

PrivacyToon: Concept-driven Storytelling with Creativity Support for Privacy Concepts

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Figure 1: PrivacyToon facilitates the authoring of comics about privacy concepts. It leverages the concept-driven storytelling process that has three stages (concept → story → comic) and offers ideation cards to support ideation in each stage.

ABSTRACT

With privacy-related concepts often abstract and difficult to define, comics can be an effective visual storytelling medium for explaining and raising awareness about privacy. However, existing privacy and security educational comics do not support content creation. To address this, we contribute PrivacyToon, a comic-based authoring tool that leverages concept-driven storytelling and ideation cards to help users create customizable privacy-related visual content. Our exploratory user study with 23 students and teachers shows PrivacyToon's potential as a creative tool for communicating privacy concepts and stories. Our results show that a wide range of creativity preferences and contexts must be considered when designing systems that integrate ideation card-based design processes.

CCS CONCEPTS

• **Human-centered computing** → **Interactive systems and tools**; • **Applied computing** → **Interactive learning environments**; • **Security and privacy** → **Privacy protections**.

KEYWORDS

authoring tool; concept-driven storytelling; concept-driven comics; privacy and security education

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1 INTRODUCTION

Young people's online interactions transpire over the Internet more than ever due to increased access to technology and near-constant use of the Internet both at home and at school [6]. Amid growing concerns over various threats to their privacy, efforts to teach basic privacy and cybersecurity concepts to improve their awareness of online risks and understanding to help them secure their personal information have grown in recent years and have led to privacy and cybersecurity lessons becoming a mandatory part of the curriculum (e.g., [21, 22, 35]). For explaining privacy and cybersecurity concepts to students, comics has been a popular medium, as it leverages visual storytelling to present abstract topics and technical ideas in an engaging and accessible manner. Previous work on cybersecurity educational comics, for example, demonstrated that it can improve lay people's digital literacy skills and mental models of privacy and cybersecurity [48]. However, with existing tools, it is time-consuming to create educational comics. Moreover, they are not designed to be customizable to capture evolving threats and new topics of interest. Further, they do not engage users in the creative process of constructing content to communicate and reflect on their understanding of the concepts.

To address this gap, we developed PrivacyToon,¹ an authoring tool that supports the creation of privacy comics and visualizations. PrivacyToon is designed with creativity support tailored to privacy concepts to trigger ideas and reflection during the creation process.

¹<https://privacytoon.github.io/>

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The hands-on tool enables free-form drawings and offers creativity support that augments the *concept-driven storytelling* process with a guided concept → story → comic design process. Creativity support for privacy concepts is beneficial because privacy can be abstract and highly individualized [34]. Creativity support could assist users in creating more expressive comics tailored to their understanding of privacy. From an educational perspective, the comic medium's visual narrative and illustrative capabilities can help enhance users' mental models of privacy and support the communication of privacy stories [39, 46, 49, 50].

We conducted an exploratory, within-subject study to assess the usability and creativity support capabilities of PrivacyToon and its potential as a creative tool for teaching and learning about privacy. We recruited 18 students and 5 teachers to use PrivacyToon to create two comics based on two lessons in the Teaching Privacy Curriculum [16] without and with creativity support. We selected material from this curriculum because it was created to aid teachers in providing actionable advice on how to protect personal privacy online to high school and undergraduate students. We found that people have different levels of creativity support preferences. While many preferred to be guided through the concept → story → comic process to organize and structure their thoughts and use ideation cards for brainstorming the comic's topic, narrative, and visuals, others preferred the freedom of free-form content creation. Our participants created a dataset of 46 comics, downloadable online.²

This paper makes four main contributions. First, the design of PrivacyToon fills a critical gap in cybersecurity educational tools literature—the lack of a customizable authoring tool that enables users to create their own visual content to communicate, teach, and document their understanding and conceptualizations of privacy. Second, we combined usability and creativity evaluations to show that users have different preferences and needs for creativity support tools and suggest that creativity support features should provide users with options to enable and disable them. Third, we contribute a design artifact that shows how the ideation card-based design processes can be integrated into a digital authoring tool. While ideation cards (or ideation cards combined with a particular design process) have been used in many prior works in a physical setting to support design processes [10, 12, 14, 20, 28, 31, 43], there has been little, if any, work to integrate them into a digital tool to support creativity. Lastly, we contribute a preliminary list of design dimensions for privacy comics based on the qualitative analysis of the comics created from our user study.

2 RELATED WORK

In this section, we summarize prior work on visualizing privacy and cybersecurity concepts, comics in cybersecurity education, and comic authoring tools.

2.1 Visualizing privacy and cybersecurity concepts

Since privacy and security information can be complex and difficult for laypeople to understand, researchers [13, 34, 40] have proposed visual methods to gain insights into the experts and non-experts' conceptualizations of privacy and security. Oates et al. [34] utilized

²<https://privacytoon.github.io/download/>

user-generated drawings to identify laypeople, experts, and children's mental models of privacy, and found recurring imagery. For example, experts' visual conceptualizations of privacy depicted online data spaces, while non-experts' drawings frequently illustrated physical public and private spaces [34]. Sturdee et al. [40] used a similar sketching method to analyze participants' understanding of cybersecurity concepts and found salient facets of imagery regarding risk, privacy, trust, and cybersecurity. In related work, Friedman et al. [18] used drawing tasks to illustrate the participants' understanding of web security and found that people associated simple visual cues like a lock icon and the presence of HTTPS with a secure connection. Kang et al. [25] provided insights into users' mental models of how the Internet works and the related privacy and security risks through user-generated conceptual diagrams. Visualization methods were also used for studies with vulnerable populations like older adults (e.g., [37]) and children (e.g., [34]) who might have difficulties articulating technical concepts through words due to their limited exposure to technology. For example, Ray et al. [37] examined older adults' perceptions of privacy in digital and non-digital contexts through drawings of their sense of privacy. While sketching is a valuable method that can visually capture users' conceptualizations, participants with poor artistic skills could be uncomfortable with free-form drawing using pen and paper [37]. Further, there could be a disparity in the level of detail in the drawings produced [37]. Through PrivacyToon, we aim to address the limitations of pen and paper by providing a digital tool that facilitates the drawing process with creativity support (concept → story → comic design guidance and ideation cards) and technical drawing support (e.g., stencils).

2.2 Comics and Cybersecurity Education

Prior research [39, 46, 49, 50] showed that comics could be an effective visualization medium for making privacy and cybersecurity topics more approachable and engaging. Comics juxtapose images and text in sequence to convey information, which helps facilitate the explanation and expression of complex and abstract concepts to a variety of audiences [50]. For example, comics have been used to teach programming concepts (e.g., [42]), scientific concepts (e.g., [32]), health issues (e.g., [23]), and cybersecurity (e.g., [39, 50]) because they increase comprehension and support memory retention [24]. Comics combine techniques from information graphics, visualizations, and other forms of visual explanations to make the presented ideas and information engaging and more straightforward for audiences to understand and recall [44]. Comics is also a familiar and iconic medium for all ages, making it accessible to a wide variety of individuals from diverse backgrounds. Further, the medium is well established across cultures, and it possesses set visual conventions that are intuitively translatable into an online format [29]. Thus, comics is an accessible and flexible medium that can be catered to communicating various topics, including privacy and cybersecurity.

Cybersecurity-related comics were developed in several formats for a variety of audiences, including (non-interactive) comic strips (e.g., [39]), graphic novels, and interactive comics and narratives

(e.g., [27, 50]). Secure Comics [50], for instance, are interactive web-based comics that enable users to see additional information by placing their mouse over images or text. Similarly, Cyber Chronix [27] presents comics in the form of interactive narratives, allowing users to make choices to impact the storyline. In comparison, Security Cartoons [39] are non-interactive online comic strips for educating users about various Internet risks. However, a review of cybersecurity educational tools [50] highlights that existing tools can quickly become outdated due to rapid technological change and evolving online threats and cyber attacks. Further, only one out of the nine existing comics for cybersecurity education was evaluated with users and adapted for classroom use [50]. Addressing this issue, our work is the first to introduce a highly adaptable authoring tool that enables rapid user-driven creation of comic strips to support teaching and learning of privacy concepts.

2.3 Comic Authoring Tools

General-purpose comic authoring tools support comics creation digitally. Pixton [4], for instance, is a commercial comic authoring tool used by universities and secondary schools. Storyboard [2] offers similar features for comics creation in digital form. Comicgen [3] provides an interface for creating comic characters using pre-defined images and poses but requires users to create the entire comic from another software, such as PowerPoint. The research community focused on developing authoring tools for specific types of comics. For example, researchers have developed several authoring tools for data comics [26, 51], a form of comics conveying insights about data. Zhao et al. [51] developed a web-based authoring tool DATACOMICSJS (Fig. 2a) as a Google Chrome extension that allowed users to capture visual clippings from any web page to use them as stencils for comic panels. The tool also allowed users to add comic stencils (e.g., captions, speech bubbles) and manage the layout and size of panels making up the comic but did not support free-form sketches (drawings). DataToon [26] addressed this limitation by enabling users to add their sketches and manipulate the layout and panels using pen and touch interactions. Our tool builds on these works—supporting the ability to add stencils and free-form drawings to assist the composition of comics—and extends them with the concept → story → comic design guidance and ideation cards that prompt moments of critical reflection during the comic creation process.

2.4 Creativity Support for Comics

While all creative processes require brainstorming ideas [7, 43], the design process for comics requires creators to brainstorm the narrative and design ideas specific to the comic medium, such as textual devices like speech balloons, captions, sound effects, and other visual symbols to indicate dialogue, narration, and other types of information. In addition, they need to decide on the size, shape, and placement of panels, as they control the narrative flow and pacing [17]. The myriad of design possibilities makes the medium highly flexible and expressive but at the same time makes designing comics challenging and overwhelming for those with no creativity support and little to no experience in creating comics.

Creativity support tools for comics include authoring tools [26], design patterns [7], adaptive conceptual guidance [33], and ideation

cards [43]. Bach et al. [7] proposed design patterns for data comics to map out the design space for data comics and support its design process. However, their work did not outline a design process for data-driven comics. Ngoon et al. [33] explored adaptive conceptual guidance that presented conceptual examples in-situ of users' drawing tasks and found that it helped users create comics with more unique stories and clearer drawings. Though the paper demonstrated the potential of adaptive creativity support through a visual, sketching-based context, the tool used in the study was a Wizard-of-Oz prototype that did not provide example templates and drawing help. Therefore, the tool addressed novice users' lack of conceptual expertise but not their lack of drawing expertise. On the other hand, the concept → story → comic design process (Fig. 3) proposed by Suh et al. [43] for concept-driven comics about programming concepts suggested both drawing support and a set of ideation cards (cf. Fig. 4)—trigger, scenario, and design cards—to fully support the comic design process. Trigger cards contain questions to help brainstorm ideas on things to talk about for a given programming concept; scenario cards show instances related to core narrative elements—settings, conflicts, characters, and actions—to help brainstorm ideas for a story that illustrates the concept; design cards display design patterns for programming concepts. Our work builds on this work by incorporating its creativity support framework—i.e., concept-driven storytelling procedure coupled with ideation cards—and extends it by implementing it in a digital format. By leveraging this framework in creating comics about privacy concepts, our work also demonstrates how this framework can generalize to creating concept-driven comics about concepts in other domains.

3 DESIGN OF PRIVACYTOON

We first review our four design objectives for our authoring tool based on our review of prior work in cybersecurity education and creativity support for comics, then showcase PrivacyToon. PrivacyToon was developed as a web application with the back-end implemented in Django and MongoDB and the front-end implemented with HTML, CSS, and jQuery. The drawing canvas was created using the open-source drawing tool, Excalidraw.

3.1 Design Objectives

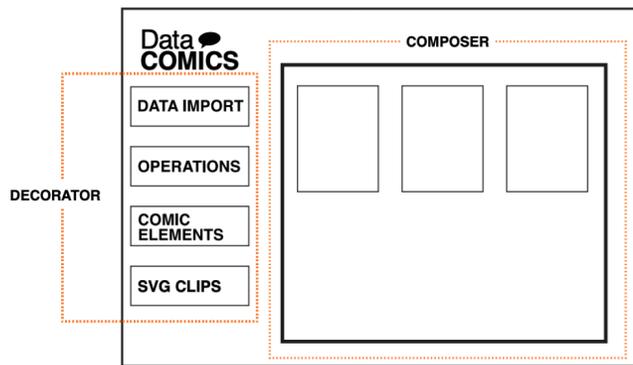
01. Facilitate Concept-driven Storytelling. In concept-driven storytelling, a user selects and reflects on the defining attributes of a concept, generates a story that explains this concept, and finally presents it in the form of comics. This design process helps users create a concept-based comic that explains the concept [43]. Thus, the first objective in the design of PrivacyToon is to facilitate this process to create concept-driven privacy comics.

02. Enable Ideation Cards Filtering. While increasing the number of ideation cards could mean more opportunities for users to be more creative, too many cards could also overwhelm and overburden users with information [43]. Thus, our second objective is to include a filter feature for the ideation cards.

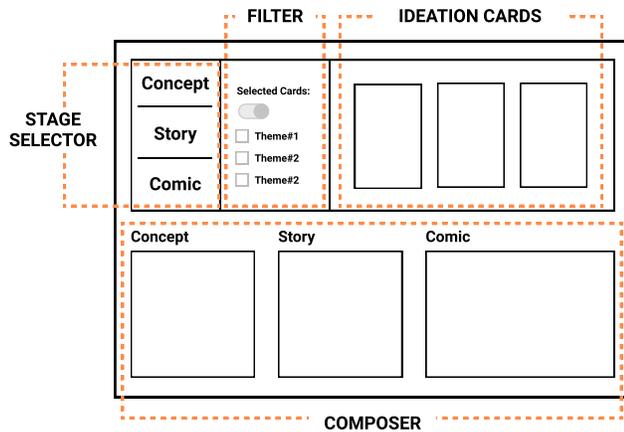
03. Allow Flexibility and Adaptability. Privacy and security threats are constantly evolving [45]. Therefore, educational content should rapidly adapt to changes to communicate recent trends, threats, and best practices. Thus, our third objective is to create a flexible tool that can accommodate new concepts and designs.

O4. Support Pen + Touch or Mouse + Keyboard Interaction.

Authoring tools are gradually supporting pen + touch interaction to reflect the increasing availability of tablets because pen + touch offers the most natural interaction for drawing [26]. Therefore, our tool should be designed to support both pen + touch and mouse + keyboard interaction. Moreover, to accommodate users who do not have access to a tablet or want to create quick, simple comics, we need to provide a set of stencils (i.e., pre-drawn templates for comics) to make the tool more accessible.



(a) DataComicJS [51]



(b) PrivacyToon

Figure 2: Wireframe comparisons of the user interface features for (a) data-driven and (b) concept-driven comic authoring tools (i.e., PrivacyToon).

3.2 System Design

We first provide an overview of the design components and creativity support features in PrivacyToon using its wireframe, then describe the final user interface design in detail.

3.2.1 *Design Components.* Figure 2b shows a wireframe outlining the main design components of PrivacyToon. Each user interface feature is designed to meet the design objectives (O1–O4).

- **Stage selector [O1]:** a selector for specifying the stage a user is at (i.e., concept, story, or comic); the other interface elements change dynamically to reflect the current stage. For example, trigger cards are shown in the ideation cards panel in the concept stage, scenario cards are shown in the story stage, and design cards are shown in the comic stage. Further, a composer panel that corresponds to the selected stage is highlighted, while the other panels are blurred and temporarily deactivated. The filter area also lists themes associated with the type of ideation cards.
- **Ideation cards [O1, O3]:** a viewer for showing any one of the three ideation card types: trigger, scenario, or design. Ideation cards can be updated to cater to concepts or topics in any domain (e.g., privacy, programming).
- **Filter [O2]:** a panel for filtering ideation cards. The panel lists (1) a toggle switch for filtering cards based on selection, and (2) a list of checkboxes for filtering cards according to the theme(s) associated with the ideation cards.
- **Composer [O3, O4]:** an editor for adding ideas for the concept, writing the story, and creating the comic. In the concept panel, users can dynamically add questions shown in the trigger cards by selecting them in the ideation cards panel. A text box is added below each question for users to type in ideas generated by looking at these questions. The story panel features a text box for writing story ideas. In the comic panel, users can add drawings (design patterns) shown in the design cards to the comic canvas by selecting the design cards in the ideation cards panel.
- **Stencil Library [O4]:** The comic drawing canvas features a library of comic stencils, such as stick figures and speech bubbles that can be added to the canvas by clicking or dragging. To make the tool flexible and scalable, we enable users to add their stencils to the library after creating some drawings if the library does not contain what they need.

3.2.2 *Creativity Support.* PrivacyToon offers two main types of creativity support for concept-driven storytelling [O1]: A) a tool-enabled *concept* → *story* → *comic* process for supporting the creative process of making concept-driven comics; and B) *ideation cards* for generating ideas for the comic's topic, narrative, and visuals.

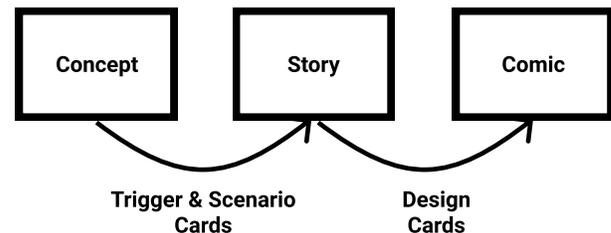


Figure 3: Design process adapted from [43]. It represents a design process for concept-driven comics, as it progresses from concept to story and to comic; this ensures the comic effectively illustrates the concept.

A: Concept → Story → Comic Process. The distinctive characteristic of *concept*-driven comics is that it is designed to explain a *concept*—like how *data*-driven comics are designed to communicate insights underlying *data* [7]. This specifies how we should design comic authoring tools. For instance, *data*-driven comic authoring tools (e.g., Fig. 2a) allow users to create comics based on *data* by providing them with an option to upload their data [26, 51]. *Concept*-driven comic authoring tools, on the other hand, need different design support to help users create comics about a given *concept*. Suh et al. [43] proposed a 3-stage design process for creating comics about programming concepts. We adapted this *concept*-driven storytelling process as shown in Fig. 3 as a framework for creating comics tailored to privacy and cybersecurity. Related design processes for comics can be found in data comics research, where they leverage a *data*-driven storytelling process that begins with data. Figure 2 shows a comparison between *data*-driven and *concept*-driven comic authoring tools. One notable difference is the ‘data import’ feature that data-driven authoring tools use to support the authoring of data-driven comics (DECORATOR) [26, 51]. The concept-driven authoring tool (PrivacyToon), as we have designed, is similar in that it also has a space for authoring (COMPOSER) but differs in that it follows a stage-based design procedure (STAGE_SELECTOR) and offers ideation support (IDEATION_CARDS).

B: Ideation Cards. To design the ideation cards, we collected recurring visual motifs from various sources, including existing cybersecurity educational tools from a literature review [48] and Oates et al.’s work on understanding mental models of privacy through illustration [34]. For instance, we added a ‘Symbolism’ (scenario) card listing symbols, such as locks, keys, and eyes, that people were found to associate privacy with. To analyze visuals related to cybersecurity and privacy, we utilized the online visual collaboration tool *Miro* [1] to accumulate notes of the visual and lexical motifs encountered during our literature review process. We followed the design process for developing ideation cards by Golembewski [20] and iteratively categorized the notes and identified recurring topics.

We drafted three types of ideation cards based on the list of categories and topics to facilitate the creation of comics about these topics: (1) Trigger Cards (Fig. 4a), (2) Scenario Cards (Fig. 4b), and (3) Design Cards (Fig. 4c). The trigger cards help users think of an explanation for a topic, the scenario cards help users think of a narrative, and the design cards help users visualize the content and flow of their comic panels. While some general cards (5 trigger cards, 3 scenario cards, 9 design cards) were adapted from prior work [43], we created new ideation cards (9 trigger cards, 19 scenario cards, 3 design cards) for PrivacyToon. For instance, we added a new theme, ‘Data’, to the design cards to include relevant design patterns such as ‘Leaving (Data) Footprint’ and ‘Sharing Data’. We also renamed the themes in scenario cards to ‘Who’, ‘What (Conflict)’, ‘What (Impact)’, ‘Where’, ‘When’ (from ‘Character’, ‘Action’, ‘Conflict’, and ‘Setting’ in [43]) to make it more intuitive for users developing privacy stories.

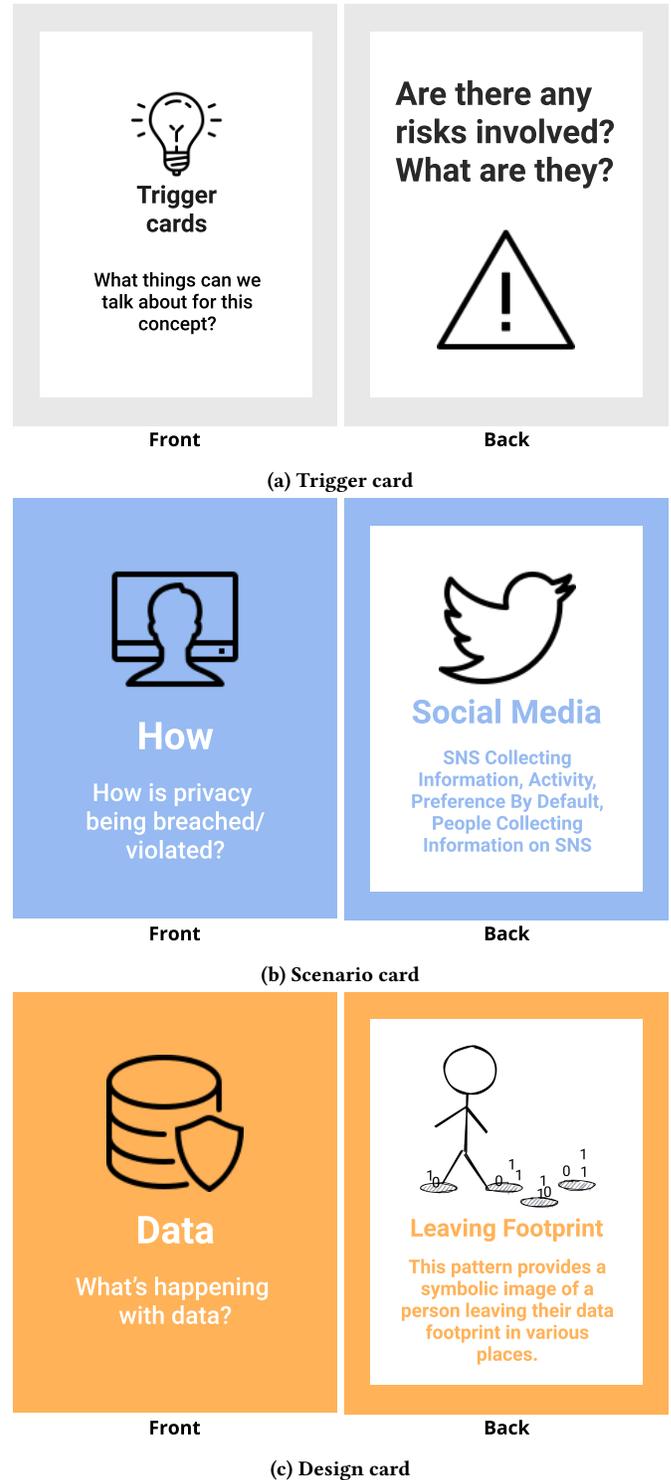


Figure 4: Examples of ideation cards

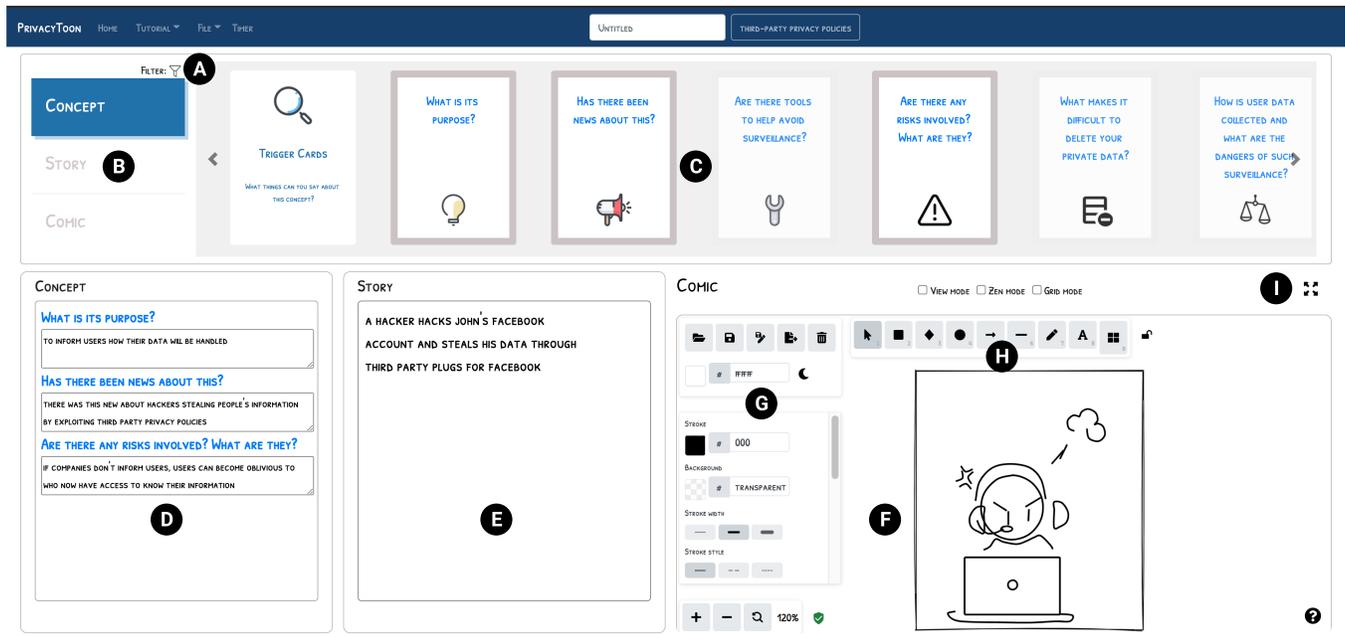


Figure 5: PrivacyToon interface: (A) button for opening filter panel, (B) panel for selecting ideation card type (trigger/scenario/design), (C) panel for viewing and selecting trigger/scenario/design cards, (D) panel for adding ideas for given concept/topic, (E) panel for writing stories, (F) canvas for creating comics, (G) style palette, (H) tool palette, and (I) button for maximizing comic canvas size.

3.3 User Interface Design

Now we showcase PrivacyToon’s interface developed using the above-mentioned design components and creativity support features. As shown in Fig. 5, PrivacyToon’s interface can be seen as consisting of two main areas: the top row where a user can browse ideation cards (Fig. 5C) and bottom row (defined as COMPOSER in Fig. 2b) where the user can add ideas for concept (Fig. 5D), story (Fig. 5E), and comic (Fig. 5F). At any point, a user can select any of the stages (Concept, Story, Comic in Fig. 5B). When a user selects one, it updates the ideation cards panel to show ideation cards that correspond to the particular stage. For instance, in Fig. 5, a user is in the ‘Concept’ stage, as shown by the stage selector (Fig. 5B). Thus the ideation cards panel (Fig. 5C) shows trigger cards.

While looking at the cards, the user can filter for specific cards by selecting a filter button (Fig. 5A). Selecting the filter button opens up a filter panel, which stretches out to the right. As shown in Fig. 6, the filter panel has a toggle button and checkboxes. When ‘Selected Cards’ is toggled, it shows only selected cards. This is shown in Fig. 6, where the selected scenario cards are shown. The checkboxes feature themes in the ideation cards on display at the moment. When clicked, only the cards that belong to that theme are shown. A user can click on multiple checkboxes and also toggle ‘Selected Cards’.

A user switches to other stages in two ways. One way is by selecting any one of the stages in the stage selector (Fig. 5B). The other is by selecting any of the composer panels in the bottom row. If a user, for instance, selects a different stage, e.g., ‘Story’, the trigger cards are replaced with scenario cards (cf. Fig. 6). Also,

panels for other stages (‘Concept’ and ‘Comic’) become opaque to avoid visual clutter and help the user focus on the current stage.

In the concept stage, a user selects a trigger card that gives them an idea about the concept/topic (e.g., third party privacy policies). The question (e.g., ‘what is its purpose?’) in that trigger card and a textbox is added to the concept panel (Fig. 5D). In the textbox, the user adds an idea, e.g., “to inform users how their data will be handled.” The user can select as many trigger cards as needed. The question and textbox are added below the existing ones. If a user wants to hide any of them, the user can select the corresponding trigger card to remove the question and textbox from the concept panel. What the user typed in is still saved, and the user can click the card again to bring it back to the concept panel.

In the story stage, a user browses through the scenario cards and selects the cards that inspire story ideas. Once the user has a story, the user filters for ‘Selected Cards’ (see Fig. 6) so that the user does not have to constantly scroll left and right to look at the selected cards. Looking at the cards, a user adds the story into the textbox (Fig. 5E). Unlike trigger cards, selecting these cards does not add anything to the story panel (Fig. 5E).

In the comic stage, a user browses through the design cards in the ideation cards panel (Fig. 5C), reads their descriptions (e.g., what they are useful for), and selects the cards. The design patterns from the selected cards are added to the drawing canvas (Fig. 5F). Once the user finishes going over the cards, the user clicks a button (Fig. 5I) to maximize the canvas size. The canvas expands to take up the entire space for the user to focus on creating the comic. At any time, the user can resize the canvas to its original size.

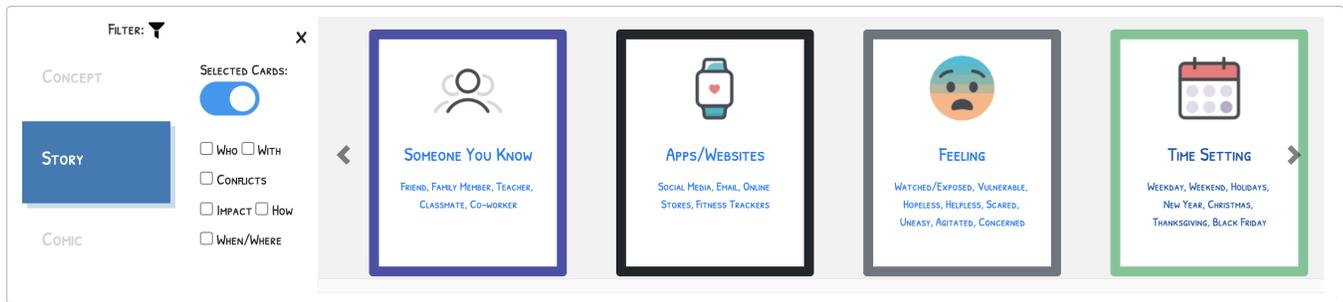


Figure 6: Filter feature. Users can click the filter button to open a panel to filter for selected cards, as shown, and filter for cards by their themes (e.g., WHO, HOW, WHEN/WHERE) by selecting one or more checkboxes.

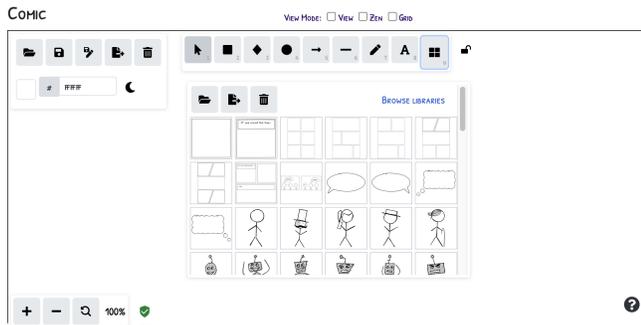


Figure 7: Library with stencils (e.g., comic panels, speech bubbles, and stick figures) for creating comics. Participants in our user study could use them in combination with tool and style palettes to create their comic.

4 USER STUDY

Due to the COVID-19 restrictions for testing our tool in a classroom setting, we recruited 23 participants remotely to participate in a user study that assesses the educational and creativity support capabilities of PrivacyToon from two perspectives, teachers ($n = 5$) and students ($n = 18$). We were also interested in whether their experience and output would vary depending on the availability of the creativity support (i.e., design guidance and ideation cards) in PrivacyToon. Thus we conducted a within-subject study where participants were asked to create two comics, once without (NO-CREATIVITY-SUPPORT) and then with creativity support (WITH-CREATIVITY-SUPPORT). Although we were aware of the order effect in our study design, we chose not to randomize the order of the two tools to avoid transfer effects in the opposite order. That is, since participants *may* use the concept \rightarrow story \rightarrow comic design process and ideation cards (learned while using the tool WITH-CREATIVITY-SUPPORT) while creating comics with NO-CREATIVITY-SUPPORT in the subsequent round, we felt this tradeoff was necessary, as the transfer effect makes it difficult for us to interpret the results and consequently the impact of creativity support.

Two pilot studies were conducted to improve the study procedure and materials. For example, we noticed that participants felt more comfortable with the drawing tasks when the facilitator did not directly observe them because it could make them feel conscientious

about their drawing ability. Therefore, we informed the participants that their drawing tasks would be screen-recorded for later observation, but the facilitator would not watch them as they drew during the session. We also expanded the recruitment group from students-only to include teachers, as we felt it is important to learn how teachers could use the authoring tool to create educational comics for teaching. The recruitment of the participants started after obtaining ethics approval of these changes. Each participant received remuneration of a \$30 Amazon gift card for a 120-minute online session. All participants were required to have access to a laptop or desktop and use a mouse for the study. This was to control the setting and minimize potential variability in their experience (e.g., creating comics using a touchpad can be more challenging and consequently discourage participants from engaging in the free-form drawing).

4.1 Participants

Students: We recruited 18 post-secondary students (10F, 8M, 0N) between the ages 21 to 31 (*Median* = 24) through our university's study participant recruitment platform. The students were from a variety of academic backgrounds, including Mathematics ($n = 6$), Arts ($n = 4$), Science ($n = 3$), Engineering ($n = 3$), and Business ($n = 2$). Fifty percent ($n = 9$) of the students self-declared to be moderately knowledgeable and 33% ($n = 6$) slightly knowledgeable about online privacy. Two students ($n = 2$) considered themselves very knowledgeable and one ($n = 1$) not at all knowledgeable. Eighty-three percent ($n = 15$) of the students had some experience with digital drawing tools, such as Adobe Creative Suite or Canva, but 16% ($n = 3$) no prior experience. Thirty-three percent ($n = 6$) of the students had some prior experience drawing comics and 67% ($n = 12$) no experience.

Teachers: We recruited five teachers (4F, 1M, 0N) between the ages 27 to 65 (*Median* = 34) through relevant Facebook groups. For this study, we sought teachers who have taught at least one lesson related to online privacy and/or cybersecurity in high school or college / university level. Since some prior knowledge about online privacy and security was required for teacher participants, we saw higher levels of understanding about online privacy and cybersecurity (60% Moderately knowledgeable, 40% Very knowledgeable). All teachers had some experience (60%) or much experience (40%) with using digital drawing tools. Like students, teachers had some (40%) or no experience (60%) drawing comics.

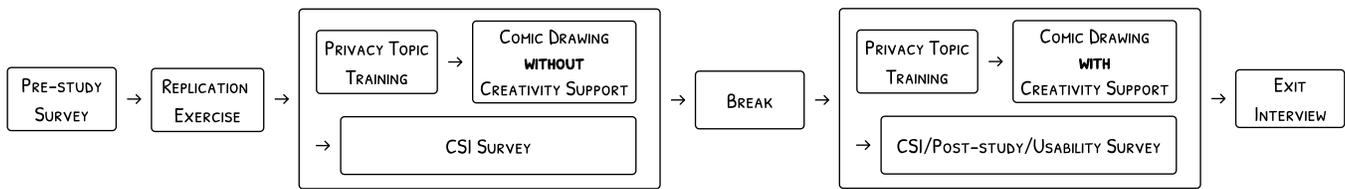


Figure 8: Study procedure for our within-subject user study

4.2 Study Procedure

After completing a consent form, we invited participants to the online study using Teams video conference software. Since the participants can be self-conscious about their drawings and direct too much of their attention and time to drawing them well, we clarified at the start of the session that we are evaluating the tool’s ability to help create comics rather than their drawing skills. We asked participants to think aloud during their drawing tasks, and the sessions were voice and screen recorded.

Pre-study survey and demographics (10 min): The participants first completed a pre-study survey containing questions about their basic demographic information (e.g., age, gender, major) and levels of experience (e.g., none, some, much) using digital drawing tools and creating comic strips. We also asked participants to self-rate their current understanding of online privacy and cybersecurity on five-point Likert scales (1 = Not at all knowledgeable, 5 = Extremely knowledgeable).

Replication Exercise with Video Instruction (15 min): After completing the prestudy survey, participants received a link to the comic authoring tool and were asked to start sharing their screen once they opened the tool. Participants were shown a tool without creativity support (i.e., ideation cards panel and a panel for adding ideas related to the concept). As shown in Fig. 9, the tool only had a panel for writing a story and a canvas for creating a comic. They were asked to click ‘Tutorial’ in the bar, which presented a series of short pre-recorded video tutorials about the tool and replication exercise task. The recording ensured that all participants received precisely the same instruction. The purpose of the tutorial was to familiarize participants with the user interface and drawing tools to minimize technical barriers during the creative authoring process. The tutorials included how to (1) use palette tools to draw stick figures and create panels for a simple comic, (2) use pre-defined stencils (e.g., panels, stick figures, speech bubbles) in the library (Fig. 7) to save time, (3) navigate in the canvas (i.e., zoom in/out, drag), and (4) add color and set styles (e.g., stroke width, opacity). Participants were asked to replicate the drawings shown in the tutorial to the best of their ability to familiarize themselves with the tool and the process of creating comics.

Privacy Topic Training (10 min): To ensure that all participants had a baseline understanding of a topic related to privacy and cybersecurity, we provided participants with segments from the Teaching Privacy curriculum³ developed for high school and undergraduate students. We selected this resource because the curriculum was found to be effective for undergraduate students with non-CS background [16]. To elicit different ideas from the participants, they

were randomly assigned to read one of two pre-selected articles for each of the two conditions before each drawing task: *Sharing Releases Control (Sharing)* about sharing information over a network and *You’re Leaving Footprints (Footprint)* about information footprints that people leave online. The order in which they read these articles was randomized to minimize the order effect.

Comic drawing task without creativity support (30 min): The participants were asked to create a comic story based on the topic in the article on their own (i.e., without ideation cards). They were told that they could create any comic related to the topic and were reminded that the facilitator would not be watching during the creation process (we covered our computer screens), and they were not judged on their drawing skills. The participants had approximately 20 minutes to complete each comic, but on occasion, we granted more time if the participants needed a few more minutes to finish their comics. All participants submitted finished comics except one who submitted a partially finished comic. Immediately after the task, the participants completed a Creativity Support Index (CSI) questionnaire⁴ to assess whether the tool helped them create their comics and allowed them to be creative. After the participants completed the survey, they had a 5-minute break.

Video Tutorial (5 min): After participants came back from the break, they were given a link to PrivacyToon. They were instructed to create and open a project. They were asked to click ‘Tutorial’ in the navigation bar of the interface and watch video tutorials about the PrivacyToon interface and its features. The tutorials explained how to (1) navigate between the stages (Comic, Story, Comic), (2) use the ideation cards for each stage, and (3) filter and select cards during the authoring process.

Comic drawing task with creativity support (30 min): Once they were ready to begin, they were asked to click ‘Timer’ in the navigation bar and select ‘Start.’ (The timer recorded how much time they spent on each stage and what stages they visited.) The participants completed a second comic using the concept → story → comic process and ideation cards. The procedure was the same as the first task. A second set of the CSI and System Usability Scale (SUS) questionnaires were administered to assess PrivacyToon’s creativity support capability and usability.

Exit Interview (15 min): After participants completed the second task, we conducted an exit interview to obtain qualitative feedback from the participants. For example, we asked about which of the two comics they liked the most, their experience using the current tool compared to other authoring tools, whether they found the ideation cards useful, potential usage scenarios outside of an academic setting, and any suggestions for improving the tool. We

³<https://teachingprivacy.org>

⁴Questions and the method for calculating the index can be found in [11]

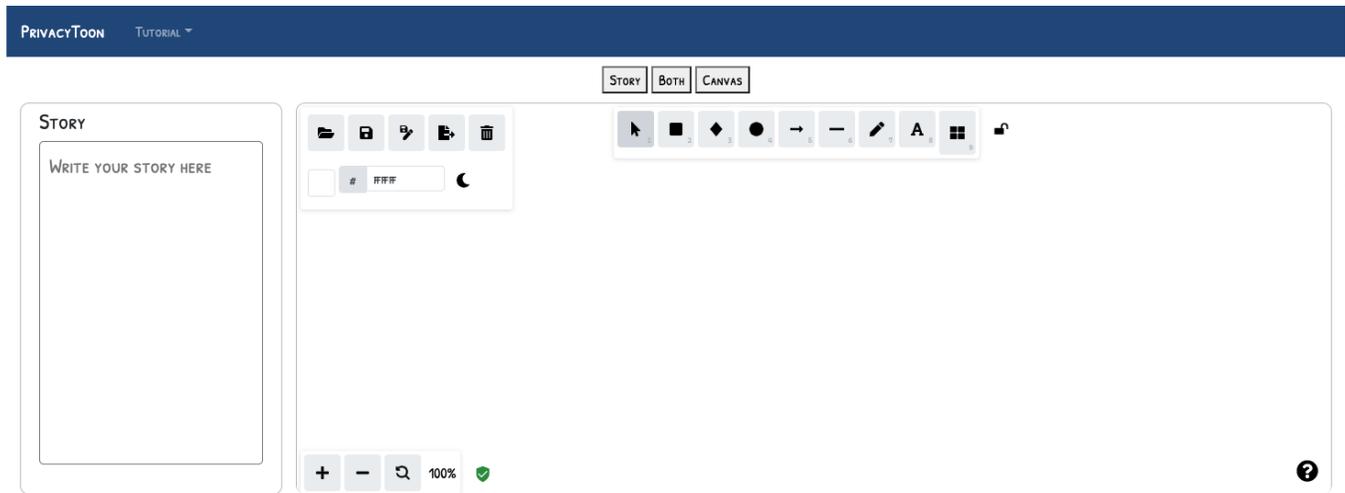


Figure 9: A simple interface without creativity support that participants used for replication exercise and first comic authoring

also had a few questions designed to elicit feedback from their perspectives as teachers and students. Specifically, we asked them to explain whether they think the tool would be useful for teaching, learning, and supporting creativity, and whether it would help students learn if used in the classroom setting. From the interview transcripts, we captured participant excerpts for each interview question on sticky notes in a virtual whiteboarding platform and conducted affinity diagramming by clustering notes that shared an affinity into groups. Two researchers openly discussed the clustered observations and iteratively refined the clusters into overarching themes.

4.3 Results

As discussed above, the participants used two types of interface: NO-CREATIVITY-SUPPORT and WITH-CREATIVITY-SUPPORT (i.e., PrivacyToon). We used NO-CREATIVITY-SUPPORT as a basis to compare participants' ability to create a comic without and with creativity support. Below, we report how PrivacyToon and creativity support were perceived, as well as any differences observed between NO-CREATIVITY-SUPPORT and WITH-CREATIVITY-SUPPORT. Then we present a preliminary analysis of privacy comics generated from this study to inform ways privacy comics can be designed.

Note that in the participant excerpts we present below, participants sometime referred to NO-CREATIVITY-SUPPORT as the "first tool" and WITH-CREATIVITY-SUPPORT as the "second tool" because that was the order they used the tool during the study. Student participants are suffixed with an 'S' (e.g., 8S), and teacher participants are suffixed with a 'T' (e.g., 5T). Since the participants read the two articles in random order, we use additional suffixes 'a' (e.g., 8Sa) and 'b' (e.g., 5Tb) to indicate whether they read in **Sharing** → **Footprint** or **Footprint** → **Sharing** order, respectively.

4.3.1 Authoring Time. Participants using the NO-CREATIVITY-SUPPORT interface spent an average of 26 minutes to complete their comics

($M = 26:19$, $SD = 10:18$). Participants using the WITH-CREATIVITY-SUPPORT interface spent a shorter time on average ($M = 24:12$, $SD = 7:15$).

4.3.2 Usability and Creativity Support. Overall, our participants found PrivacyToon usable and providing creativity support. It satisfied the standard usability score ($M = 68$, $SD = 19.85$), suggesting that minor design changes may be helpful but no significant usability issues exist [9]. While one important contributor to users' perceived usability of authoring tools is whether they enable them to create visuals easily, our analysis suggested that the stencil library and drawing tools successfully supported this. Approximately 70% of the participants used a combination of free-form drawings and stencils to create their comics; 30% used stencils only. Interestingly, we did not observe inexperienced participants relying on stencils. In fact, those who self-declared to have low-drawing skills showed they were just as comfortable drawing free-form as the more experienced participants, suggesting that tools in the drawing canvas were usable enough and that drawing skills did not hinder participants from engaging in the comic drawing.

Participants scored moderately on the creativity support index (CSI), but we did not find statistically significant differences ($p = 0.49$) between participants' average CSI scores for the tool with NO-CREATIVITY-SUPPORT ($CSI = 75.59$; $SD = 12.69$) and WITH-CREATIVITY-SUPPORT ($CSI = 73.36$; $SD = 14.79$), or the CSI scores of the six dimensions of creativity support between the two tools. For comparison of average CSI scores, we used Paired Samples T-Test as the data were normally distributed (Shapiro-Wilk test: $p = 0.87$ for NO-CREATIVITY-SUPPORT and $p = 0.93$ for WITH-CREATIVITY-SUPPORT) and had equal variance (F-test: $p = 0.48$); there were also more than 5 values in each group to pass the minimum number required for the parametric test.

Interestingly, our other analyses also mirror this similarity in average CSI scores between the two tools. When asked which tool the participants preferred using, while more participants (61%; $n = 14$) preferred using the tool WITH-CREATIVITY-SUPPORT, a nontrivial

number of participants (35%; $n = 9$) also said they preferred using the tool with NO-CREATIVITY-SUPPORT, and one participant said they like both equally. In addition to this fairly even distribution of the preferences, our analysis of the used ideation cards further supports this observation. Our analysis revealed that participants, on average, used several ideation cards to generate ideas in the Concept, Story and Comic stages (*Trigger Cards*: $M = 3.4$, $SD = 3.0$; *Scenario Cards*: $M = 6$, $SD = 3.7$; *Design Cards*: $M = 3.3$, $SD = 2.0$). However, we noticed that the range varied widely (*Trigger Cards*: [1, 15], *Scenario Cards*: [1, 12]; *Design Cards*: [1, 7]), suggesting that while some used them heavily, others did not rely on them as much. Another analysis that aligns with these results is the SUS ratings. Those who preferred NO-CREATIVITY-SUPPORT consistently provided much lower usability ratings for the WITH-CREATIVITY-SUPPORT tool ($SUS = 56.33$, $SD = 5.19$) compared to participants who preferred the WITH-CREATIVITY-SUPPORT tool who gave much higher usability ratings ($SUS = 78.93$, $SD = 3.80$). This suggests that our participants' preferences strongly influenced their perceived usability of the creativity support features in PrivacyToon. Finally, a similar trend can be observed in Fig. 10a, where 44% of the participants found the ideation cards very or extremely useful, while 26% found them moderately useful, and another 26% thought that they were slightly useful. In the following, we describe the responses of the exit interview to capture the reasons for these results.

The participants who preferred WITH-CREATIVITY-SUPPORT mentioned several reasons as they explained their preferences. Several mentioned that it gave them “a more structured way to approach the task” (4Ta). 9Sa recalled, “[the creativity support] helped with organizing my thoughts and also planning my next steps. Basically, they gave me an idea of where to go, whereas in [NO-CREATIVITY-SUPPORT] I didn't have those, so I didn't know or think ahead about what I wanted to do next.” They also mentioned that the creativity support resulted in better stories and comics. 1Ta said, “[the creativity support] gave me more depth to be able to write the story and think more logically about how the comic would progress.” 30Sb spoke in a similar vein, saying, “I prefer this second one because I got to write out the story a bit before and think more about what I'm actually trying to draw rather than just fishing around in my head first and just drawing.”

Several participants mentioned the concept → story → comic design guidance. 14Sb said, “the second one is better because it has different sections where we could think about the topic and then... develop a story to relate to some personal experience... The second one was more specific, which was a little more time consuming, but I think it was more productive.” Others felt this allowed them to “stay on track... [and] quickly develop the topic [they want to talk about]” (15Sa) and ultimately “draw a better comic” (1Sa). 10Sb said:

“I [like] the second one, because I was able to break down my thoughts into the concept, the story, and the comic. It just gave me more confidence as to what I was actually putting down in the comic, so I think the second one was a better tool in terms of thinking through the process and coming up with something creative.”

Participants also appreciated various benefits ideation cards offer. 4Ta mentioned how the prompts helped organize his thoughts, saying: “seeing the prompts on there helped me organize my ideas. I'm a type of person where... it takes me a long time to brainstorm

something because there are just too many thoughts in my head. So having the ideation cards helped me narrow down what I could write about” (4Ta). 12Sb explained that ideation support facilitated creative exploration:

“Those prompts helped me refine the idea and come up with different ways that I might be able to take the comic in different directions... If I'm struggling to come up with ideas or something, then the first tool without all of that would probably be pretty difficult because it is a blank slate without any real guidance.”

Interestingly, what some participants saw as the benefits of creativity support were seen as downsides. Although many participants found the ideation cards useful for brainstorming, as mentioned above, some who already had ideas felt it limited their creativity because the ideation cards were leading them to think in another direction. For instance, one student said, “I tend to prefer to just jump right into it... and try some ideas and see if they work, whereas [PrivacyToon] was more like having to come up with the concepts beforehand... If I were coming up with a more intricate comic, then [WITH-CREATIVITY-SUPPORT] would help plan things a little better” (12Sb). Several participants noted that they did not need ideation support because they already had some ideas after reading the article. For example, 13Sa explained:

“I just thought that [WITHOUT-CREATIVITY-SUPPORT] was not as complex... I think [WITH-CREATIVITY-SUPPORT] is good if someone doesn't have lots of ideas to get started with, but I had the idea in my head and just wanted to create versus going through all those cards.”

This may be explained by the fact that participants read the article offering several examples related to the topic just before engaging in the comic drawing. In fact, a few participants mentioned in the interview that they were already forming ideas about what to create as they were reading the article; in line with these statements, many of the comics contained examples and ideas from the articles, suggesting that while some nevertheless liked the chance to organize ideas with creativity support, participants like 13Sa preferred jumping right into the creative process, especially since they had just learned about the topic and can recall related examples and ideas. Several participants recognized these dynamics. 12Sb said:

“I think having the ideation cards is super helpful for refining an initial idea and exploring different ways to express yourself, especially if your idea isn't fully formed yet. At the same time, I value being able to jump right into the design part, too, because often, I work better when I can just freely express myself without constraints upfront. So I could see either strategy working well in different scenarios.”

These results collectively suggest that we should consider various dynamics (e.g., personal preferences) and contexts that can influence the need for creativity support. And that we should not assume that users will always want creativity support. As such, providing users with options to turn on and off creativity support features might be a reasonable design choice for systems that leverage ideation card-based design processes if the goal is to accommodate as diverse user preferences and scenarios as possible.

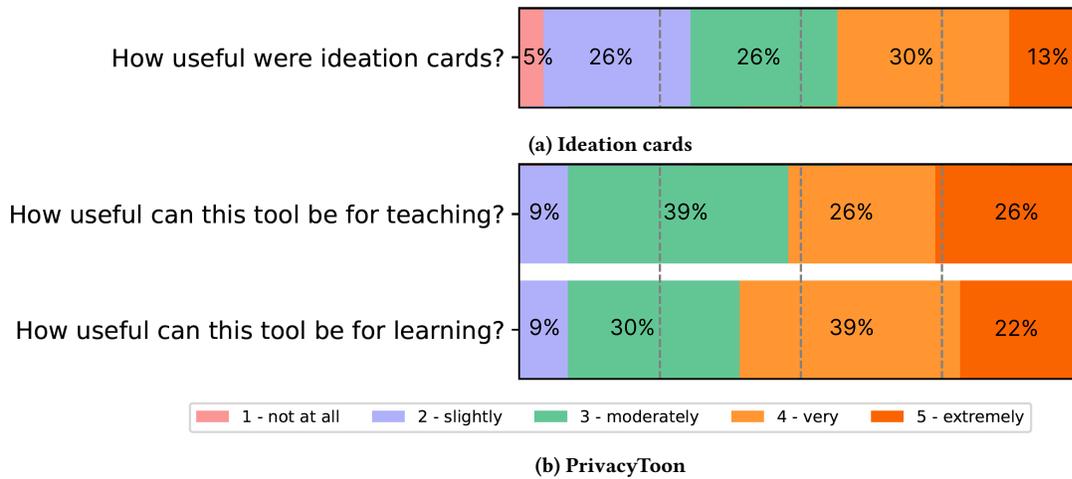


Figure 10: Post-study survey results

4.3.3 *Perceived Utility of PrivacyToon as an Educational Tool.* As shown in Fig. 10b, 52% of the participants said the tool would be very or extremely useful for teaching, and 39% found it moderately useful. Teachers thought the tool would increase students’ engagement in the classroom by “integrating their interests, which are drawings, comic books or manga and anime... When students feel like their interests are being included in the lesson, they’re more engaged and immersed” (3Tb). Further, creating a comic about a topic “reinforces the concepts that [students] learn” (1Ta). Students agreed: “I could see this being useful for getting your students to engage a little bit more with the material... taking a particular topic from the course and writing a comic about it would force the students to think a little bit more critically about the stuff that they’re learning... [as they] make connections between different things and put it into a more expressive format.” (12Sb).

For learning, 61% said the tool would be very or extremely useful, and 30% found it moderately useful. Teachers liked the option of using stencils and ideation cards because they put students with varying artistic skills “on a more level playing field”; “students can just copy and paste [stencils] and move them around and then if they are comfortable then they can draw their own stuff” (4Ta). For students, they liked how the tool enables learning-by-doing: “I’m all about learning by doing, and I think that having to explain a concept in... a couple of panels is a really great way to fill your eyes with the content that I’m learning... It helps to find connections and be a little bit more clear in how you’re expressing yourself so that other people can understand it” (12Sb). Many students liked the visual and narrative approaches to learning to increase the retention of information. One student explained, “[reading an article] is very descriptive and [students] understand things with pictures and... I think everyone understands stories... and stories are defined in the form of comics [in PrivacyToon]... They’ll always keep [the story] in mind if something [similar] happens in future about privacy... People usually remember stories rather than the articles because [articles] tend to be a theoretical concept” (15Sa).

4.4 Qualitative Analysis of Comic Content and Design

Our participants generated a corpus of 46 comic drawings, half for the *You’re Leaving Footprints* concept and half for the *Sharing Releases Control* concept. A researcher and a research assistant conducted thematic analysis by gathering all participant-generated comic drawings in an online whiteboarding platform. In the first iteration, the researchers identified symbols, metaphors, context, and design elements and generated keywords on sticky notes. Next, the two researchers met to review the keywords and descriptions, then independently conducted an analysis for 22% (10/46) of the drawings. A Cohen’s Kappa (κ) test found very good agreement between the analysis of the two researchers, $\kappa = 0.857$ (95% CI, 0.771 to 0.943), $p < 0.005$. The researchers met to resolve any discrepancies in the analysis and reached an agreement; then a research assistant coded the remaining drawings. To gain a deeper insight into the comic creation process and broaden our understanding of various ways privacy comics can be designed, the lead researcher conducted a second analysis of the design dimensions and expanded on the themes from the original analysis. For example, while the first analysis identified social media and other digital communication as one of the contexts where participants portrayed privacy issues, the second analysis further identified data types shared on social media and other communication by tagging sticky notes of data types to the comics in the whiteboarding platform.

In line with our participants’ CSI scores, our qualitative analysis did not identify noticeable differences in the quality of comics created with NO-CREATIVITY SUPPORT and WITH-CREATIVITY-SUPPORT tools, such as the length of the narrative and the number and types of visual motifs used. Therefore, we report our combined qualitative analysis of the comic content for all participant-generated comics to identify salient design elements in our sample. For reference, however, we use the red star sign (★) to indicate that the comic was created WITH-CREATIVITY-SUPPORT.

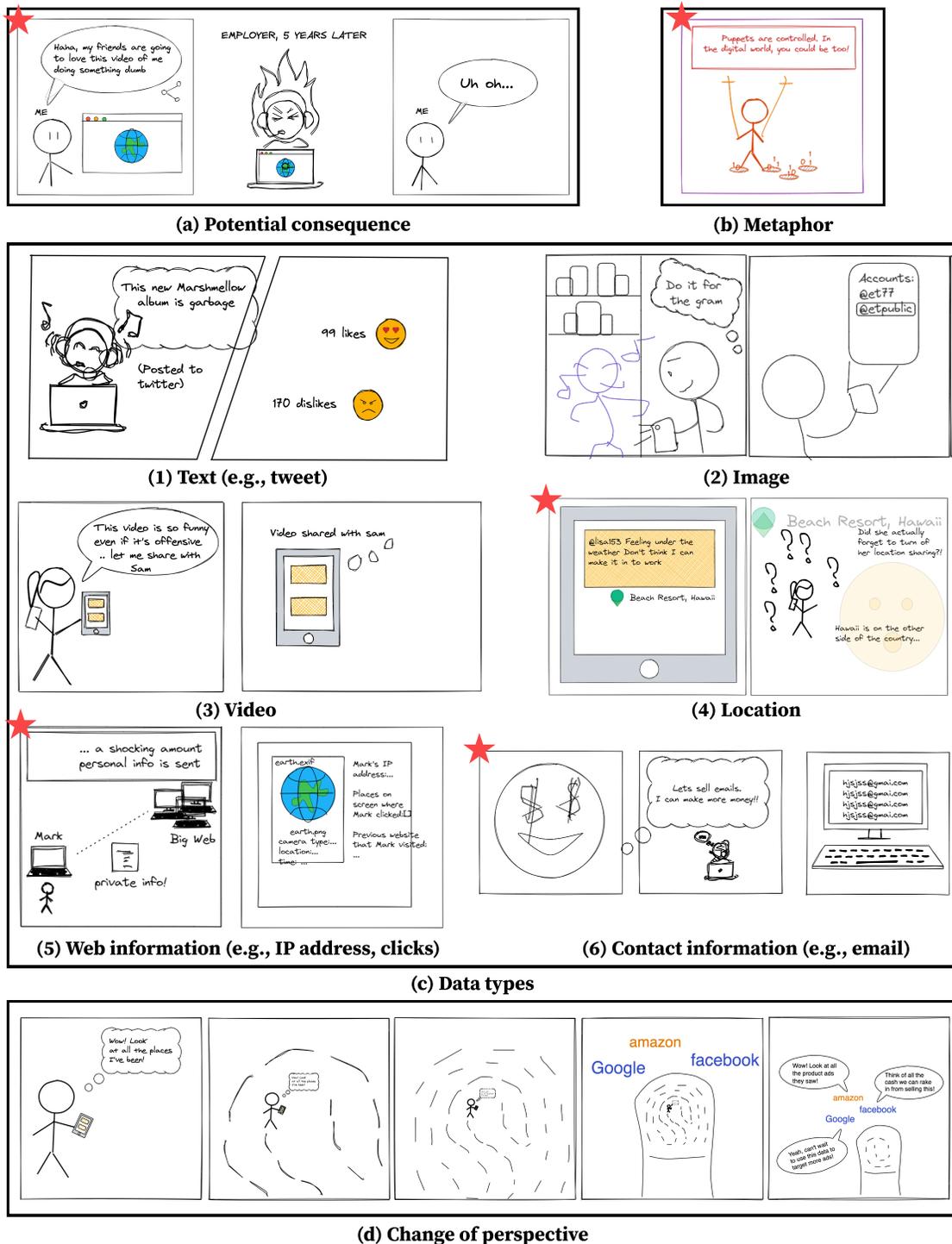


Figure 11: Gallery of comic examples for design dimensions

Data. All of the comics contained some form of data in varying complexity showing that privacy is about protecting one's data. Data types ranged from general (no reference to data type) to

specific data types such as location, photo, video, browser search history, and text postings (e.g., tweet), as shown in Fig. 11(c). The participants used a variety of visual elements to represent data

from the stencil library and their drawings. For instance, Fig. 11(c-1) shows a comic using the smile and angry faces from the stencil library to represent ‘likes’ and ‘dislikes.’ Fig. 11(c-4) shows a location icon that a participant drew. The wide range of design choices suggests the need to support the representation of various data types in privacy comics.

Metaphor & Analogy. Our participants frequently used metaphors and analogies in their comics. For example, one participant used “chocolate cookie” as a metaphor for ‘HTTP cookie.’ They also referred to a browser as an “oven” to evoke a concrete image for the abstract concept of HTTP cookie. Like metaphor, analogy was used to enhance the comprehension of abstract ideas. Analogy is a logical argument that can use metaphor and simile to draw a comparison for the purpose of making an explanatory point. Figure 11(b) begins with an analogy to make the point about how one can be controlled in the digital world like puppets. These examples show that access to metaphors and analogies would be useful for users creating privacy comics.

Humor. Privacy is generally regarded as a ‘serious’ topic, as it necessarily invites discussions of numerous dangers and harms it can pose in people’s lives. However, difficult and serious topics can make reading about these issues less enjoyable and engaging. The use of humor has been shown to help offset social, emotional, and cognitive challenges when communicating privacy and security topics in prior work [15, 47]. Similarly, our participants used funny scenarios, comical drawings, and metaphors. For example, a comic depicted an amusing scenario where a child got caught lying to his father about what he has been up to because his phone tracked where he has been. Another comic used the ghost metaphor to explain how information shared over the Internet can be permanently saved. In the comic, the ghost exclaims, “I’m the ghost of your Internet past and will haunt you forever!” We noticed a relationship between humor and metaphor in the comics from our sample, which is in line with previous literature that metaphors are frequently used in humor as they invite readers to “entertain the comparison being made” [30].

Presentation. The main purpose of privacy comics is to convince readers to make the right choices about privacy and to explain the issues / topics of privacy in a comprehensible way. We observed several presentation techniques that the participants used to achieve these goals:

1. **Direct vs. Indirect.** Comics can either directly address the reader (**direct**) or do not (**indirect**). The ‘direct’ comics speak directly to the reader, using ‘you’ (reader) in the text. These comics had step-by-step instructions to protect one’s privacy and a character telling the reader practical tips and explanation of a concept. On the other hand, all of the ‘indirect’ comics showed various scenarios demonstrating how their privacy can be violated in certain situations.
2. **Change of perspective.** Eliciting behavioral changes can be challenging because it can be difficult for people to recognize the long-term implications and potential consequences of their privacy choices. Therefore, depicting cause-and-effect relationships can help raise awareness about the potential consequences. For example, in the first panel in Fig. 11(d), a character shares its location data. In the following panels, the frame zooms out to

show that the character’s unique fingerprint (as a metaphor for digital footprint) is tracked and exploited by large tech companies. Another comic in Fig. 11(a) shows a character getting called into the work office for his video post five years ago, suggesting that what people upload can come back to haunt them years later.

3. **Question.** Our participant-generated comics used questions in two ways. One is a **question & answer** pattern in which a comic asks a (rhetorical) question and then provides an answer to it. The other approach is **quiz** where a question is asked with answer choices, to nudge readers to reflect on and test their understanding, as shown in Fig. 12.

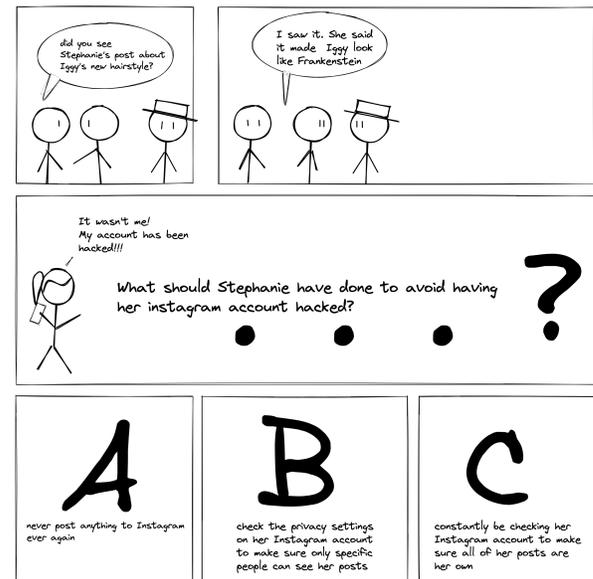


Figure 12: Quiz

In this section, based on our participants’ 46 comics, we introduced various design dimensions and choices for privacy comics. While further work is needed with additional privacy comics to make the analysis more comprehensive, we believe this analysis contributes a useful starting point to build on. Even if the dimensions and comic examples are not exhaustive, these dimensions can still be useful as they can be combined to generate many new designs. For example, consider a comic created by combining **potential consequence** and **quiz**. In this comic, the reader is asked what the consequence would be if they shared their location data and then is provided with three possible scenarios for the reader to choose from. Moreover, they can generate new questions to explore. For instance, one may hypothesize that because **indirect** comics do not directly address or instruct readers to take specific steps like in **direct** comics, they may have relatively limited impact compared to **direct** comics on readers’ privacy practices. Overall, even though our analysis did not include a large number of comics, these design dimensions—as shown—can still serve as a useful starting point for us to broaden our understanding of the design space and considerations for privacy comics.

5 PRACTICAL IMPLICATIONS AND USAGE CONTEXTS

In this paper, we presented the usability and utility of creativity support in PrivacyToon and a preliminary analysis of 46 comics by students and teachers on two privacy topics. As indicated by a recent survey of creativity support tools [38], most of the evaluations focused on usability and not creativity and did not use creativity metrics such as the Creativity Support Index (CSI). Although few studies (e.g. [33]) found general preferences for creativity support features, our study with combined usability and creativity evaluations suggests that users have different creativity preferences and that needs can change with context. Therefore, we recommend that (comic) authoring tools leveraging ideation card-based design processes should accommodate users' preferences and changing needs by providing options to enable/disable creativity support features. We describe three potential use cases for PrivacyToon: (1) privacy and cybersecurity education, (2) mental model research, and (3) privacy stories.

5.1 Educational contexts

Educating users about complex privacy and security issues through comics is an accessible educational approach that could reach a variety of audiences and effectively improve their privacy and security awareness [39, 45, 50]. However, producing high-quality educational comics is a tedious, labor-intensive, and expensive process due to the time, tools, and software needed. PrivacyToon could enable educators and students to create their own custom comics for teaching and learning. For example, a teacher could supplement a privacy lesson with explanatory images created in PrivacyToon to streamline the creative process of producing visuals for their lesson. Likewise, a student could use the tool to create fun comics as a creative exercise to demonstrate their understanding of the lessons and share it with the class. PrivacyToon could also be used to create comics that communicate and inform privacy and security best practices in corporate settings. For example, the creativity support offered within PrivacyToon in the form of ideation cards could support employees and employers in creating educational comics, either digitally or as printouts in the office, to share with their colleagues to increase their awareness about privacy and security-relevant issues.

5.2 Mental model research tool

Researchers have proposed identifying mental models of privacy [34] and cybersecurity [40] through illustration as a research method to explore “the visual culture of privacy” to inform privacy-related visual design (e.g., iconography, risk communication). Further, researchers have also shown that comics is an effective educational tool for building privacy and security mental models due to their visual storytelling and illustrative capabilities [39, 46, 49, 50]. Using sketching activities with users could help to surface nuanced mental models that are difficult to uncover through written and verbal articulation. [34, 40]. However, there is currently no all-in-one tool that helps collect, facilitate, and distribute user-generated drawings for cybersecurity research. While the Privacy Illustrated web-based system [8] enables users to upload JPEG drawings by taking a picture or scan of a paper-based drawing, or upload a digital version

created by a tablet or other medium, it does not offer creativity and technical drawing support during the drawing process. We believe researchers could use PrivacyToon to collect and distribute user-generated drawings with optional creativity and drawing support features for users who prefer them. For example, researchers [19] have found sketching to be a useful tool for understanding experts and non-experts' conceptualizations of complex cybersecurity tools like Tor. Researchers could customize ideation cards in PrivacyToon to elicit users' understanding of specific cyber threats (e.g., password guessing attacks, malware) or how they think certain types of security mechanisms work (e.g., encryption). As PrivacyToon is instrumented to record user clicks, time-on-task, and how users create their pictures, it could enable researchers to gain insight beyond the finished drawing and into *how* users think about the concepts behind their illustrations.

5.3 Privacy storytelling

The concept-driven storytelling process embedded in the tool promotes the telling of privacy security stories. It is recognized that many users learn about security informally from stories they hear from other people, and these stories impact the way people think about security and their subsequent security-relevant decisions [36]. Therefore, stories are an important aspect of non-experts' security “education” [36]. However, to our knowledge, there has not been any platform or tool specifically designed for privacy storytelling. PrivacyToon could be an effective tool for assisting content creation and sharing security-related stories as engaging comics. And while comics are a perfect medium to tell stories because of their sequential format, creating them can be time-consuming and inaccessible to people with low-artistic skills [48]. The creativity and technical drawing support in PrivacyToon address this limitation, allowing anyone with a computer or tablet to create, download (in PNG or SVG), and share a comic in under 30 minutes.

The ease of privacy storytelling allows us to envision ways for privacy and cybersecurity stories to be easily shared to raise awareness about privacy and security related issues. For instance, people could share their privacy stories in the form of comics on social media platforms and allow their social network to amplify its spread. In future work, it could be implemented, for instance, as a third-party application on social media so that social media users can log into the app, create visual content, and share directly on the platforms through their story or timeline. In some cases where a verbal presentation of the privacy stories is sufficient, users may also use PrivacyToon to quickly generate stories without necessarily creating comics.

5.4 Limitations and future work

There are several limitations to note in this study. The evaluation of the tool was conducted online in an artificial setting due to limited access to our desired user group during the pandemic. Thus, our questions on the usefulness of the tool for teaching and learning relied on participants answering in a hypothetical sense. Also, our online user study design could have been vulnerable to social desirability bias. The participants' experiences with the tool could have been different if they used tablet and stylus instead. We did

not randomize the order of tools in the evaluation study to minimize the transfer effects of the creativity support process onto the NO-CREATIVITY-SUPPORT interface. However, the study design might still carry some transfer effects due to similarities between the two user interfaces except for the elements relating to creativity support. We used two different privacy topics to seed their design process to minimize learning effects. Still, some learning effects could have carried from the first to the second drawing task, leading to participants forming ideas for the second comic and impacting their perceived usefulness of creativity support. We evaluated the tool under a typical education scenario, where students would first receive a short lesson and then be asked to use the tool to reflect on the lesson by creating a comic based on the topic. As a result, imagery and metaphors embedded in the Teaching Privacy curriculum may have influenced the type of comics created by our participants. Future work could assess the tool's usefulness for different usage contexts, such as using the tool with no pre-training to evince mental models as opposed to learned materials.

Furthermore, we observed that participants could generate quality comics using the NO-CREATIVITY-SUPPORT interface, which is similar to many comic authoring tools in its functionalities and drawing support (e.g., stencil library). This brings into question whether similar results can be achieved with other comic authoring tools already available and in what circumstances the creativity support in PrivacyToon would be most useful. In our study, we found participants reusing ideas from the articles they just read to create their privacy stories and comics. In a different scenario where participants create comics about privacy topics they are already familiar with but are not given any materials to review before engaging in the creative process, they may find the ideation support more useful, as they may need to rely on the ideation support to remember and generate ideas. In other words, the benefits of creativity support in PrivacyToon may be more salient in this context. While this was the case in prior work where participants were tasked with creating comics about programming concepts [43], it should be tested with PrivacyToon in the future. Finally, our qualitative analysis of the comics is based on the comics created for only the two principles in the Teaching Privacy curriculum. Thus, as we mentioned, the design dimensions and elements observed in the generated comics are not exhaustive; there can be other design dimensions and elements as more privacy comics are created and more topics are covered.

In future work, we hope to confirm our results, such as the usefulness metric in the classroom environment, and evaluate any impact on privacy attitudes and behavior among teachers and students in the classroom setting. A panel of experts can also evaluate the resulting artifacts between the two tools to assess whether having creativity support is more effective for enhancing understanding of privacy concepts, capturing privacy mental models, and eliciting privacy stories. We will also need to map out a more comprehensive design space for privacy comics covering a wider range of design elements and topics. The design elements can then be used to build a library of sketches and icons for developing a visual vocabulary of privacy and security. Starting with options to enable and disable creativity support features, we plan to enhance PrivacyToon with new features, some of which include those suggested by user study participants. For instance, while most participants utilized visuals

in their comics, some comics were text-heavy. We can guide users' design by expanding our library and design patterns found from our preliminary list of design dimensions; we can also leverage research on auto comic generation (e.g., [41]) to automate parts of the comic creation process in PrivacyToon; 14Sb requested a conversational agent that can assist users when they are stuck. The agent can assist users in various ways, e.g., inform users if certain comic parts contain too many words, provide design suggestions, and use language models (e.g., GPT-3) to help users brainstorm ideas related to the topic and offer story ideas. Finally, since the concept-driven storytelling process (concept → story → comic) is general enough that it can work with any domain [43], we plan to add features that would help PrivacyToon scale beyond the privacy and cybersecurity domain. To expand to other domains, we need ideation cards tailored to those domains, as ideas, stories, and designs are generally grounded in the domain they reside in. For instance, data structure visualizations are appropriate as design patterns for programming comics but not for privacy comics. Since developing ideation cards for various domains will likely require a lot of work and maintenance, we hypothesize that the way to make this sustainable and successful is by turning PrivacyToon into an open, flexible platform that allows users to easily create and share new sets of ideation cards. We can also allow users to form their own collection of ideation cards from the existing ones in order to customize the tool for their needs. If successful, this can evolve into a platform that supports various forms of communication (e.g., science communication) via visual storytelling. As a next step, we plan to extend PrivacyToon in this direction.

6 CONCLUSION

In this paper, we introduced PrivacyToon, a comic authoring tool with ideation card-based creativity support for privacy concepts. We conducted an exploratory study with students and teachers to examine its feasibility as a creativity tool and test the effectiveness of our creativity support features. We demonstrated PrivacyToon's potential as a creative tool for teaching and learning of privacy concepts. Our user study suggests that users' creativity preferences can impact the need for creativity support. Therefore, systems aiming to incorporate concept-driven storytelling process and ideation card-based creativity support should embed options for users to enable and disable creativity support features. Finally, we analyzed the comics created by user study participants to contribute a preliminary list of design dimensions for privacy comics. While they are based only on a set of 46 comics and two topics, they contribute a useful starting point to build on as we explore the design space for privacy comics.

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A APPENDIX

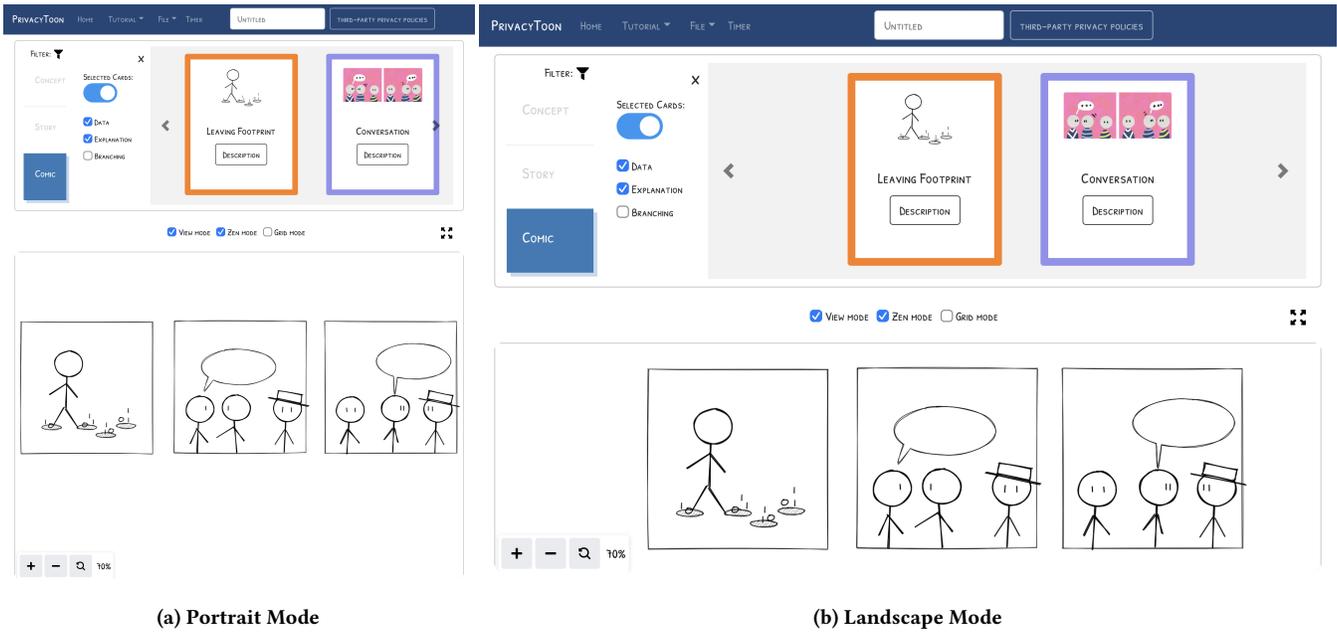


Figure 13: Screenshot of PrivacyToon on iPad. PrivacyToon can also be used with pen & touch-enabled tablet devices. As shown, when design cards are selected, the design patterns are added to the canvas for the user to easily and quickly create their comic.