Idea-Centric Search: Four Patterns of Information Seeking During Creative Ideation

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ABSTRACT

As search evolves and Generative AI enables users to express more complex information needs and goals, it is an opportune moment to investigate how the search for information influences creativity. Little is known about how creators — especially novices who lack domain-specific terminology — use web search when developing an idea, and vice versa, how new information shapes an idea. To investigate how ideas evolve through web search, we conducted an online lab study with 56 design students who engaged in a 3-week product redesign project. Through a mixed-method analysis of web search logs, surveys, and interviews, we report on the different search behaviors, strategies, challenges and four distinct patterns–Orienters, Refiners, Confirmers, and Pivoters–that illustrate how the impact of search depends on the maturity of an idea. We discuss design opportunities to enhance web search systems for ideation and pedagogical interventions to teach creators how to improve idea-centric search.

CCS CONCEPTS

• **Human-centered computing** → **Web-based interaction**; *Hypertext / hypermedia*; • **Information systems** → **Personalization**; *Web log analysis.*

KEYWORDS

Creative search, information seeking, ideation

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1 INTRODUCTION

Web search is one of the most frequently used, but perhaps overlooked, creativity-support tools. Creators often seek information throughout their creative process [53, 55, 56]: to understand the background of a problem [14, 57], to find inspiration for solutions [61], and to discover new tools that facilitate the process [36]. As the nature of Web search evolves from simple retrieval, to natural language queries, to generative AI (GenAI) and beyond, we stand at a pivotal moment for shaping the tools for complex and creative information goals. However, less is known about how people seek information online to shape their ideas, or vice versa, and how their evolving ideas affect how they search the Web. This paper explores this relationship — what we define as *idea-centric search.*

The concept of "idea" has many notions. The Merriam-Webster Dictionary defines an "idea" as a formulated thought or a plan for action [39]. Ideas can be expressed in different modalities (i.e., visual, auditory, etc.) or presented in different representations (i.e., text, images) [44, 61]. Our work in this paper studies ideas expressed as *text.* This is because, fundamentally, all ideas can be expressed as text, even if they were created with different representations (e.g., a napkin sketch can be described with words). Since web search primarily relies on text [20], we anticipate that people infuse language from their ideas when conducting idea-centric search. Also, by working with text, we can apply modern text analysis techniques to systematically compare ideas at different time points and to measure how Web search influences an idea.

Ideas are not static but constantly evolving throughout a creative process, and they differ in their level of maturity. For example, ideas can be vague and ill-defined, like a fleeting thought in the shower [27], or on the other hand, ideas can be more concrete and well-thought-out, like an elevator pitch [15]. Our research hypothesizes that the level of maturity for an idea will impact how people search the web to inform that idea.

To study the relationship between the maturity of an idea and web searches, we conducted an exploratory study in a college design course where 56 novices were working on a product redesign assignment. We observed individual students during 60-minute Web search sessions by collecting search log data, pre- and post-session idea descriptions, and reflective interviews about their experience using web search while working on their project. The research team collaboratively analyzed how each participant's idea evolved and coded different behavioral patterns for idea-centric search. We also

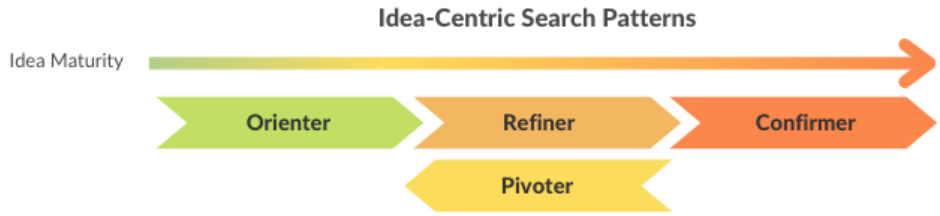


Figure 1: An analysis of idea-centric search uncovers four distinct patterns exhibited by participants — Orienters, Refiners, Pivoters, or Confirmers — depending on how the maturity of an idea and what information is accessed.

ran statistical analysis on search patterns (#, type of queries, # and time of web pages accessed, etc.) for all participants.

Our analysis finds that Web search affects participants' ideas in four qualitatively different *idea-centric search patterns* (Fig.1): (1) *Orienters* started with problem-driven concepts and/or vague ideas and got oriented to domain information that helped them generate an initial idea , or (2) *Refiners* started with vague ideas and found information on the Web that helped add concrete details to their ideas, or (3) *Pivoters* started with a concrete idea, but came across information that motivated them to change their focus, or (4) *Confirmers* also started with a concrete idea, but tended to focus on information that validated their initial idea.

Furthermore, we found that these idea-centric search patterns aligned with different types of web search activity. Refiners were the most active, issuing significantly more queries and opening more web pages, compared to the other patterns. Orienters, who started with the least fleshed out concepts, issued significantly fewer search queries compared to the other types, perhaps indicating they spent more time reading content rather than searching. Refiners and Pivoters visited the most different websites and also changed their ideas more compared to Confirmers and Orienters. Across all patterns, participants reported challenges around struggling to articulate useful queries in part due to a lack of domain vocabulary and knowledge. Also participants reported that Web search results often lacked inspiration or felt too homogeneous, impacting participants' creative process.

Our findings contribute to a better understanding of how people use the internet to search for information that shapes their ideas and how their ideas, in turn, influence their online search behavior. We conclude our paper by discussing how indicators of idea-centric search behavior — including web activity, information needs, and user experience challenges — can inform future creative search systems.

2 RELATED WORK

This research builds on prior work on creative ideation and how people use web search during a creative process.

2.1 Ideation and the Creative Process

Research from cognitive psychology defines an "idea" as the basic element of thought and can be expressed in various forms such as language, imagery, or even sensory perception [26, 62]. The maturity of an HCI idea may range from a description to a polished product [17]. Kerne et al. (2014)[30] defines "ideation" as creating new ideas, but do not specify the definitions of ideas. Depending on the task context, i.e., personal, academic, or professional, new ideas can be any planning or deliverables on the relevant topics and are information-based [30].

Creativity refers to the process that leads to generating ideas that are novel and useful [53, 55]. While the creative process has been conceptualized and defined in a myriad of ways across multiple disciplines, it is generally considered a non-linear and iterative process. For example, Wallas' four-stage model [60] suggests that creative thinking involves knowledge acquisition (preparation), unconscious information processing (incubation), emergence of the idea (illumination), and finally, evaluation of the idea (verification). Guilford's Structure of Intellect model [56] sees creativity as moving between iteratively generating multiple solutions to a problem (divergence) and effectively evaluating and choosing solutions (convergence). Stuart Pugh invented the Selection Matrix that decomposed design criteria to evaluate creativity of alternative ideas [49].

The creative thinking process has also been conceptualized in industry design practice as Design Thinking (e.g., Stanford Design School's Design Thinking framework [14], and British Design Council's Double Diamond [13]). This usually includes iterating between key stages of empathizing and understanding the problem, defining the problem, ideating solutions, and prototyping and testing the solutions. [14]. In this paper, we focus on ideation, i.e., generating, developing and iterating on ideas. One way creativity and its processes are taught is through experiential learning in project-based classrooms [21, 70, 71]. We observed design students while they were still in the early stages of empathizing with potential users and discovering information and had not yet started prototyping or testing their design concepts.

2.2 Web Search and Creativity Support Tools

Whether writing academic research papers, designing a building, or creating a new product – searching and exploring online is integral to creative work [68]. A recent review of the HCI literature on creativity support tools (CSTs) found that the majority of CSTs were developed to support the ideation stage of the creative process [17]. However, they did not characterized the general web search as a possible CST. Web search is currently optimized for lookup tasks rather than for tasks that require more exploration, learning, synthesis, and creative insight [2, 38, 50, 64]. By some estimates, creative workers, such as interaction designers, spent about one-fifth of their time, or one day each work week, searching

for and gathering information [12]. Therefore, it's important to gain a deeper understanding of how creators leverage the Web during their creative processes.

Creators have different information needs and goals during specific stages of the creative process [37, 68, 69]. For example, they search to find procedural information, domain information, finished examples, recommendations, and inspiration [68]. In the early stages of the design process, creators typically explore the information space of the topic to discover design patterns and criteria and find inspiration to plan and generate ideas [45]. With the exponential growth of online information and the rapid evolution of web search systems to include more generative AI capabilities, it becomes crucial to investigate how the information requirements of creative individuals are changing.

Prior work by the "search-as-learning community" has extensively studied user interaction with web search systems, particularly for complex informational [5] or exploratory [65] search tasks. Such tasks typically comprise three stages [1, 41]: *query formulation* (i.e., generating and refining search keywords), *search results triage* (i.e., determining which parts of the search engine results page – the SERP – are most relevant to the task at hand, and which link to open), and *information extraction* (i.e., gathering and making sense of the sought-after content).

Prior work has focused on the relationship between search behavior and information tasks, such as remembering, understanding, applying, analyzing, and evaluating, but not creating [28, 46, 66]. These studies report that as the cognitive complexity of the task increased, the amount of web search activity also increased in a correlated manner. Furthermore, these studies underscore that the community needs to better understand web search behavior during creative work in order to build more effective web search systems [51, 63]. Our study takes individual searchers' working problems and knowledge into context and examines how the search behaviors vary in corresponding to those.

In general, people searching the web face some common challenges, such as articulating information needs accurately [32, 45, 58]. To overcome this challenge, searchers often showed "active search" behaviors such as issuing multiple queries quickly and iteratively: issuing broad queries with context or information sources and adding specific terms later in the search session [3, 45]. Other studies observing students doing creative research suggest that students struggle to complete complex search activities that require advanced search strategies and mental capacities [25, 59]. These studies suggest that our concept of idea-centric search may present its own unique challenges and difficulties, as it requires iteration, cross-referencing and linking concepts, and serendipity. Our study uses a mixed-methods of not only analyzing search behaviors quantitatively but also tracking idea changes qualitatively.

With the rapid advancements in Generative AI models (GPT-4, Gemini, LLAMA, Midjourney, Make-A-Movie etc.) [6], we stand at a pivotal moment in the evolution of web and AI technologies where we can re-imagine such systems to better support creative activities. This study takes a first step by studying how people seek information online to shape their ideas, or vice versa, and how their evolving ideas affect how they search the Web.

3 STUDY METHOD

In this study, we investigate idea-centric search, i.e., how people seek information online to shape their ideas, or vice versa, and how their evolving ideas affect how they search the Web. the web search process for Confirmers did not lead to changes to ideas. We collected web search logs, pre- and post-study idea descriptions, and self-report reflections. We interviewed participants about their experiences and challenges when conducing idea-centric search.

3.1 Participants

We recruited 56 students from an introductory college-level project-based design course where they were working on a product redesign assignment. Some examples of products participants were working to redesign include video-conferencing chats, bike racks, earbuds, drink cans, digital calendar apps, mechanical pencils, etc. Students received 1% extra credit in the course grade as compensation for participation.

The 3-week assignment had three main stages: in the first week, students conducted primary user research by interviewing users of the products they had chosen to redesign. In the second week, students explored the web to conduct competitive analysis and develop their ideas (i.e. performed idea-centric search). In the third week, teams refined their idea, created sketches, and presented their redesigned products to peers. As we wanted to observe idea-centric search in a realistic and ecologically valid scenario, we observed students who signed up throughout a search session.

Since students were part of an introductory design course, the participants had little to no prior design experience. When asked to report their prior knowledge on their chosen topic on a scale of 1-5, where 1='no knowledge at all' and 5='know a lot', most participants reported some prior knowledge of the topic ($\mu = 3.6, \sigma = 1.12$). In terms of experience searching online, all participants reported extensive prior experience with web search, including using web search multiple times per day for at least five years. However, participants reported having less experience on researching multi-faceted topics, or ideating for a creative project, i.e. not searching frequently and not feeling confident in their search skills.

3.2 Procedure

To record web search activity, we developed a custom browser extension that automatically logs search queries, search results pages, and web pages visited during a fixed session (similar to [1]). To maintain transparency, the participants had the option to view their data logs in the form of a table or timeline visualization at any point by accessing the extension's homepage. To safeguard their privacy and give them greater control over their data, participants had the choice to delete log data before sharing it with the research team. All shared log data was automatically anonymized before being saved in our cloud database.

At the start of the 60-minute study session, the researcher explained the study procedure and guided participants through how to install and use the browser extension to collect, share and reflect on their logged activities. Participants filled out a pre-task survey that asked them to summarize their current thinking about the

[1] https://addons.mozilla.org/en-US/firefox/addon/history-master/

team's chosen topic in 3-5 sentences. They also listed any topic-specific terms and concepts that might be used during their web search session and rated their prior knowledge on the topic on a 5-point scale. This survey also captured their prior web search experience, prior design experience, prior domain knowledge, and information-seeking goals.

Then, each participant was given 30 minutes to search the Web and work on their idea. After their idea-centric search session, participants filled out a post-task survey where they were again asked to summarize their knowledge about the topic in 3-5 sentences, list any topic-specific terms and concepts that they had learned during their search, and rate their post-task knowledge on the topic on the same Likert scale. The post-task survey also asked participants to report any challenges faced and strategies used when using web search during this early-stage exploration. Finally, participants were interviewed for 10 minutes about their experience. This procedure and analysis plan was approved by our organization's institutional review board.

3.3 Data Analysis

We employed a thematic analysis approach to understand [10] participants' responses to (i) the survey questions to identify information-seeking goals, challenges faced, and strategies used during the task, (ii) the recording of post-task reflective interviews, and (iii) their thinking of evolving ideas from before and after the search activity . The interview recordings underwent an intelligent transcription, i.e. removed pauses, filler words, and made minor grammar adjustments. To identify user challenges, strategies, information needs, and influences of web search on idea development, two authors independently coded 10% of the participants' responses through open coding. The two coders then discussed the emerging themes and agreed upon a common vocabulary. Once similar codes and themes were identified across participants with few discrepancies, the two coders finalized the coding scheme and shifted to a focused coding approach. Then, they coded the remainder of the participants' data. To validate inter-rater reliability [52], we compared the independent coders' results from the focused coding. There was a 92% to 99% agreement level, which translated to a Cohen's Kappa score of 0.82 to 0.91 across all categories. We report on the coverage, i.e., the number of participants who mentioned a particular theme in the results. To understand search behavior, we calculated the number of queries issued and the number of unique web pages opened during the search session from their search logs.

4 FINDINGS

4.1 Four Patterns of Idea-Centric Search Behavior

To investigate how web search influences the ideation processes, the research team used a qualitative approach to analyze how participants' ideas evolved from before to after the web search session. Our analysis found that participants exhibited four patterns of how web search impacted ideas. Depending on the maturity of the initial idea and the information accessed during the web search session, we find that participants typically exhibited one of the following patterns:

- ***Orienters*** (n=6) started with problem-driven concepts and/or vague ideas and got oriented to domain information that helped them generate an initial idea.
- ***Refiners*** (n=30) started with vague ideas and found information on the Web that helped add concrete details to their ideas.
- ***Pivoters*** (n=13) started with a concrete idea, but came across information that motivated them to change their focus.
- ***Confirmers*** (n=7) also started with a concrete idea, but tended to focus on information that validated their initial idea.

4.1.1 Orienters get familiar with domain information. 6 out of 56 started mostly from problem-driven concepts and vague solutions and ended in a place where they were still formulating an idea. Compared to Refiners and Pivoters, the Orienters curated background knowledge but did not transform information to improve the ideas directly. Because of the status of their original idea, their search experience and goals focused more on curating information, which were different from who focused on refining and pivoting their ideas.

PID	Pre-Search Thinking	Search Queries	Post-Search Thinking
P31	redesign the **structure** of drink can	drink can redesign, redesign drink can, Existed redesign drink can	**curved tab**. The **shape** of the drink can. The **holding problem**
P34	redesign **packaging**	cereal box, pinterest, **annoying** cereal box design, **why** do cereal boxes have empty space, cereal box **annoying**, 90s cereal, **history** of cereal boxes, 1960s cereal boxes, better cereal box design, brown rice, **why is the cereal box always in a cardboard box, does recycling even reduce waste?**	I would go for a foldable cereal box

Table 1: Orienters P31 and P34 worked on redesigning drink cans and cereal box packaging respectively. Both of them started from vague thoughts and their search queries focused on the background information.

As shown in Table 1, P31 started from a vague thought that they were going to redesign the 'structure' of a drink can prior to the search. During the search session, they did not have concrete keywords to begin with, and became oriented to search the 'curved tab' (pull tab) of the drink can by looking into existing designs. By the end of their search session, in the post-survey P31 decided to focus on the 'shape' and the 'holding problem', indicating more concrete thinking around the problem space. P34 had not thought about how to redesign the cereal box redesign and primarily focused on searching for problems and background information using keywords like 'annoying', '90s', 'history', etc. They ended up generating an initial direction–a foldable box–for the solution. However, they were not able to develop a more specific solution with detailed features immediately, mostly because of their initial status and the type of information gathered.

4.1.2 Refiners incorporate existing solutions into their ideas. 30 out of 56 of the participants not only articulated a concrete notion of a problem, they also ideated possible solutions before our web search session. Refiners tended to find inspirational content from the web

search centered around their own ideas, and incorporate features into their iterated ideas. We describe this most common type of idea-centric search behavior as a 'refiner', as participants concretely refined their idea when answering how they would iterate their idea after the web search'.

PID	Pre-Search Thinking	Search Queries	Post-Search Thinking
P13	Changing the shape of the earbuds and making it easier for users to assess the **charge level** of their earbuds and case.	apple airpods, samsung earbuds, google earbuds, apple airpods 2nd generation vs 3rd generation, samsung galaxy buds, samsung galaxy buds case dimensions, apple airpods case 2nd generation, solar **charging** wireless earbuds, wireless earbuds **charge indicator**, raycon earbuds	I would incorporate the use of **air vents** into our redesign of earbuds since they seem to improve the level of comfort to the user. I would also improve upon the current systems to indicate **case charge level** to make it easier to gauge.
P41	Design something to lift the spam out of the container and make the edges not as sharp	spam can, **air tight** containers, **airtight** containers, **airtight** cans, can designs, **resealable** cans, **resealable** tin cans, toaster	I wouldn't make a spam can with a lid that requires a can opener. Instead I would make a lid that has a rubber **seal** or maybe a button to **release air pressure**.

Table 2: Refiners P13 and P41 worked on redesigning earbuds and Spam cans respectively. They searched concrete products or features, and borrowed concepts from existing solutions.

For example, in Table 2, P13 worked on redesigning earbuds, and searched for earbuds with brand/model names and specific features (i.e., solar charging, change indicator, etc.). During their research on existing solutions, they noted "air vents that balance the pressure in your ear and increase airflow - increases user comfort and fit" after viewing a specific product like 'Galaxy Buds Pro.' Later, they added 'the use of air vents' in their idea iteration. Prior to the web search session, P41 was thinking about how to lift Spam out of the can more easily and safely. After researching 'airtight cans', they refined their idea from a 'lid' design (what) to 'releasing air pressure' (how).

4.1.3 Pivoters discover new competitors or key barriers. 13 out of 56 participants reevaluated the specific focus of their idea after learning more during the web search session about the background, problems, and stakeholders behind their ideas. These participants shifted direction because they found content similar to their ideas and they perceived a lack of novelty compared to existing designs. Unlike the Refiners, Pivoters proposed new solutions immediately after the web search.

As shown in Table 3, P9 came in with an idea for how to redesign Snapchat, proposing a '1location/topic-based posting interaction". They started searching for existing problems with the current products and then similar features in different competitive products. During this research, they revisited their original idea and raised concerns about its safety and for broader stakeholders like "international communities" in the post-search thinking. P22 proposed an initial solution to redesign Zoom Chat - making the chat window more easily accessible with bigger buttons and separate windows. Similarly, they also searched existing usability issues and many competitors. They started by researching different competitors and then looked into the usability issues and user scenarios of their product choice and features in other competitive products. Through the web search process, they pivoted to focus more on designing

PID	Pre-Search Thinking	Search Queries	Post-Search Thinking
P9	We want to make location/topic based communities for people to post to and discuss in.	snapchat issues, snapchat reviews, messaging apps, top social media apps, spotify social media, spotify social media removal, did spotify have social media features, wechat moments, wechat moments, WeChat features, **telegram** photo sharing, whatsapp **telegram**, imessage photo sharing	I think maybe I would put more emphasis on **Safety**, as well as think about the international community and how they might receive features.
P22	A zoom redesign that includes bigger buttons and separate windows for each chat	zoom competitors, zoom competitors programs, zoom chat problems, zoom chat errors in user, zoom chat redesign, why is zoom better than competitors, zoom for school, how is zoom good for school, how to make zoom more interactive, zoom chat hidden features, zoom chat user design, zoom chat, how to make zoom easy to use, google meet chat features, google meet private message, skype view chat and video call, what are common problems people have with zoom, how to fix zoom chat design, zoom chat **not engaging**, peoples **favorite way to message**, best app for messaging	I feel like we focused too much on usability and *oversighted* how to convey people's feelings. I would re-design to add something that promotes **conveying emotion** better during video interactions.

Table 3: Pivoters P9 and P22 worked on redesigning Snapchat and Zoom Chat, respectively. They started with concrete features and ended up in revisiting the problem they wanted to solve.

for emotions than usability without proposing a specific solution because they learned the problem that users were not able to convey emotions during search.

4.1.4 Confirmers keep ideas without adding details. 7 out of 56 participants stuck with their original ideas or intentionally kept those. Unlike Refiners, Pivoters, and Orienters, the web search process for Confirmers did not find information that led them to change or even refine their idea. Instead, they felt they had confirmed the uniqueness of their ideas.

As shown in Table 4, P7 proposed a specific map-based networking idea for Snapchat. They first searched for similar features in general, and then soon switched to checking whether this specific feature already existed in their product and whether the feature had existed for any products at all. Because the participant did not find their desired feature in the product, they concluded that the idea was unique and did not require changes. Prior to the web search, P49 had proposed a specific solution for bike racks that was a combination of many features. After searching popular products and products with specific features, they did not find their specific feature list. As a result, they also concluded that their idea was unique and ready without any changes.

4.2 Web Activities During Idea-Centric Search

Overall, we observed participants exhibiting a range of search strategies and accessing a variety of sources when probing for information that could inform their work-in-progress idea. On average during the 30-min search period, participants issued 8.2 unique search queries (σ = 5.4) with a length of 12.4 characters

PID	Pre-Search Thinking	Search Queries	Post-Search Thinking
P7	Build within the app a feature where you can connect with new people through forums, similar to discord and reddit, using the **snap map** that is already featured on snapchat.	friends connection on social media, snapchat meet new friends, snapchat meeting new friends, **have users stopped using snapchat**, **why has snapchat not incorporated community building**, **why is it hard to meet new people on snapchat**, what made snapchat so popular	No I would not (change my idea) because there aren't any similar ideas to the idea we came up with.
P49	We to redesign the bike racks to have a built-in **solar-powered light**, built-in **mechanical lock**, **control panel**, **smartphone app**, slimmer **racks** to reduce crowdedness	common bike **racks**, bike **rack** pros and cons, public bike **racks** pros and cons, Best 4 bike **rack**, Best 4 bike **rack** brands, Best 4 public bike **rack** brands, Best 4 public bike parking **racks**, Best 4 public bike parking **racks**, bike rack with **solar powered lights**, bike **rack** with **mechanical lock**, bike **rack** with **mechanical lock** and **smartphone app**, Bike **rack** with **built in lock**, preventing bike theft, latest bike **rack** designs, latest bike **rack** redesigns, best public bike **rack**	I think there wasn't many new ideas that popped up during my search.

Table 4: Confirmers P7 and P49 worked on redesigning SnapChat and bike racks, respectively. They also started with concrete features but decided to keep their ideas after search because no new inspirational information surfaced.

(σ = 5.2 *chars*), visited 27.6 webpages (σ = 16.0), and spent 1.1 minutes (σ = 4.5 *seconds*) on each webpage.

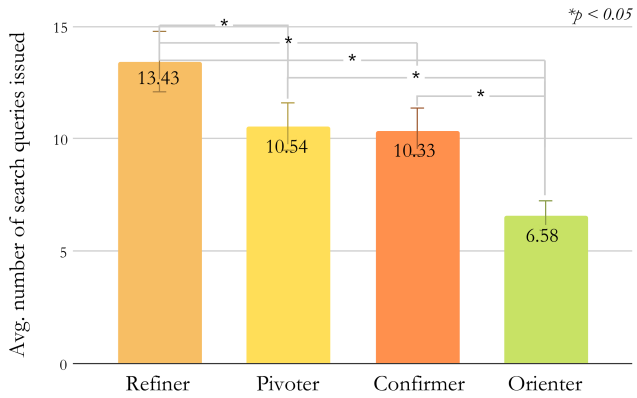
4.2.1 Some participants leveraged diverse information resources. While most participants leveraged classic text-based search engines that yielded text-based results, some participants (10 out of 56) appreciated multi-media search results. Participants noted that the different formats of search results such as text, images, and video can be useful for different purposes. P56, a Refiner, said:

> "I tended to look first on Google images to scan through the products, visually looking at their features and seeing if something unique caught my eye. ... If there were very specific products I was interested in, I would try to find a video of how they would be used."

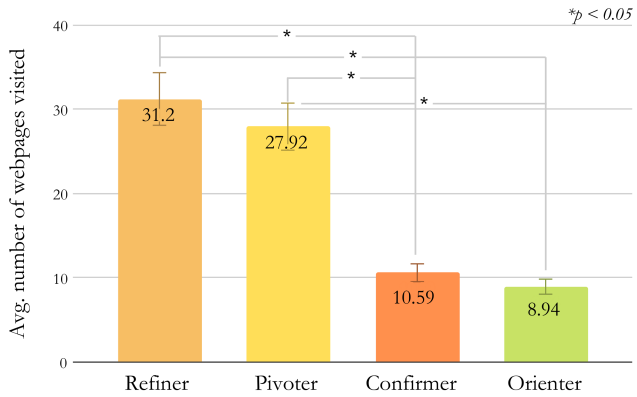
Participants often looked for 'hacks' and tutorials to gain a better understanding of the competitive landscape. For example, P38 got inspiration from videos showing techniques for removing Spam from the can and related it back to their ideas, saying:

> "[I] went on YouTube to see how people get Spam out of the can with the existing packaging. And then there was one guy who pressed on the sides of it and then it comes out automatically. So then I thought that, maybe instead of having a pushing mechanism, we just need a better signifier of where people should be pressing on the can."

Several participants mentioned specific platforms in search queries, i.e., 'Reddit' or 'Amazon reviews', as a way to crowdsource secondary field research on the user experience of a specific product. P18 used it as a way of researching "specific, more niche communities to guide my search. For example, the Reddit page for mechanical pencils was very useful in my research, as well as written guides with tradeoffs of different materials and grip." P54 looked "into the



(a) Refiners issued the most search queries while Orienters searched the least, compared to Pivoters and Confirmers.



(b) Refiners and Pivoters, who changed their ideas, visited more webpages than Confirmers and Orienters who did not iterate their ideas.

Figure 2: The four patterns of idea-centric search exhibit differences in the numbers of (a) search queries and (b) webpages visited.

Amazon reviews of brands (their previous) interviewees used and looked for pain points, likes, and dislikes from reviewers." Each individual query and search result offered participants opportunities to explore their product redesign space, to find inspiration for features, or to dive deeper into competitors.

4.2.2 Refiners issued the most queries, while Orienters searched the least, compared to those who had concrete ideas. To understand how search behavior might relate to different levels of impact the creators' process, we ran ANOVA tests and post-hoc Tukey's HSD test comparing search metrics of participants across the different impact groups. Each type of searcher shows different characteristics in search behaviors and patterns in idea iteration. This analysis finds a significant difference in the number of queries issued for the different types of impact on the creators' process ($F(3, 52) = 2.99, p < 0.05$, Fig. 2a). Post-hoc analysis of interaction effects shows Orienters issued significantly fewer queries than those who refined, pivoted or confirmed their ideas ($Q = 3.75, p = 0.05$).

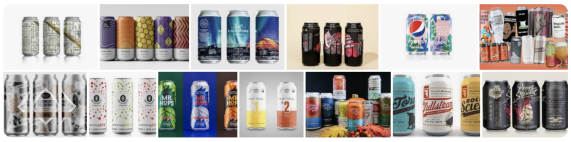
4.2.3 Refiners and Pivoters visited more webpages. There was also a significant difference in the number of webpages visited across the different types of impacts on the creators' processes ($F = 3.70, p = 0.03$, Fig. 2b). Post-hoc analysis of interaction effects shows that participants who were still orienting in the design space visited significantly fewer webpages than those who pivoted ($Q = 4.01, p = 0.04$) or refined their ideas ($Q = 4.29, p = 0.02$). Furthermore, those who pivoted ($Q = 3.92, p = 0.05$) or refined ($Q = 3.77, p = 0.05$) their ideas opened significantly more webpages than those who just confirmed their idea.

4.3 Challenges Faced During Idea-Centric Search

We observed that participants encountered four key challenges during idea-centric search occurring during the process of query formation (C1, C2), and search results triage (C3, C4).

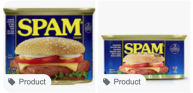
4.3.1 C1: Participants struggled to articulate their complex ideas in query format. One of the most commonly mentioned challenges was that (C1) participants knew the existence of the knowledge but did not know the language to describe it, finding it hard to formulate their information needs into concrete queries. For example, P40, who was researching 'Spam cans', struggled to articulate queries to access information they felt existed: "I struggled with not being able to come up with comparable designs *that I already know about or have seen*." P43, who was searching for information related to suitcases, said, "it is hard to search because I didn't know a specific term ('duffle bag'). I tried to search for related things ('suitcase' and 'travel backpack') to try to recall the right terms to convey what I was looking for." Even when participants knew the domain-specific keywords, many still did not know how to best formulate queries to get desired results. As P29 said,

> "Because I can't think of *how to phrase a question*, I use individual keywords ('Discord notifications', 'Slack notifications vs Discord notifications'). When I scan the webpages after the search, I am looking for relevant signals on my particular topic, but I am mostly looking for *a better-stated question* (i.e., 'How to Bold in Discord')."



(a) Top search results for 'can designs'

(b) Top search results for 'tin can'



(c) The product to redesign: Spam can

Figure 3: A set of P41's queries and search results, which shows how they moved from brand-specific to more general ways of accessing related products.

P41 was looking for different can designs to redesign Spam cans. They decided to search for related designs ('can designs'), but that only led them to find more soda cans and view a diverse array of soda can labeling designs (Fig.3a), which was not inspirational for rethinking the mechanical properties of a can. P41 was hoping to find diversity in functionalities, shapes, or opening mechanisms:

> "At first, I started off with looking up Spam container, Spam can, just see what it looked like again. And I searched 'can designs', but then that brought up different labeling designs. So that didn't really work. And then I had to rephrase it and I just looked up 'resealable tin cans'. When I searched 'resealable cans', soda cans came up, and that also wasn't what I was looking for. When I did 'tin cans' that finally worked."

Both 'can design' (Fig. 3a) and 'tin cans' (Fig. 3b) should represent a variety of product designs. However, the diversity in search results for 'can design' only resulted in different brands and labels, whereas 'tin can' gave differences in shapes and materials. In this participant's case, the design goal was to revamp Spam cans' functionality and opening mechanisms, but the diversity in the 'can design' results was not as useful as the 'tin can' results, which gave participants alternative ways of thinking about the functional design of the Spam can. Notably, the generic term did not yield the desired diversity in results, but focusing on a specific dimension (e.g., 'tin') can unlock variety, in this case, of different container shapes and mechanisms for opening the can.

4.3.2 C2: Participants were not aware of what they did not know. Yet the fundamental reason of query formulation difficulties may comes from that (C2) participants lacked the domain knowledge to learn the existence of potentially useful information. P38 mentioned that "most of the challenges just came from my own *idea block* and *not being able to think of anything else*." Several participants expressed that they ran out of ideas and felt they had exhausted their search queries in the process, as P53 mentioned "towards the end I ran out of queries and *was stuck on* what else I wanted to search for." Compared to the previous challenge where participants had knowledge but struggled finding the right queries (C1), the lacking knowledge discouraged participants from making more searching efforts.

4.3.3 C3: Search results do not emphasize details important in creative context. Many participants looked for certain type of information, but (C3) the current web search did not surface or interpret the results with emphasis on the implicit details that users desired, e.g., design artifact details, case studies, problem-driven discussions, etc. Often participants needed to dig to find any information related to their redesign. When P34 searched 'cereal box redesign', the results were mostly on "the *marketing aspect* of the actual box" rather than "the *functionality* of new features that they would put on the box."

P19 searched four highly similar queries in series ('zoom chat redesign', 'zoom chat redesign case study', 'zoom chat case study', 'zoom chat case study redesign'), hoping to find a well-suited example of how to fulfill their product redesign. After the search period, this participant said:

> "When I searched for 'redesigns', there weren't many I could choose from, because a lot of designers who

> have redesigns on their websites use designers' name as the primary search keyword rather than the product or idea content ... Because I didn't know the specific names for redesigning in a UX/UI context, I had a hard time searching 'zoom chat redesign case studies', and only a few popped up."

A few participants attempted to get design inspiration by probing at the problem, but compared to design solutions, websites tended to give less detail about the underlying problems. P2 worked on redesigning seatbelts and searched for the fumbling activity and the stuck problem as an attempt to find information related to seat belt usage problems. They claimed:

> "I couldn't find people running into the same 'fumbling' activity (unable to fit the seatbelt tongue with the buckle) online, so I just transitioned to researching the next problem. "

P27 also seemed to explore the problem space for their product redesign on digital calendars by issuing a series of short problem-related queries, i.e. '[Brand] Calendar deficits' and '[Brand] Calendar inconveniences'. However, the participant mentioned that they "looked over a few articles there at first, but some of the information is irrelevant, and couldn't really be used (to apply to my redesign)."

Participants wanted to access problem-driven discussions from other formats like case studies, but as one participant working on redesigning a virtual meeting chat noted: "I thought (the 'case study that had issues') could be interesting to look at if they could potentially be 'problems' with our redesign." Information about the underlying problems behind products seemed harder to find or required the designer to really stretch to make connections to their product.

4.3.4 C4: Participants found results to lack diverse inspiration. With the goal of searching for inspiration, participants looked primarily for diversity among the solutions they found: either some product that seemed to be an outlier among existing solutions or some solution that deviated significantly from their own idea. When there are so many similar ideas addressing the same problems, participants looked for out-of-the-box ideas and tried to identify what makes them unique. The challenge that many participants encountered was that (C4) search results often looked homogeneous for inspiration. P30 speculated that "(since) there's a standard for all competitors to have the same design for drink cans, it is harder to do a competitive analysis in that way." P34 echoed that their chosen product to redesign (cereal boxes) "have not changed in the last hundred years and people are very used to how they are designed." P42, for example, explained how he looked for alternatives or different types of Spam cans that he would be "scrolling down the list forever until I saw something interesting" because "all competitors looked the same". When creators look for competitors, the goal is not only understanding what those are but also leveraging the knowledge of competitors to improve their own ideas. Locating a bunch of homogeneous competitors was not sufficient for inspiration.

For example, the log data showing that P55 searched for 'detachable clamp curling irons' (see Fig.4a) and 'detached clamp for curling iron' seconds later, before changing their query to 'removable clamp curling irons' (see Fig.4b) in hopes of finding useful and diverse information. The wording nuances seemed to yield more diverse results (see Fig.4).

(a) Top image results for 'detachable clamp curling irons'

(b) Top image results for 'removable clamp curling irons'

Figure 4: While most of the image results on the left look similar, there were clear visible differences in color, size, number of curling wands, etc. Notably, 'removable clamp curling irons' yielded more different results than 'detachable clamp curling irons'.

5 DISCUSSION

Our paper explores this notion of idea-centric search to investigate how web search and idea development influence each other, we conducted a mixed-method study with n=56 design students who searched the Internet to help iterate on their existing ideas. From analyzing search logs, interview transcripts, and qualitative survey responses, we identified four patterns of idea-centric search that varied depending on the idea maturity — Orienters, Refiners, Pivoters, and Confirmers. We also discovered four key challenges that users faced when formulating queries and triaging the search results. Based on our findings, we discuss design implications and potential future research directions for idea-centric search.

5.1 Scaffold idea-centric search based on idea maturity

Our findings suggest that information goals, search behaviors and search results differ depending on whether a creator's initial idea is vague or concrete. Orienters typically started with a vague idea, and therefore, focused more on learning the domain and developing a more concrete direction for their idea. With a slightly more concrete initial angle, the Refiners searched and found inspirational information that allowed them to add details to their idea. Creators who had the most concrete ideas tended to be Pivoters and Confirmers, depending on the information accessed during search. Pivoters got new information to switch problem focus, and Confirmers did not find similar ideas so locked in on their initial idea. Although Confirmers did not update their idea, they still benefited confirming the uniqueness of their idea but also showed a potential for confirmation bias [43].

Each pattern exhibited different search behaviors. For instance, Refiners searched the most queries and visited the most web pages on average. Pivoters and Confirmers searched the moderate amount

of queries but Confirmers, who did not change their ideas, visited significant less web pages. Orienters who also visited less web pages, even searched less queries to begin with. Our paper underscores the potential of situating search behavior within the creative process to inform more effective search tools and interventions.

Based on these findings, we propose that *information search systems could be tuned to better support creativity by suggesting tailored search paths by accounting for the states of an idea.* Advances in NLP and LLMs have made it possible to interpret language, even in a vague sense [34], which could potentially help predict how concrete or vague is a user's idea. The search experience could be adapted to users' situations, depending on the specificity of the initial idea. For creators who only start with vague or no ideas like Orienters, we can potentially suggest more background information on the problem area[8]. Instead of using auto-completion to complete a user's query, LLMs have shown potential to reconstruct vague and fussy ideas into more structured, fluent thoughts to help them think [4, 67].

For creators who already have concrete ideas like Pivoters and Confirmers,the search results pages could highlight more existing solutions and competing ideas so they can confirm the uniqueness of their ideas, realize limitations of existing solutions, or integrate features from the existing solutions [31, 54]. For users who are ready to engage with specific details of a problem, showing how other users searched and curated could highlight more design specifics [9, 31, 35].

5.2 Support active querying by understanding users' intent

The major challenges for query formation may be due to the 'known unknown' (C1. Lacking vocabulary), or 'unknown unknown' (C2. Lacking knowledge). To address the challenge that creators lack terminology (C1), we propose that search systems may suggest alternative phrases to modify creators' existing queries. The alternative suggestions may not share the exact same meanings or always co-occur with the existing keywords, but they may be assembled with similar contexts across different domains [7, 16]. Furthermore, the search systems may understand users' intent more to seek analogical concepts in their intended field [7]. Understanding creators' intent may make more precise queries.

To address the challenge that creators do not have domain knowledge (C2), the search system may suggest potential related domains that have analogically similar definitions. As suggested from prior literature on analogy mining for inspiration, searching adjacent solution spaces can help expand thinking by mapping the structure of problem-solution pairs [18, 22].

Another strategy for future search systems might be to provide an interactive overview of the landscape of the information space (using LLM-generated summaries or table of contents), and highlight what the user has already explored and direct attention to what has not been explored yet. Existing search engines have started implementing AI-powered overviews [19, 48] to synthesize web search results. This could be extended by combining generative AIs with creators' intent closely to create more *user-centered* AI-powered overviews.

The web content recommendations are often based on a user's profile and search history, but they lack the internal knowledge of users or what users are working on [11, 33, 47]. Some new emerging LLM-empowered tools aim to help users understand complex work, and potentially complement local knowledge bases with web resources [42]. Suggesting common questions is powerful when users hold general questions. However, when the problems become more unique and individualized, the suggestions may be not as helpful. Potential future work directions for addressing C1 and C2 involves understanding users' working context and helping them articulate their specific information needs.

5.3 Present search results aligning with creative information seeking goals

The next challenge from idea-centric search is finding information with emphasis on implicit details that are not surfaced by traditional search (C3). Creators would especially benefit from seeing problem-centered discussions, case studies, example galleries, etc., presented in a way that supports different ideation goals. Current search results are not presented in the way that creators would use for idea development. To help structure queries to adapt to multimodal input, search systems may enable users to query semantically meaningful parts of images, videos, and other multi-modal information resources [40]. Designers might want to integrate inspirational resources, such as searching for specific products by recognizing material textures in other images, so that they do not need to use specific language for keyword searches.

As for the challenge of providing a diverse set of search results for inspiration (C4), search algorithm could be tweaked such that they toggle between retrieving just relevant information to provide not only relevant but also semantically diverse search results, based on the status of ideas – this could include techniques like analogical search, or search along design dimensions rather than just keywords [18, 22–24, 29]. Creators at the Refining and Pivoting stages may benefit from divergent thinking to improve their ideas. Creators at the Orienting and Confirming stages may benefit from finding information that helps them ground ideas. Thus, the search algorithm can toggle to find more relevant information than unorthodox and but stimulating results.

5.4 Explore idea-centric search patterns in other domains

Our study used design project ideas as a springboard to study the relationship between idea status, information need, and web search behaviors. Creative work can extend beyond ideas and exist in more formats or domains, for example, sketches of visual designs, illustrations of mechanical designs, descriptions of conceptual designs, etc. Idea formats beyond text may need various means to assess their maturity (for example, computer vision to categorize sketches), but our findings that the information goals vary depending on the maturity of ideas leading to the idea iteration can still hold true.

Even though our study focuses on project idea development, the results can be potentially applied to any other domains centered around one's work progress, e.g., literature research, code debugging, etc. Analogous to our Orienter, Refiner, Pivoter, and Confirmer patterns, academic paper writing may show similar search patterns:

Orienting to background information to scope the writing project, and later Refining their knowledge or Pivoting to new unexpected topics, and eventually searching to Confirm or validate key arguments. Similarly, the programmers may decide on the program infrastructure, find existing functions, debug, or optimize existing solutions, depending on the stage of work. Future tools that can monitor the work status and integrate information-searching at different stages in a workflow.

As for a more direct real-world implication, project-based classes could benefit from providing more advice for leveraging secondary research throughout the creative process. Secondary research with the web is a common practice complimenting primary user studies. Based on our observations in the project-based learning setting, we recommend students conduct light amount of secondary research frequently whenever the idea changes or new thoughts come up, whether moving forward or backward with their ideas, rather than compiling secondary research all at once after the idea becomes concrete. The initial search may help the students sync with online knowledge and with each other to begin brainstorming. Later in the process, search may help students confirm and validate the uniqueness of their ideas, prevent "reinventing the wheel", and give shape to the implication details.

5.5 Limitations and Future Work

It is worth noting that we only used the default Google search system in our study, although we do not expect big differences in performance between major search systems or their impacts on the research questions we investigated. Future work could investigate how users' mental model of web search gradually changes over the time, especially as chat-based AIs become more prevalent.

This paper studied intro design students doing a product redesign. Our study population was mostly design students, not experts in design. Interestingly, professionals can still learn new domains and be considered novices, and conversely, amateurs can develop a deep understanding of specific issues and be considered as experts in their own topic. Exploring how search patterns vary across different expertise levels could enrich our understanding idea-centric search.

We also acknowledge that our study was conducted under specific constraints on time and assignment goals. The search sessions represented a small time snippet of the whole design project. We tracked web searches and idea iterations but only for a fraction of the process. Our study allowed us to observe the relationship between web search and idea development in a more controlled environment. In the future, more longitudinal studies with creators in the field can be conducted to investigate idea-centric search in the wild.

6 CONCLUSION

In summary, this web search study with participants in the context of a produce redesign assignment attempts to investigate the influence of using the web as an additional source for inspiration and developing individuals' ideas, and vice versa. Through our analyses of interviews, surveys, and search logs, we present how participants searched based on their ideas and how the web search is associated with idea iterations. Further, we discuss the opportunities for designing a better idea-centric web search experience and the pedagogical strategies of using idea-centric web search to support creativity.

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