How Researchers Manage Ideas

NANNA INIE, IT University of Copenhagen, Center for Computing Education Research (CCER), Denmark
JONAS FRICH, Aarhus University, Centre for Digital Creativity, Denmark
PETER DALSGAARD, Aarhus University, Centre for Digital Creativity, Denmark

Research ideas are pivotal in research practice. While research domains, topics, and methods are often outlined by specific research fields, the process of capturing and developing research ideas is less categorical. Conceiving and developing research ideas requires continuous creative thinking, usually supported by various different tools, each more or less carefully selected by a researcher to fulfill a specific purpose. In this paper, we investigate the creative work practices of academic researchers, with a focus on the workflows and tools they employ to manage ideas. Through a qualitative survey (n=51) and in-depth interviews (n=18) with researchers from a wide range of fields, we identify and describe typical processes of managing research ideas, different types of research ideas (*a research question or problem*, *a method, a hypothesis or antithesis*, and *a theory*), properties of good research ideas, as well as potentials for tools and technology to support idea management for researchers.

CCS Concepts: • **Social and professional topics → User characteristics**; • **Human-centered computing → User studies**.

Additional Key Words and Phrases: idea management, tools, cognition, creativity, research ideas, science of science, idea types

ACM Reference Format:
Nanna Inie, Jonas Frich, and Peter Dalsgaard. 2022. How Researchers Manage Ideas. In *Creativity and Cognition (CC '22), June 20–23, 2022, Venice, Italy*. ACM, New York, NY, USA, 20 pages. https://doi.org/10.1145/3527927.3532813

1 INTRODUCTION

Creative ideas are the cornerstones of scientific achievement and innovation. Descriptions and characterizations of the most impactful ideas in the history of science have been a continuous area of interest, both in popular science and in formalized research (e.g., [3, 11, 28, 36, 41, 43, 55]). Yet few studies examine the daily practices of professional researchers and how they use tools to work with their flow of ideas. Scientific ideas (in which we include both the natural and social sciences) are the first steps of any scientific innovation, that is, creativity with a defined purpose [36]. Despite this, we know mainly how the ideas behind major scientific breakthroughs were conceived and little about the rest.

Contrary to most artisanal creative professionals, few early career researchers study best practices or guidelines for the generation, selection, or management of ideas. Researchers must, for better or worse, discover and develop their own best practices and assemblages of methods and tools, and this makes the resulting processes and workflows fascinating to study. In Simonton's words, "all domains of creativity contain distinct elements that define the very nature of that domain" [45]. This study aims to deepen our understanding of how humans engage individually and socially in creativity and how computers and other technology can affect creative processes and outcomes.

Manuscript submitted to ACM

It has been argued that we live in a *post-idea* era, where neither researchers nor anybody else have time or inclination to come up with bold ideas, in part because we are swimming in information: "We are inundated with so much information that we wouldn't have time to process it even if we wanted to, and most of us don't want to (...) Few talk ideas. Everyone talks information" [18]. Whether it is true that we see more incremental innovation at the expense of radical innovation [13] in science or not, it is an inescapable truth that we are dealing with an colossal increase in available information. This could potentially lead to more and better ideas – provided that researchers have the right set of tools and skills to filter, sort, and use this information in productive ways. Unfortunately, empirical studies have shown that knowledge workers often experience frustration with their information becoming fragmented [49], and the data from the study presented in this article show that while the management of ideas is important for researchers, idea management is less structured than research work in general (Figure 1). Creativity and idea management processes in research practice are therefore both fascinating and important topics for the field of creativity and cognition.

In this paper, we investigate three research questions: **1) How do researchers**[1] **use tools to manage their ideas – personally and collaboratively? 2) How do researchers define ideas? and 3) How do they define *good* ideas?** We investigate these questions by an empirical and inductive approach, asking researchers and analyzing their responses for patterns and exceptions.

2 RELATED WORK

Existing research on ideas in science is characterized, first, by a focus on *H-creativity* (historical creativity, ideas that are creative with respect to the entire human history) [6] or Big-C creativity [29], as in *greatest* or the most influential people and ideas in scientific evolution and, second, on *natural sciences* [3, 28, 41, 55]. Third, psychology research has focused mainly on scientific creativity *in vitro*, studies of the creative individual, or experimental studies of the creative process [44]. This leaves a lacuna of dedicated research on **in vivo** creativity (that is, **P-creativity** (personal creativity; that which is creative for the individual) and **Pro-c** [6, 29]), as continuous everyday creative practice by professional researchers, **including social sciences and the humanities**. Personal creativity is essential to historical creativity: *"creators have to create first before their creativity can even receive consensual appraisals. (...) The creator might change their assessment later, but for the most part, what is done cannot be undone"* [48].

This section presents a selection of work related to our specific research questions, focusing on work on typologies and definitions of creative ideas, and professional idea management. It also presents an overview of previous research on the interplay between creativity and *tools*.

2.0.1 Idea management. A wide range of research has been conducted on *Personal Information Management* (PIM) and knowledge workers in general, e.g. [4, 5, 21, 31, 39, 49, 54]. A few studies have focused on researchers [30, 53]. Although idea management is clearly related to PIM, it is also distinct. It is not the available resources that constitute our ideas, but rather our conceptions of how information or concepts *relate* to each other [20, 32].

"Idea management" is a term most often used in the literature on innovation and management, where the goal is to provide organizations with the best frameworks and methods for fostering and enhancing innovation [19, 27, 35]. It has become more prevalent in the field of interaction design and information technology, where the interest is mainly in identifying and developing creativity support tools [22, 24–26, 35].

In 2006, Kaye et al. conducted a thorough study of 48 academics and how they managed their personal archives [30]. Kaye et al. identified *goals of archiving* ('finding it later', 'building a legacy', and 'sharing resources'), as well as

[1] In the paper, we use the term "researcher" to describe people who are employed at a an institution of higher education to conduct research professionally.

structures, academics use for their personal archives in both physical and digital spaces. The study concluded that tools and technology designed to support personal archiving for researchers should be built on *values* rather than functionality, and that best practices in this domain "resist standardization".

2.0.2 Tools and idea management. Coughlan and Johnson presented a first exploratory investigation into how professional creatives use tools to manage *ideas*. They found that the most valued property of idea management devices was *ubiquitousness*, and that different representation forms were desirable at different stages of idea management.

Building on the study by Coughlan and Johnson, Inie and Dalsgaard [24] presented a grounded theory-analysis of idea management for interaction designers. The analysis identified the core activities of idea management as *capturing*, *developing*, *organizing*, *retrieving*, and *sharing* ideas and showed that designers employ different tools depending on whether they work divergently or convergently. Later research has shown that tools, in return, influence whether designers think divergently or convergently during design ideation [17].

In design research, it is well-established that tools and technology support creativity and exploration by guiding perception and helping designers see, understand, explore, and experiment [14]. Tools help designers shape their environment and influence human behavior [34]. There is no reason why the same would not be the case for researchers. Currently, however, few in vivo studies exist of how researchers use tools and how tools affect thinking and creation.

2.0.3 Types and definitions of creative ideas. Inie and Dalsgaard [23] identify seven definitions of design ideas as they have been described in previous research. The types are '(Re)framing the problem', 'Opportunity', 'Suggestion for part solution', 'Suggestion for solution', 'Design move', 'Insight moment', and 'Plan for action'. This review shows that there are many different conceptions of "an idea" even in research that focuses on ideas. Another point is that within the field of design, ideas are inherently tied to gathering inspiration for current or future solving of design problems, or purposeful progression towards design products.

In a chapter on serendipity and creative discovery, Simonton [48] describes scientific creators as different from artistic creators in that they more often combine ideas that come from experiences that are closer to their knowledge domain than far from their domain. On the topic of scientific ideas, Simonton [47] presents a formal typology of three combinatorial parameters to define *creative* ideas: 'initial probability' or originality (the likelihood that others would generate the same idea), 'final utility' and 'nonobviousness' according to the scientist's prior knowledge of the final utility. From these follows a typology of combinations, where only one combination qualifies as a creative idea, namely when the *originality*, the *utility*, and the *nonobviousness* are all high.

3 METHODS

Our study design consisted of a survey and follow-up interviews, the data of which were analyzed inductively through thematic analysis. This method was used to *discover* stories and patterns while capturing the complexity of daily work practices [2].

3.1 Qualitative survey

We distributed a questionnaire to various research communities and universities, aiming to reach as diverse a range of fields as possible. We used mailing lists and internal communication platforms at different universities to distribute the call. Responses were collected between March 2020 and February 2021. The survey questions can be found in Appendix A, and were inspired by questionnaires from previous research [12, 22]. The survey was qualitative in nature, as it

Code	Theme
simple, advanced, tool overload, losing ideas	**Bricolages of tools**
remembering, cognitive offloading, capture satisfying, capture constraining, filtering, old ideas important, old ideas irrelevant	**Purposes of idea management**
availability and constraint, transition, overview, manipulation, exploration, serendipitous discovery, casual tools, enhanced by digital tools, talking	**The roles of tools**
idea archive, idea ownership, idea donation	**Working with ideas as a material**
definitions of ideas, elements of an idea, core idea, size of the idea, formats of ideas, idea type: question, idea type: method, idea type: hypothesis, idea type: antithesis, idea type: theory	**Idea types and the core idea**
definitions good ideas	**The good research idea**

Table 1. Codes from thematic analysis. Themes were revised several times both before and while writing this article.

consisted primarily of open-ended questions, with a few exceptions. The survey received 51 responses from researchers from a wide range of fields, from art to astrophysics.

3.2 Interviews

The questionnaire asked participants to provide us with their email if they were willing to be contacted for further interviews. We recruited 18 participants for follow-up interviews. An overview of the interview participants is shown in Appendix B. The interviews were conducted in late 2021. This meant that there was more than a year between answering the survey and participating in the interview for some participants. This temporal distance allowed us to ask the participants to reflect on their survey answers without them remembering their exact answers. Some participants had also adopted different tools or work practices during the time between their survey response and the interview and could elaborate on why this had been necessary or appealing.

All interviews were conducted through online video calls, so participants could show their idea management systems, either by holding them up to the camera or sharing their screen. This proved to be highly generative for supporting reflection on other tools or idea archives. The interviews were semi-structured [9], and the interview guide can be found in Appendix C. The interviews were recorded, which amounted to a total of 682 minutes of video (about 38 minutes per interview on average).

3.3 Data analysis

Interviews were transcribed and both survey responses and interview data were analyzed using thematic analysis [8] in Miro. Thematic analysis was performed by the first author and focused on 'identifying and interpreting key, but not necessarily all, features of the data, guided by the research question' [10]. All survey responses and interview transcripts were read several times while initial codes were generated. All codes and themes are shown in Table 1. The sections in Findings are organized according to the final themes, and individual codes are highlighted in **bold**.

The goal of the thematic analysis was to identify patterns that reflect the data for this context [38]. We do not report explicitly on the frequency of codes and themes, as we consider this the goal of content analysis rather than thematic analysis [51]. In the presentation of the data, we focus on the elements of the quotes that are central to *ideas*, and omit references to specific research fields. For clarity and space purposes, the quotes in the paper are not represented verbatim.

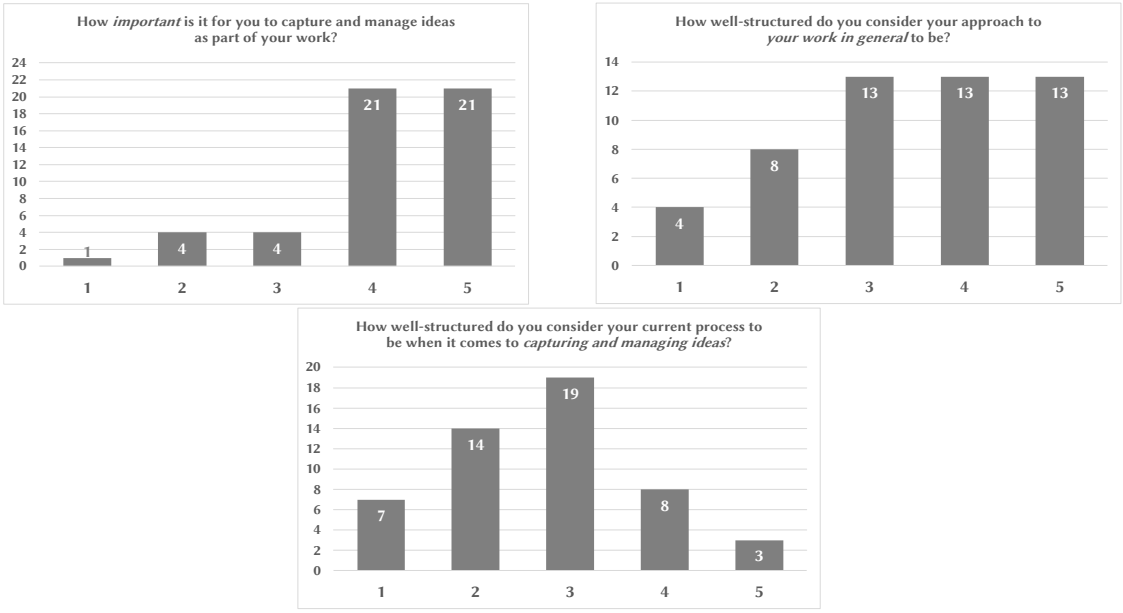

Fig. 1. Survey responses. More than 80% of respondents believe it is *important* or *very important* to capture and manage ideas (top left), 51% believe that their approach to their work in general is *structured* or *highly structured* (top right), while less than 22% of respondents consider their current idea management to be *structured* or *highly structured* (bottom).

4 FINDINGS I: IDEA MANAGEMENT TOOLS AND SYSTEMS

4.1 Bricolages of tools

A total of 60 different tools used for idea management were described in the survey responses. The tools mentioned more than once are shown in Table 2 in order of frequency. The most common trait in all survey responses and interviews was the uniqueness of bricolages of tools and processes that each individual researcher described: No two processes were the same. Some researchers used very **simple combinations**, such as pen and paper for idea capture and text editors for development and collaboration, while others described **advanced technical setups**: *"I can star emails and use a IFTTT service (like Zapier) to create a Trello card on a specific board, then I can put due dates on those cards. That keeps my inbox clean. I have an IFTTT setup on Alexa; when I add to-do items, it creates a tagged Trello card"* (survey response).

In the survey, we asked respondents how important they considered idea management to be for their work, and how structured they considered their approach to idea management to be. We see in Figure 1 that while most participants consider idea management to be quite important, and believe to have a mostly structured approach to their work in general, they consider their idea management processes to be less structured.

Although structure is not necessarily a premise for a good process, many of the respondents described that they would sometimes **lose ideas**: *"I lose my Google Docs. (...) I forget where they are located, I forget what name I gave the documents so then I just have to go and dig and find, it's super difficult"* (P12), *"I do find myself kind of stuck. Like if I have to work from home and I didn't bring my notepads home, then I'm kind of stuck* (P17).

Individual use	Pen & paper, Post-it notes, Word, Whiteboard, Google Docs, native 'Notes' app (phone or computer), Email, Evernote, native Reminders/To do app (phone or computer), OneNote, GitHub, Phone photos, Browser bookmarks, TextEdit/Notepad, Excel, ReMarkable, Overleaf, Slack, PowerPoint/other slides, Blackboard, Notepad++, Markdown editor, Dictaphone, Scrivener, Memory, Workflowy, LaTeX documents
Collaborative use	Whiteboard, Pen & paper, Google Docs, Overleaf, Video meeting software, Word, GitHub, Microsoft Teams, Google Drive, Post it notes, Email, Slack, PowerPoint (one mention of Keynote), Blackboard, HackMD

Table 2. A list of frequently mentioned tools for idea management.

Several respondents described an experience of **tool overload**: *"there is already too many tools, and I feel people are wasting energy on using too many different platforms"* (survey response), *"there's so many tools already just adding on one more, there's a lot of, I don't know, resistance. But for me, it really needs to be super... I prefer not to be first mover on trying new tools, [until] they are established, and everyone is using it"* (P2). Rather than an all-embracing tool or platform, most researchers expressed that better integration between different tools would be desirable: *"I would love if different programs were better coordinated/in sync, making it easier to pull archives together"* (survey response).

4.2 Purposes of idea management

Some researchers reported that they record ideas primarily for the purpose of **remembering** them. For this purpose, messaging oneself is common: *"if I find something on the weekend, I'll usually set a reminder to at least ping me on Monday morning. And then on Monday morning, I can decide okay, I'll look at this on Thursday. And I'll set another reminder"* (P3). Email and Slack, although developed as communication tools, are frequently visited during the workday, and therefore convenient as a ubiquitous reminder. The idea entries created to remind the participant of an idea serve as a form of "index card" for the idea, putting the researcher in the same frame of mind and reasoning as when they first had the idea. Sometimes people remember the *time* or *place* when they had the idea, the *people* they were with, or even *names*: *"Whenever I think Adam Heller, I sort of come up with an idea. (...) hooked to the front page of the paper, just like my own doodle can be a tool to remember my ideas"* (P16).

Several researchers described the capture of their ideas as almost compulsory **cognitive offloading** [40]:

> *"**Why do you capture ideas?** (...) Anxiety. Reducing anxiety. And it's not that I've forgotten important things before but it's a kind of more out of sight out of mind thing that I stop some loops in my brain"* (P11).
>
> *"I cannot stop doing it. I have to have an outlet and have to put it somewhere. (...) Once it's out, and it's down somewhere, I can relax"* (P15).

Whether ideas are captured or not, appears to depend on an immediate metacognitive evaluation of whether the researcher considers themselves to be likely to remember the idea: *"I write it down if it's a really, really good idea. And I recognize that it's something that might disappear"* (P16). It is worth noting that cognitive research has shown that this immediate evaluation is potentially erroneous, leading to suboptimal offloading strategies [7, 40].

Externalizing ideas to a tool was described as sometimes **satisfying**: *"nine blackboards with the entire argument, that would correspond to maybe 8 pages of A4 manuscript or something. And that is super satisfying. (...) when I see that I can sort of feel my mind settling down"* (P18), and in some instances as **constraining**:

> *"I don't type them in the first instance. Ever, actually, I find usually like typing is where my ideas go to die, actually, like you start writing the idea and then, maybe fit into some kind of pattern about what has to be included in a write up of an idea"* (P4)

> *"As soon as you put something written down, two things happen. One is that you actually need to think a little bit more to make it make sense. And second, then you're committing to something. As long as you're thinking in your head, you're kind of free of it not making perfect sense, which is good"* (P17).

Some of the participants described their memory as a sufficient tool for both remembering, but also **filtering** ideas: *"The best ideas stick"* (survey response), *"They've been exposed to natural selection. If they were so great, I would have worked on them already"* (P2). Some participants believed **old ideas** to be of great value and **importance** to their current work:

> *"And I actually am very stubborn. I never want to abandon ideas. I think that, especially if I invested emotion and a little bit of labor in them, I will revisit them over and over again, before I can publish something of them"* (P17)

> *"if I'm working on a particular thing, then I will mine that document of research ideas to make sure I'm reminded of all the bits and pieces that I think are relevant (...) you want to make sure you touch on all the things that you have invested time and energy in thinking about"* (P15)

Others believed that their old ideas were largely **irrelevant** to their current work:

> *"in the academic world, again, because of this temporary employment, we are often jumping from one institution to another from one project to the other. So then some ideas that were relevant at that point of my career when I was researching a specific topic, it becomes completely irrelevant three years later"* (P12).

P17 described how personal development and new knowledge can be a driver for continuing to pursue old ideas:

> *"when I look back at an old idea, I just think, okay, years have passed, I'm a different person. Now I have developed other things, are these new tools that I created helpful, can they unlock something that I didn't know? And so, basically, what happens is that the original idea gets morphed into something that can be adapted to the new tools that I have, and may not necessarily look identical to what it was then. (...)? So I just use my growth as a person to inform the idea and to make it grow and to make it more feasible".*

4.3 The roles of tools

The most ubiquitous and important tool for most researchers to capture their ideas was *pen and paper*. Usually for the reasons of **availability** and being **non-constraining**:

> *"I'll try and write it down on a bit of paper with pen that I have nearby. And if I don't have that, it has to go on my hand. And if I have neither of those things, I become slightly more persnickety (...) And will make the world's problem to supply me with something to write down the idea. (...) writing has to be pen and ...skin, preferably mine. Preferably pen and paper."* (P4).

> *"you can use [pen and paper] more for schematics or diagrams, connecting the dots, if you like. And doing that on a laptop is super tedious, right?"* (P2).

The advantage of non-digital tools is also clear in terms of having a distraction-free environment: *"Some of the most creative work in recent years was on a train trip (...), where I had had my bag, computer, books etc stolen, and therefore was in possession of only a notepad and a ballpen"* (survey response).

When developing ideas, the **transition between tools** was sometimes fluid – where the researcher would move back and forth between different tools – but sometimes completely clear-cut:

> *"there was one weekend where I deliberately got to work. Took a cup of coffee, then went down into lecture hall B. And then wrote the entire proof down (...) I distinctly remember at the late Saturday afternoon, being able to take a step back (...) I did take pictures of it. But interestingly, it was no longer necessary"* (P18).

One survey respondent described how "simpler" tools allow for the initial molding, until the idea is ready for the text editor (which is usually the final tool in research idea development): *"The simplest tools allow me to do the initial analysis, to remember key ideas, to organize ideas, to tease out the most important aspect of something. I then use Word for write-up"* (survey response).

Depending on the level of maturity of the idea, most researchers would use some tool that allows them a sort of **overview** over the idea and related information: *"There's thoughts that **are** the idea, and then there's like associated thoughts, perspective...things, where I would like my [Notion] list to be just the idea. But then, for each point of the idea: this is all kind of relevant to this, or this relates to that"* (P7). Some examples of tools used for this were Evernote, Notion, Miro, or sometimes printed documents laid out on the floor.

When researchers actively develop an idea, tools that allow for **manipulation** would be relevant: *"sketching is more like, once I've had an idea, it's engaging with it in a way that's ... concretizing it towards something that's being developed [] a little bit past ideation"* (P8). As the standard format for communicating research ideas is text, all researchers used text editors (either Google Docs, Microsoft Word, or LaTeX) to develop and mature their ideas. Few participants reflected on the role of text editors in their creative development, although those who did, did so vehemently:

> *"On my laptop, I use word. I passionately hate word. Yet I use it all the time. I have usually up to 40 files open at the same time and I crash once every two months"* (survey response).

Ideas and data must be available for **exploration**, and tools that allow this can help researchers generate more ideas. This is not necessarily a structured process, and different visualizations of data may be of great importance [16]:

> *"I'm also using film as a tool of exploration. And I'm equally interested in, like, unexpected stuff that might happen. It's a bit back and forth between having ideas of what could happen and what is needed for a film, and then also being open to other stuff. Usually, it's the other stuff that's most important or interesting"* (P1).

Some tools or file formats specifically afford **serendipitous discovery** of old ideas, such as flipping through a physical notebook or scrolling through a text document:

> *"I go through my ideas in the notebooks, often linearly, because they are physical books. Whereas the ideas kept online, I do not process linearly, I use the hyperlinks, to explore by topics. (...) I traverse them based on content, based on what I want to read next. This is quite interesting, because this means that it's actually worth having both the paper medium and the electronic medium"* (P13).

Some participants enforced processes of transferring ideas from one tool to another: *"I don't mind these transfers (...) that's part of the reviewing and refreshing. Checking. (...) It's enjoyable to go back and think, Oh, well, actually, that was quite a good idea. I'm glad I wrote that"* (P15).

Some participants emphasized the value of **casual tools** for idea exchange, such as Google chat or Twitter Direct Message: *"email is formal, and there's sort of record of thing. (...) but a direct message on something like Twitter is (...) informal, and it's casual"* (P15). They compared this type of exchange to the informal chats that would occur when going to the pub together after work, which was described as generative by more than one researcher: *"a little bit typical*

of really good ideas. They happen after work hours, often with a beer in hand" (P3). The social aspect of idea development was described as highly motivating, interestingly sometimes **enhanced by digital tools**:

> *"I really enjoy that feeling of you're really working together on the same document, you can even see the position of the other person in the text, and there's a feeling of community"* (P1)
>
> *"[Miro] just raises the level of everyone. Because then, you know, everyone sees what somebody else is doing. And they get inspired"* (P9).

A lot of scientific writing is done with shared text editing software, often Google Docs or Overleaf. Most of the participants had tried using more visually oriented digital tools to collaborate with colleagues, such as Miro or Padlet. But a vast majority of the study participants preferred **talking** to colleagues when collaborating, especially if accompanied by the possibility of sketching:

> *"we'll discuss the drawing of plans/maps on a whiteboard, taking pauses, handing over the pen between us (a bit like the conch in the Lord of the Flies)"* (P4, survey response).
>
> *"what I write down on the pieces of paper are the formal parts of the argument. But all the linking words, (...) those are just in my head. And it would be difficult to communicate the entire argument to somebody else without the linking words"* (P18).

Although all researchers preferred to talk about ideas to discuss them, some described that ideas can get stuck this way: *"If it's a sort of brainstorm session, then we would probably use something like PowerPoints to show some data, and then basically discuss it and come to new ideas. And then it gets a bit fuzzy, because then everyone has their own notes. And then usually what I find is that nothing happens"* (P6).

4.4 Working with ideas as a material

The interview participants reported varying degrees of structure of their idea organization. About half of the participants (8) used a digital **archive or file specifically for ideas**. Those were kept in a personal Slack channel (P3), plain .txt files (P4, P13), Notion (P7), RemNote (P9), OneNote (P13), LaTeX (P15), and Google Docs (P17). Some of these archives were extremely elaborate, dating decades back:

> *"in the LaTeX document, which is now you know, hundreds, probably over 1000 pages, I can't remember. And it is indexed. (...) I have a set of about 20 or 30 terms relevant to me, my main topics of interest. (...) And just by selecting the right index term, I will generate a sub document, which only contains those items (...) I began to notice, sometimes I have the same idea – brilliant idea – twice!"* (P15).

In the ideas-specific archives, participants used self-invented structures to distinguish between different types of ideas:

> *"the big tall [elements on the board] are the books that I'm trying to work on. And the purple, these guys are the papers that are finished. (...) the red are all art projects (...) Blue means they're not immediately working on them. Purple means I am working on them right now. (...) all of these green ones are actually like classes that I'm teaching, but not this year. And all these dark green ones are grants* (P9).

The rest of the interview participants either did not keep a record of their ideas after the ideas were "carried out", or they stored ideas in folders related to individual projects:

> *"for my PhD, things were really organized, I have a notebook with all the ideas there. But in following projects, things got more fragmented. I have files for each context, (...) and the the ideas are scattered in those contexts, so that that's sometimes a challenge"* (P10).

Two of the participants spoke about idea **ownership** and how conceiving the idea felt as an individual rather than a collaborative process:

> *"ideas, they're so intimate, right? It's, it's either my idea or your idea (...) I'm not saying that I'm a genius and I get all these ideas by myself, I get all my ideas by stealing half phrases from everybody, right? But then I recombine them in my head* (P17).

Consistent with the metaphor of ownership, two participants even described **donating** ideas:

> *"I decided to pass on the idea to someone else (...). I just tweeted it hoping that someone else will notice it and use it and apply for grants or something"* (P12).

> *"I decided to capture an idea outside of my own area of expertise entirely. So basically creating an entry that may never be used by anybody. Or maybe I bump into a researcher who is an expert in that idea space, then I can donate them this idea"* (P13).

In this section, we have described how participants manage ideas, how they use and appropriate tools, and how they work with ideas as a material. In the following section, we will elaborate on how researchers conceptualize and define ideas. Defining ideas as a 'material' is essential to understand how technology supports idea management in research practice.

5 FINDINGS II: CHARACTERIZING RESEARCH IDEAS

5.1 Definitions and types of research ideas

Researchers from seemingly remote fields (and most with little or no relation to creativity research) used remarkably similar words to describe ideas more generally, such as "connecting things", "putting stuff together", which is similar to idea definitions in creativity research [1, 6, 42]. Many participants also described a sense of **a core idea** as a simple entity with potential layers of complexity on top:

> *"I think a problem that many people have when developing ideas is that they don't develop them long enough to get back to simplicity. (...) once you start developing an idea, you often add layers of complexity to kind of fit everything into that idea. And it becomes like, bloated and bulky. And then often people stop at that point and say, Okay, now we have, we've covered every base."* (P3).

The following definitions or categories cluster how participants described research ideas – an overview is presented in Table 3. They are not necessarily mutually exclusive, and one idea could contain more of these elements (for example, a research question *and* a method to study it).

5.1.1 ***A research question or problem.*** A research idea was often described as a formulation or definition of a novel problem or research question to study: *"I think good ideas in my field are the ones that capture the big salient, a big salient issue that the field is facing"* (P17), *"most of my ideas are centered on questions that are current or recurring"* (P16). Metaphorically, if we conceptualize science as the process of *mapping the world*, the research question idea can be described as **identifying holes in the map, either by discovering or formulating them**: *"I try to formulate questions that aren't clear for me yet. I try to become more aware of the gaps that are still there and why they're still there"* (P14).

5.1.2 ***A method.*** One of the most common descriptions of ideas was "an application of a new method to a problem or a different field". This could be a new method entirely: *"I often need to define new methods, or conceive new methods."* (P13),

Idea type	Description	Metaphor
Research question or problem	An identification of knowledge of the world that we do not yet have	Identifying an unknown area of a map
Method	An identification of a way of generating (some) knowledge, which we do not yet have	Finding a road that leads to a new area of the map
Hypothesis or antithesis	An educated guess about what knowledge may be generated or refuted	A guess of what an unknown area of the map could contain
Theory	A way to systematize, model, frame, or abstracting knowledge	Drawing a map over existing roads in the world

Table 3. Description of the four research idea types identified through the thematic analysis. An idea of any of the types could be considered more or less *creative* according to standard definitions of creative as *novel*, *useful*, and *nonobvious* [44]. We highlight that these are descriptions of *research* ideas related specifically to research practice. The four types do not describe ideas pertaining to other parts of researchers' lives, such as ideas for how to run a research group or how to design an office space.

or the application of known methods to a new problem or field. Most research fields have open "canonical" problems that are relatively well-defined, and researchers will come up with ideas for how to solve these open problems, e.g.: ***(while demonstrating an entry in a file called "Research ideas")****"we've got this general problem. (...) the subheading here is one instance of how one could address that general problem"* (P4).

One attribute of knowledge work is that, given the same input, each knowledge worker provides different output to a problem [31]:

> *"I have very, very good command of a very narrow set of tools, my only competitive advantage is that I can command these tools so other people can ask me; here is a fresh problem. I know that you understand how to do x very well. Can we use x for that problem?"* (P18).

One participant described how individual researchers will be uniquely positioned to find such applications:

> *"the reason why it's a good idea, it's because, it's something that's so interdisciplinary, it's kind of like you need to be on the right spot at the right time with the right mindset, and with the right background to to make it work"* (P17).

One participant described that more 'satisfying' ideas would involve both coming up with a problem and a method: *"So there's both the idea of identifying the issue, research question part of it, and then identifying the approach of it. And I think for me, those two, like one without the other isn't very satisfying"* (P7). The method idea can be described as **identifying new paths to unknown places on the map**, or ways to generate knowledge that we do not yet have.

5.1.3 ***A hypothesis or antithesis.*** Some research ideas were equated with hypotheses for how to solve (or partially solve) a specific problem. Several participants, especially those from the natural sciences, described their ideas as something which can be *tested*:

> *"I ask a question, how does something work? I have an idea of how it could work. So for me to capture my idea would be to test if my hypothesis is correct or incorrect"* (P6).
>
> *"often when I get the idea, [...] I don't know if it's good or it's bad, but we do the experiment, we test the idea"* (P16).

One participant described their ideas as refutations or antitheses [41]: *"this example (like 99 out of 100) is a *counter*-example. A *refutation* of a conjecture. Almost all I do as a working scientist is *refuting* ideas, not *getting* them"* (P18, survey response). Staying with the metaphor of mapping the world, a hypothesis/antithesis idea can be described as **an educated guess about what a method may or may not reveal**: *"The idea is to test the hypothesis using an empirical experiment"* (P13).

5.1.4 ***A theory.*** A common product of research is frameworks or theories, and therefore researchers often have ideas for how to structure, model, or conceptualize existing knowledge:

> *"there were like kind of two main methods that other people had published. And people were really assuming that it's a very different strain of strain of methods. (...) for some reason I connected those two strains. Unfortunately, I could not go to sleep. So I had to get up and draft almost the entire paper"* (P11).

The formulation or conception of a theory idea can thus be described as **systematizing, modelling or abstracting knowledge, like the drawing of a map over existing roads**. The theory idea can said to be the product of *sensemaking*, the process of creating a mental model [32]: *"I wrote out just the names of the different people and the different constellations that I could see. Through that process, I could see a different constellation of a research project that (...) was like a different perspective on the next four years"* (P1).

5.2 *Good* research ideas

We asked participants to tell us about at least one *good* idea of their own, a good idea in their field, and talk about why these were good ideas. The participants described that the recognition of good ideas of their own was sometimes defined by **external** feedback or impact: *"it's a good idea because there was good feedback about it. And I could see it creates a value it was also supposed to create"* (P14), but more often on **internal** factors:

> *"you can maybe picture how a dinner will be like, even though it's like a new group of people, but you have a cozy feeling about it, or you can picture what it would be like to win some kind of sports event with your team. And I think a good idea captures that feeling a bit in the start."* (P11).

Good ideas were characterized by the participants as having at least two of the properties *novelty*, *usefulness*, or *nonobviousness* (but not always all three).

5.2.1 "I'm just in the wrong century". **Novelty**, or originality, describes, in the context of research ideas, that the idea has not been seen (either by the person or in the research field) before:

> *"9 out of 10 times when I'm excited about actually having solved something, then you start the process of looking (...) And then often after a few hours, you get the depressing insight that some bloody Hungarian already did this in 1936. Right, and at that moment, it becomes no longer publishable.* ***Interviewer: Does that make it less of a good idea?*** *No, certainly not. You can be very proud with yourself saying (...) I actually came up with something that [X] came up with, I'm just in the wrong century* (P18).

While some participants believed that their fields valued *incremental* innovation [37] too highly:

> *"my field is broken. Because everybody is claiming that every single paper has to have some technology focus, like, we're curing cancer, solving the energy crisis. And what they really do is that they do an experiment showing the exact same thing, but with now with blue instead of yellow. And this has been happening the last 15 years. So now it is like self-consistent mass delusion"* (P16),

other participants believed their fields to value *radical* innovation too highly:

> *"I think the originality of it is unfortunately, too valued because (...) more emphasis should be put also in finding novel ways for the same ideas (...) it seems that by the fact that someone has built a solution, it's done. Nobody else is going to publish about that"* (P10).

This dichotomy illustrates that even the definition of 'novel' is not an easy criterion to use in research evaluation [15, 50, 52].

5.2.2 "One of those "P"-things". **Usefulness**, also sometimes described as *fit*, *utility*, or *appropriateness* [44], invariably differs between research fields. In academics, the utility of or usefulness of the idea is inherently tied to academic performance metrics: *"early in my career the end product [of capturing ideas] would be a **Project** or a **Proposal** or a **Paper**, right, one of those "P"-things* (P4). For most researchers, especially those who are not yet tenured, the translation of ideas into 'one of those "P"-things' (not to be confused with P-creativity as *personal* creativity [6]) is an unavoidable criterion for useful ideas:

> *"we had a number of ideas building up around this. (...) this was really fun [...] and we were doing brand new things. And no one else really cared about the research. But I learned a tremendous amount. [...] I should write a book about that one day, but there's no incentive to my career to doing that. So I haven't done it"* (P4).

While this can be seen as somewhat detrimental to creative innovation, one participant described the direct relation between performance metrics and impact as:

> *"I think a good idea is probably a funded idea. (...) Because those are actually the ideas that get somewhere in the end, because if they're not funded, no one is ever exposed to those ideas"* (P12).

Several participants also described good ideas as feeling *inherently purposeful*: *"I think this is brilliant idea. It seems profoundly meaningful (...) I don't have this problem 'why am I working?"'* (P1). This researcher also described how applied research could sometimes be detrimental to creativity: *"I once was involved in something that got too applied, too intertwined with very complex political debates (...) It had a negative impact on my openness and my curiosity to approach those topics"* (P1).

5.2.3 "Obviousness with the benefit of hindsight". A standard, three-criteria combinatorial definition of creative ideas is that they should be novel, useful, and **nonobvious** [46] or contain an element of surprise [6]. P4 said about an idea of theirs:

> *"this didn't seem so much like a creative idea as just a, like a poundingly obvious research direction that, God, why has no one thought of this before?, to the point where it became a highly driven industrial feeling project. (...) So maybe this is one that felt like it was a very important idea. (...) But it wasn't necessarily fun, just driven to execute. (...) I understood all of the steps in the research, what the issues were and how to overcome those. Didn't feel very creative, though. It was too obvious"* (P4).

This quote encapsulates the experience of a novel and useful idea not being *creative* (even if important), because it is too obvious. Simonton [47, 48] describes nonobviousness as the person's knowledge of the idea's final utility, which can rate from 0 (the generator has no idea of the utility in advance) to 1 (the utility is already known perfectly at the moment of generation). However, this can also be described as *obvious*:

> *"the obviousness with the benefit of hindsight, that is really not obviousness because otherwise, other people would have already done it. So there are some ideas when you describe them to people, they say, Yeah, of*

> *course! But then they didn't come up with it in the first place. (...) it's not easy to come up with it. But once you describe it to people, they immediately get it. So it's kind of obvious. (...) They may even contest that it's something, you know, because it seems a straightforward, derived or incremental thing to say"* (P13).

We note that we asked participants for their understanding of *good* research ideas, not *creative* research ideas, and that these characteristics may be different in a practical research context.

In this section, we have presented different conceptions of research ideas. In the following section, we will discuss challenges and opportunities for tools and technology to support the idea management of researchers in practice.

6 DISCUSSION: POTENTIALS FOR TOOLS AND WORKFLOWS TO SUPPORT IDEA MANAGEMENT

The researchers who participated in the study did not generally state that they were severely *lacking* tools (with one consistent exception of being able to draw better – freehand and diagrams – on the computer). Some researchers claimed the abundance of different tools would sometimes cause ideas to get lost, but some also expressed being willing to give those ideas up, as "the best ideas stick" (section 4.4ß).

6.1 Fewer tools, more integration

At least half of our respondents *are not missing tools, they miss integration* between tools: *"there are too many tools that different people use"* (P11, survey response), *"I would love if different programs were better coordinated/in sync, making it easier to pull archives together. I tend to have notes all over the place (...) making it quite messy processes"* (survey response). Rather than suggesting implications for novel tools to support idea management, the findings from the study indicate that many survey respondents already have too many tools and that the main challenge is to establish workflows and integration between tools. Many of the interview respondents used .txt files and markdown for their idea capture and storage, simply because pure text files are "permanent" and "perpetual" (P13). But clearly, text files are not appropriate for all kinds of visualizations: *"when I capture ideas on my laptop is usually texts, and that is linear, it's structured. So it's kind of difficult when the idea is still not super defined, it's very difficult to put in linear structure that makes sense"* (P17). It was recurrently mentioned that drawing and manipulating graphics on a computer is difficult, partially because of the input modality, and partially because there are no standards for transferring digital graphics between different software or from analog to digital tools. We summarize this as a potential for idea management tools to **support integration between multiple tools, multiple file formats, and manipulation in different modalities**.

6.2 Not all ideas fit in Zettelkasten

There were expressions of *tools imposing a format or structure on ideas*, especially when people had committed to a specific idea archiving system, their future idea entries needed to fit some structure or file format of that archive. As an example, one researcher said about the application *Workflowy*: *"I started thinking too much about, where should this thing go? How should I structure things? And then I do not do it because I'm deciding the best way, and then it gets lost and I pick up a paper and write it down"* (P10). One researcher described how all aspects of an idea do not fit in one format: *"the tool should have a separation between content and process. I think people try to put that together, often [...]. So the Google Doc will have both links to relevant papers or websites, but also the project plan of who does what, and then everybody does something, maybe in their own system"* (P11). Some idea selection and development therefore happens based on how well the idea fits into a specific tool, or attempting to make the idea fit into a specific, collaborative platform. This may have adverse effects to creativity – individual, as well as collaborative. We see an untapped potential

for idea management tools that **allow different researchers to construct different mental models of an idea**, rather than by structuring content in a predefined way. This is part of what makes ideas different from *information*, and why systems such as Luhmann's Zettelkasten method [33] are not one-fits-all solutions: *"we should be careful to provide tools which enable diversification - tools which embed a model of a knowledge worker's task in the software do not"* [31].

6.3 Good systems require time and reflection

A frequently raised issue by participants was a lack of *time to discover and reflect on deliberate systems* for idea management: *"it's time that's our major problem. We don't have enough time to really sit and reflect"* (P6), *"I don't miss a tool, I miss a process"* (P10, survey response), *"I do [miss a tool], but my problem is that every time I try something new I lose track of where I keep my ideas"* (survey response).

As evident from the rest of this paper, researchers are rarely taught specific processes for idea management, and rely on their own discovery and appropriation of different tools. Two researchers (P5 and P15) mentioned the concept of *lab books* having had an influence in their structural approach to managing ideas: *"I've always kept lab books. From the start of my research career. (…) as the years have gone by, I've gradually updated the technology"* (P15). Rather than imposing best practices or predefined systems, it may be more beneficial to expose and discuss various systems and tools employed by other researchers. Several of the interview participants also said that the interview for this study was a welcome opportunity to reflect on their practices, and expressed interest in seeing the results of the study. Therefore we highlight the need for the research community and knowledge workers in general to **openly discuss and share different systems and processes for managing ideas in practice**.

7 CONCLUSIONS AND FUTURE WORK

Through an explorative survey with follow-up interviews, we contribute with a thematic analysis of how researchers select and employ tools to manage and develop ideas in their daily practices, and how they understand research ideas.

The respondents use a great variety of tools and systems in unique bricolages, and no two processes were the same. We find that even though researchers consider it important to capture and manage ideas, their approaches to doing so are less structured than their work practices in general.

Research ideas were defined by participants as *research questions or problems*, *methods*, *hypotheses or antitheses*, and *theories*. Researchers define good ideas in a way that is consistent with traditional conceptions of ideas in creativity research, namely by the qualities of *novelty*, *usefulness* and *nonobviousness*, although nonobviousness may not be a criterion for *good* research ideas (albeit *creative* ideas).

We identified the greatest potentials for supporting even better idea management to be focused on allowing researchers to use different tools, but *support integration* between tools, to *not force a specific mental model upon the idea by virtue of the tool employed*, and to continue to *openly discuss and share different processes for idea management in practice*.

Our findings point at several promising avenues for future research. First, it would be interesting to more closely examine the types of tools and workflows researchers employ for exploring the different idea types. This might enable us to identify the potentials and limitations of specific tools and approaches, and possibly uncover best practice examples that can inform and inspire other researchers. Second, we wish to examine whether and how the practices and conceptualizations of idea management and development in research compare to other domains, for instance, design, in which recent contributions have similarly examined practitioners' conceptions and workflows around idea management [22, 24]. Third, we intend to further examine if and how the labels of idea types can be integrated into methods and processes that can aid idea generation and management for researchers. We speculate that the articulation

of ideas and their categorizations could be generative for both individual and collaborative creative research work. As most respondents agreed that a good idea often implies applying a known process or method in a new domain or to a new research problem, we hope that future work can help researchers do so, either afforded by more dedicated idea management tools or more likely as (discussions of) idea management methods that they can adapt to their particular work practices.

In conclusion, we see great potential in furthering the study of idea management and development in research, since it is clearly a highly valued and pivotal aspect of academic researchers' work, yet one that all respondents in our study wish they had more knowledge about how to approach in a structured manner.

ACKNOWLEDGMENTS

This research was supported by a research grant (37176) from VILLUM FONDEN and by the Independent Research Fund Denmark 0132-00111B, Managing Ideas in Creative Work.

REFERENCES

[1] Teresa M Amabile, Mary Ann Collins, Regina Conti, Elise Phillips, Martha Picariello, John Ruscio, and Dean Whitney. 2018. *Creativity in context: Update to the social psychology of creativity.* Routledge.

[2] Teresa M Amabile and Jennifer S Mueller. 2008. Studying creativity, its processes, and its antecedents: An exploration of the componential theory of creativity. *Handbook of organizational creativity* 3162 (2008).

[3] Peter Atkins. 2004. *Galileo's finger: the ten great ideas of science.* OUP Oxford.

[4] Deborah Barreau and Bonnie A Nardi. 1995. Finding and reminding: file organization from the desktop. *ACM SigChi Bulletin* 27, 3 (1995), 39–43.

[5] Richard Boardman and M Angela Sasse. 2004. " Stuff goes into the computer and doesn't come out" a cross-tool study of personal information management. In *Proceedings of the SIGCHI conference on Human factors in computing systems.* 583–590.

[6] Margaret A Boden. 2004. *The creative mind: Myths and mechanisms.* Routledge.

[7] Annika Boldt and Sam J Gilbert. 2019. Confidence guides spontaneous cognitive offloading. *Cognitive Research: Principles and Implications* 4, 1 (2019), 1–16.

[8] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative research in psychology* 3, 2 (2006), 77–101.

[9] Svend Brinkmann and Steinar Kvale. 2018. *Doing interviews.* Vol. 2. Sage.

[10] Victoria Clarke, Virginia Braun, and Nikki Hayfield. 2015. Thematic analysis. *Qualitative psychology: A practical guide to research methods* 222 (2015), 248.

[11] B Jack Copeland and Diane Proudfoot. 1999. Alan Turing's forgotten ideas in computer science. *Scientific American* 280, 4 (1999), 98–103.

[12] Tim Coughlan and Peter Johnson. 2008. Idea management in creative lives. In *CHI'08 extended abstracts on Human factors in computing systems.* 3081–3086.

[13] Richard L Daft and Selwyn William Becker. 1978. *The innovative organization: Innovation adoption in school organizations.* Elsevier Publishing Company.

[14] Peter Dalsgaard. 2017. Instruments of inquiry: Understanding the nature and role of tools in design. *International Journal of Design* 11, 1 (2017).

[15] Magda Fontana, Martina Iori, Fabio Montobbio, and Roberta Sinatra. 2020. New and atypical combinations: An assessment of novelty and interdisciplinarity. *Research Policy* 49, 7 (2020), 104063.

[16] Jonas Frich, Michael Mose Biskjaer, Lindsay MacDonald Vermeulen, Christian Remy, and Peter Dalsgaard. 2019. Strategies in Creative Professionals' Use of Digital Tools Across Domains. In *Proceedings of the 2019 on Creativity and Cognition.* 210–221.

[17] Jonas Frich, Midas Nouwens, Kim Halskov, and Peter Dalsgaard. 2021. How Digital Tools Impact Convergent and Divergent Thinking in Design Ideation. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems.* 1–11.

[18] Neal Gabler. 2011. The elusive big idea. *The New York Times* 13 (2011).

[19] Sophia Gerlach and Alexander Brem. 2017. Idea management revisited: A review of the literature and guide for implementation. *International Journal of Innovation Studies* 1, 2 (2017), 144–161.

[20] Vlad P Glăveanu. 2022. What's 'Inside'the Prepared Mind? Not Things, but Relations. In *The Art of Serendipity.* Springer, 23–39.

[21] Yujong Hwang, Hui Lin, and Donghee Shin. 2018. Knowledge system commitment and knowledge sharing intention: The role of personal information management motivation. *International Journal of Information Management* 39 (2018), 220–227.

[22] Nanna Inie and Peter Dalsgaard. 2017. How interaction designers use tools to capture, manage, and collaborate on ideas. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems.* 2668–2675.

[23] Nanna Inie and Peter Dalsgaard. 2017. A Typology of Design Ideas. In *Proceedings of the 2017 ACM SIGCHI Conference on Creativity and Cognition* (Singapore, Singapore) *(C&C '17).* Association for Computing Machinery, New York, NY, USA, 393–406. https://doi.org/10.1145/3059454.3059464

[24] Nanna Inie and Peter Dalsgaard. 2020. How interaction designers use tools to manage ideas. *ACM Transactions on Computer-Human Interaction (TOCHI)* 27, 2 (2020), 1–26.

[25] Nanna Inie, Peter Dalsgaard, and Steven Dow. 2018. Designing idea management tools: Three challenges. (2018).

[26] Nanna Inie, Allison Endo, Steven Dow, and Peter Dalsgaard. 2018. The problem solver and the artisan designer: Strategies for utilizing design idea archives. In *Proceedings of the 10th Nordic Conference on Human-Computer Interaction*. 397–406.

[27] Anna Vagn Jensen. 2012. A literature review of idea management. In *DS 71: Proceedings of NordDesign 2012, the 9th NordDesign conference, Aarlborg University, Denmark. 22-24.08. 2012.*

[28] Steven Johnson. 2011. *Where good ideas come from: The natural history of innovation.* Penguin.

[29] James C Kaufman and Ronald A Beghetto. 2009. Beyond big and little: The four c model of creativity. *Review of general psychology* 13, 1 (2009), 1–12.

[30] Joseph'Jofish' Kaye, Janet Vertesi, Shari Avery, Allan Dafoe, Shay David, Lisa Onaga, Ivan Rosero, and Trevor Pinch. 2006. To have and to hold: exploring the personal archive. In *Proceedings of the SIGCHI conference on Human Factors in computing systems*. 275–284.

[31] Alison Kidd. 1994. The marks are on the knowledge worker. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. 186–191.

[32] Gary Klein, Brian Moon, and Robert R Hoffman. 2006. Making sense of sensemaking 1: Alternative perspectives. *IEEE intelligent systems* 21, 4 (2006), 70–73.

[33] Niklas Luhmann. 1981. Kommunikation mit Zettelkästen. In *Öffentliche Meinung und sozialer Wandel/Public Opinion and Social Change*. Springer, 222–228.

[34] Wendy E Mackay. 1990. *Users and customizable software: A co-adaptive phenomenon.* Ph. D. Dissertation. Massachusetts Institute of Technology.

[35] Elina Mikelsone and Elita Liela. 2015. LITERATURE REVIEW OF IDEA MANAGEMENT: FOCUSES AND GAPS. *Journal of Business Management* 9 (2015).

[36] Roberta B Ness. 2012. *Innovation generation: How to produce creative and useful scientific ideas.* Oxford University Press.

[37] Donald A Norman and Roberto Verganti. 2014. Incremental and radical innovation: Design research vs. technology and meaning change. *Design issues* 30, 1 (2014), 78–96.

[38] Lorelli S Nowell, Jill M Norris, Deborah E White, and Nancy J Moules. 2017. Thematic analysis: Striving to meet the trustworthiness criteria. *International journal of qualitative methods* 16, 1 (2017), 1609406917733847.

[39] William Odom, Abi Sellen, Richard Harper, and Eno Thereska. 2012. Lost in translation: understanding the possession of digital things in the cloud. In *Proceedings of the SIGCHI conference on human factors in computing systems*. 781–790.

[40] Evan F Risko and Sam J Gilbert. 2016. Cognitive offloading. *Trends in cognitive sciences* 20, 9 (2016), 676–688.

[41] Albert Rothenberg. 1996. The Janusian process in scientific creativity. *Creativity research journal* 9, 2-3 (1996), 207–231.

[42] Mark A Runco and Garrett J Jaeger. 2012. The standard definition of creativity. *Creativity research journal* 24, 1 (2012), 92–96.

[43] Andreas Schwill et al. 1994. Fundamental ideas of computer science. *Bulletin-European Association for Theoretical Computer Science* 53 (1994), 274–274.

[44] Dean Keith Simonton. 2003. Scientific creativity as constrained stochastic behavior: the integration of product, person, and process perspectives. *Psychological bulletin* 129, 4 (2003), 475.

[45] Dean Keith Simonton. 2010. Creativity in highly eminent individuals. *The Cambridge handbook of creativity* (2010), 174–188.

[46] Dean Keith Simonton. 2012. Taking the US Patent Office criteria seriously: A quantitative three-criterion creativity definition and its implications. *Creativity research journal* 24, 2-3 (2012), 97–106.

[47] Dean Keith Simonton. 2021. Scientific Creativity: Discovery and Invention as Combinatorial. *Frontiers in Psychology* (2021), 3603.

[48] Dean Keith Simonton. 2022. Serendipity and creativity in the arts and sciences: A combinatorial analysis. In *The Art of Serendipity*. Springer, 293–320.

[49] Jaime Teevan, William Jones, and Benjamin B Bederson. 2006. Personal information management. *Commun. ACM* 49, 1 (2006), 40–43.

[50] Brian Uzzi, Satyam Mukherjee, Michael Stringer, and Ben Jones. 2013. Atypical combinations and scientific impact. *Science* 342, 6157 (2013), 468–472.

[51] Mojtaba Vaismoradi, Hannele Turunen, and Terese Bondas. 2013. Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. *Nursing & health sciences* 15, 3 (2013), 398–405.

[52] Jian Wang, Reinhilde Veugelers, and Paula Stephan. 2017. Bias against novelty in science: A cautionary tale for users of bibliometric indicators. *Research Policy* 46, 8 (2017), 1416–1436.

[53] Nosheen Fatima Warraich, Irfan Ali, and Shazia Yasmeen. 2018. Keeping found things found: Challenges and usefulness of personal information management among academicians. *Information and Learning Science* (2018).

[54] Steve Whittaker and Julia Hirschberg. 2001. The character, value, and management of personal paper archives. *ACM Transactions on Computer-Human Interaction (TOCHI)* 8, 2 (2001), 150–170.

[55] Charles M Wynn and Arthur W Wiggins. 1996. *The five biggest ideas in science.*

A SURVEY QUESTIONS

1	Please describe your job title and main research area(s):
2	Which tools do you use to record ideas, hunches and inspirational material? (e.g. a notepad, diary, dictaphone, post It-notes, mobile phone, laptop or anything else). Please describe these tools in as much detail as possible (i.e. if you use a specific software, do you use it on both mobile, tablet and laptop, or only one of them?). Also, if possible, describe when you have these tools with you and how you make use of them:
3	Describe how you represent ideas and inspirational material using the tool(s). What form do they take? (e.g. written text, sketches, photos, video, voice recordings, scraps cut from magazines etc.):
4	How do you integrate the tool or tools as part of your work, if you do so?
5	Do you ever collaborate with other people using the tool(s)? If so, when and how?
6	How do you present your ideas to other people - colleagues or personal relations?
7	If you collaborate with other people on idea development, which tools, if any, do you use as part of this (e.g. paper and pen, a computer, specific software etc.) and how are they used?
8	Have you ever missed a tool for collaborative creative project management? How do you imagine such a tool might look?
9	Can you recall ever having a good idea related to a project or challenge in your work at an unexpected or inappropriate time? Examples of this would include when you were travelling, in bed, shopping or doing another activity away from your work or practice. Does this happen often?
10	If you can, please describe a situation like this. Did you manage to bring the idea into your work, and/or did you record it?
11	Do you feel that you have forgotten good ideas in the past because they occurred at an unexpected time and you could not record them?
12	Do you share ideas with others while you are developing them? Please describe how and why:
13	How well-structured do you consider your current process to be when it comes to capturing and managing ideas? (1-5)
14	How well-structured do you consider your approach to your work in general to be? (1-5)
15	How important is it for you to capture and manage ideas as part of your work? (1-5)
16	On average, how often do you actively revisit old ideas that you have captured as part of your work?
Optional	If you would be okay with us contacting you about a follow-up interview based on your questions, please leave us your email below:
Optional	Do you have any other comments or thoughts related to the questions above?

Table 4. Qualitative survey questions.

B INTERVIEW PARTICIPANTS

Gender	Position	Field
F	Assistant professor	Virology and immunology (biomedicine)
M	Associate professor	CSO chemistry/materials science
M	Associate professor	Anthropology
F	Associate professor	Biophysics
M	Associate professor	Energy metabolism, obesity, neuroscience
M	Professor	Science & Technology Studies and anthropology
M	Assistant professor	Interaction design
M	Associate professor	Complex network analysis
F	Research assistant	Natural Language Processing
M	Associate professor	Machine learning
M	Professor	Artificial Intelligence
M	Professor	Spoken Language Processing
F	Postdoc	Cognitive science/psycholinguistics
M	Professor	Information retrieval, web technologies and databases
M	Professor	Theoretical computer science
M	PhD student	Distributed machine learning and data governance
F	PhD student	Hybrid tools for design and feminist design research methods
F	Associate professor	Machine learning and medical imaging

Table 5. List of interview participants. Participant numbers are not specified in this overview, in the interest of preserving anonymity.

C INTERVIEW GUIDE

Intro 1	Can I ask you to state your name and affiliation, and confirm that you are OK with this interview being recorded and used for research purposes?
Intro 2	In this interview, we would like to ask further questions in relation to the survey you have filled out about how you manage your ideas. In this context, "ideas" is open-ended and up to your interpretation. It can include any definition of idea that makes sense to you. Do you have any questions before we begin?
1.1	Which tools do you use to capture your ideas? • When you're at work? • When you're at home? • When you're at "inconvenient places" (i.e. on a walk, in the shower, running etc.)?
1.2	Can you remember the last time you captured an idea? Describe what happened.
1.3	Why do you capture ideas? What's the end goal-product? And how does archiving contribute to that?
1.4	Imagine the ideal tool, in your mind, for continuously capturing ideas. What would the interface of this tool be like, and what key features would it have?
2.1	Where do you keep your ideas?
2.2	How do your ideas look? E.g. sketches, audio files, texts, image collections etc.
2.3	Imagine the ideal tool, in your mind, for storing ideas so they are easy to find and use when you need them. What would the interface of this tool be like, and what key features would it have?
3.1	Do you ever look at your old ideas? Why/why not?
3.1.a	If yes: How do you use your old ideas for later projects?
3.2	Take me back to the last time you went through or otherwise used an idea archive of yours. What did you learn from it?
4.1	Which tools do you use when you collaborate with others in generating/developing ideas? Why these tools?
4.2	Do you ever experience difficulty in representing your ideas so you can communicate them to others?
4.2.a	If you think back to the last time you faced this situation: describe what happened?
4.3	Imagine the ideal tool, in your mind, for collaborating on ideas with your colleagues or team. What would the interface of this tool be like, and what key features would it have?
5.1	Can you tell me about one or two of your really good ideas? Why were they good?
5.2	In your field more generally or historically, what do you think is a really good idea? Why?
5.3	Did that make you think of other good ideas of your own?
5.4	Would you say you primarily do basic or applied research?
Debriefing	Do you have any more questions for me? If you think of anything else, feel free to reach out to me on email at any point.

Table 6. Interview guide.