims for a grant application [P8.R].

Workshops also produce about that is valuable for winnowing the ideaspace, and we *use workshop insights for evaluative design methods* [$\mathcal{R}$.17]. More specifically, key ideas from the analysis provide considerations and constraints that can be used to evaluate prototypes. Examples of considerations include: *"everything in three clicks"* [P2.R] and *"access underlying database keys"* [P5.R] from visualiza-tions. Evaluative design methods include validating decisions, from the problem characterization to visual encoding. A common theme of output from our neuroscience workshop was to *"analyze multi-hop relationships"*, which validated our decision to focus on visualizing graph connectivity [P5.R].

After discovering the high-level goal of graph connectivity analysis, we conducted additional interviews to better understand how
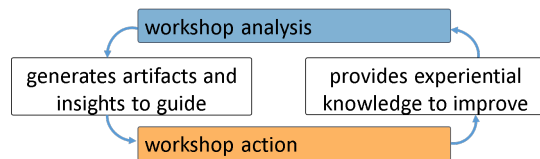
Fig. 7. Workshop analysis and action occur in a cycle. During analysis, we glean knowledge from workshop artifacts and experience. This knowledge influences our actions. These actions provide knowledge to improve our understanding of workshop artifacts.

analysts reason about it. This revealed low-level tasks and inspired subsequent prototypes. It also illustrates that workshops provide a starting point for more ecologically valid user-centered design methods. More specifically we *complement workshops with other methods* [R.18] such as interviews and contextual inquiry.

In addition to influencing design methods, workshops rapidly establish a broad understanding of domain goals while building trust and rapport with collaborators. We encourage the visualization community to *explore additional uses of workshop knowledge* [R.19] beyond what we have described here. We are particularly interested in using workshop output as a seed for adversarial collaboration between visualization researchers. We are also interested in using workshops to aid in the automation of domain problems. Importantly, as we explore the possible uses of workshop output, we should reflect on our actions to establish general practices for the field.

6.6 Reflection

The entire process of conducting a workshop is nested in reflection. Reflection enables us to make sense of our experience, decisions, and actions. Reflection results in insights that are valuable internally, to evaluate the efficacy of our actions, and valuable externally, to create knowledge for the visualization community.

Reflection enables us to *report workshops results to communicate and explain design decision provenance* [R.21]...

Maintain an audit trail of workshop decisions and actions [R.20]...

7 DISCUSSION

This section discusses the tradeoffs of research based in reflection, describes the intended use of ideas in this paper, compares creativity requirements workshops to other methods, and outlines areas for future work.

7.1 Critically Reflective Practice

Critically reflective practice is appropriate for analyzing our experiences when compared to other research approaches. It captures experiential knowledge and subjective interpretation of experience that is omitted in grounded theory, thematic analysis and similar qualitative methods. Through rigorous reflective methods, we have reached a consensus on the interpretation of our experiences and agreed on prescriptive recommendations for future workshops.

We recognize that prescriptive recommendations do not exhibit predictive validity. This is a common challenge in applied and ecologically valid research, especially where creativity is involved. Creativity relies on intrinsic motivation [38], which can be hard to replicate in controlled environments for laboratory experiments.

7.2 Intended Use of this Framework

We intend for this framework to provide descriptive language about the intent of workshops, workshop methods, and workshop analysis. All recommendations are meant to describe a likely beneficial courses of action based on our experience. They are not predictive. Nor do

they exhaustively describe all the characteristics of creativity workshops. In fact, one strength of creativity workshops is that they are a flexible method that can fulfill many roles in the design process. Our framework should be used in a way that supports the divergent use of creativity workshops—celebrating their flexibility and exploring their possibilities.

7.3 Comparison of Workshops to Other Methods

7.4 Future work

We focused our collective reflection and analysis on creativity requirements workshops, used for the *understand* and *ideate* design activities. We hope to continue this analysis to describe our experience using workshops for the *ideate* and *make* design activities too.

8 CONCLUSION

This paper presents the results of a many year reflective collaboration analyzing the use of creativity requirements workshops for applied visualization. It contributes a framework describing a process model and thinking tools for navigating the space of workshop design. It supports the framework with <**REVISE ME:** 15(?) > actionable recommendations for using workshops in future projects.

The framework and recommendations are intentionally pre-sented at a high-level of abstraction in order to identify common ideas from our experience using workshops in diverse visualization projects. They identify useful ideas for using workshops while accounting for the nuances of visualization: by connecting workshop to existing pro-cess models; by describing how methods can be tailored to explore aspects of visualization, data, analysis and automation; by selecting methods to support mutual learning of researchers and collaborators; by designing workshops that support revisiting concepts and evolving ideas; and by using workshop output in a way that accounts for the fuzzy nature of visualization software requirements. We intend for this framework to be complemented by low-level guidance on specific workshop execution. Resources that we have found particularly useful include books by Gray et al. [14] and Hamilton [15].

Looking forward, we hope that our work provides guidance for the use of creativity workshops in future research collaborations. We are excited to see how these methods can be used in creative ways. We encourage the continued reflection and sharing of knowledge generated about the possibilities of creativity workshops.

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