ABSTRACT
We investigate how students engage in free-form web curation as a means of design ideation. Free-form web curation is a spontaneous, improvisational, and divergent creative process that involves choosing, sketching, writing, and assembling elements spatially. We take a design research approach, involving iterative design of a web curation system and pedagogy, building a relationship with our study context, collecting data, and analysis. Through this research, we identify and articulate five constituent processes of web curation: Gather, Assemble, Shift Perspective, Annotate, and Exhibit. In our classroom field study, 1247 students engaged in free-form web curation to perform ideation assignments. We develop mixed methods analysis of visual data, ideation metrics, and engagement measures. This informs implications for supporting design ideation through web curation, and more broadly, for conducting design research in the classroom.

ACM Classification Keywords
H.5.2 Information Systems Applications: Misc.

Author Keywords
Curation, ideation, creativity support tools, web multimedia

INTRODUCTION
We investigate how students engage in free-form web curation as a means of design ideation. Designers, from the professional [30] to the everyday [59, 35], interact with large amounts of content online. Through web curation, people keep, organize, and think about encountered [39] content. Popular web curation systems include Facebook, Twitter, and Pinterest. These systems present discrete elements in linear feeds and boards to help users organize and understand. However, these presentation forms provide limited support for ideation, during which web content becomes particularly “intertwined” [42].

Ideation tasks often involve curating content to stimulate imagining, and developing new ideas [29]. Synthesis and emergence are essential components of ideation [14]. Gathering a variety of content incorporates diverse perspectives. Kolko demonstrates the importance of synthesis in design processes [32, 31]. During synthesis, designers gather, organize, manipulate, prune, and filter diverse forms of data [61]. Designers identify and forge implicit connections by freely moving and manipulating content [30]. These processes of synthesis are inherently reflective and messy.

The present research investigates supporting student design ideation with free-form web curation. Free-form web curation is a spontaneous, improvisational, and divergent [34] creative process that involves choosing, sketching, writing, and assembling elements spatially. We took a design research approach [15], which involved iterative design of a web curation system and pedagogy, building a relationship with our study context, collecting data, and analysis.
We found that pedagogy—here, what we teach students about web curation, in the context of primary course curricula—plays a significant role when design research is situated in education. As the field study progressed, we used understandings gained from each semester to improve assignments and presentations in the next one.

Through our design research, we identified and articulated five constituent processes of web curation: Gather, Assemble, Shift Perspective, Annotate, and Exhibit. Gather involves finding, choosing, and collecting digital content. Assemble is the artistic process of organizing, arranging, and visually transforming gathered content. Shift Perspective involves transforming the view of the curation space through pan and zoom. Annotate involves adding sketches, labels, and expository texts to further associate, explain, and contextualize. Exhibit is the act of sharing and presenting a curation. We use these processes as a lens for our research.

This paper contributes an investigation of processes of web curation, interactive capabilities that support them, and pedagogy that explains them to students. We conducted a mixed-methods field study to examine how design iterations affected ideation processes and products. To support people performing these processes of web curation, we iteratively developed the IdeaMâché system [free to use at http://bit.ly/RpR2MU].

We conducted a field study over four semesters, situated in the undergraduate course, The Design Process: Creativity and Entrepreneurship. Facilitated by evolving pedagogy, 1247 undergraduate students used IdeaMâché to perform assignments. To see effects of this design intervention, we derive three kinds of data. Visual data takes the form of exemplary creative works authored by students (Figures 1, 3). Ideation metrics [29] measure the quantity and diversity of elements assembled in students’ curations. Engagement measures use interaction logs to show how students used specific interactive capabilities to manifest the processes of web curation. Findings inform our derivation of implications for supporting design ideation in web curation systems.

RELATED WORK

We assembled related work across fields. First, we situate the present research within the tradition of curation. We present work on prior media for organizing information, spatial hypertext and information composition. Finally, we incorporate work on design and forms of curation in the classroom.

Curation

In art, curation is the spatial arrangement of exhibition forms to conceptualize and express context [43]. Central to curation is Duchamp’s method of choosing found objects, shifting their contexts, and thus transforming meaning [36]. Curation processes and products support people in open-ended creative tasks and activities in which users generate and develop new ideas while interacting with information [29]. This research takes the position that human expression is inherently valuable in experiences of information and learning.

Spatial Hypertext

Various forms of hypertext are antecedent. Intermedia enabled associative authoring of assemblages of mixed media and text, across multiple windows, with spatial layout and hypertext links [63]. Spatial hypertext enabled information to be organized in 2D space, using features such as position and styling [41]. Rosenberg found that in addition to linking, gathering is also a key hypertext activity [49]. We build on his notion of a gathering interface, fulfilling prescriptions such as providing free-form spatial structuring and automatic context capture. When studying the use of hypertext for information triage, Marshall and Shipman likewise noted that systems should support rapid assimilation of new material into an information space [40].

Prior spatial hypertext tools were designed to enable gathering, organizing, and annotating information [52, 4]. However, as people organize web information for re-use, they additionally require portability, persistence, ease of access, ease of maintenance, and ease of sharing [23].

Information Composition

Information composition is a holistic medium for the curation of digital content [29]. It incorporates methods and techniques from spatial hypertext and the artistic practice of assemblage. Composition visually and semantically juxtaposes and contextualizes curated elements. Studies have shown that information composition supports creativity [25, 26, 28, 29]. The present research employs information composition as a medium for web curation.

A prior study investigated the use of free-form composition with IdeaMâché for presentations in a graduate seminar during a single semester [34]. The present study investigates the process of curation, rather than focusing on presentation, over an extended period, in a large undergraduate course.

Design

Design has been called a “conversation with materials,” connecting form and content [45]. It holistically addresses symbolic and visual communication, material objects, services, and environments for living, working, playing, and learning [7]. Buchanan develops the notion of placements, provisional associations and categorizations that evolve through iterative design processes [7]. He elevates the importance of design thinking in relation to final products, emphasizing the continuous iterative design of problem definitions that are connected to design of problem solutions.

SUPPORTING WEB CURATION PROCESSES

In design research, Forlizzi and Battarbee established the need to address user experience as a whole [15]. In concord with this prescription, our research takes a holistic approach, integrating interactive design capabilities in the IdeaMâché system to support web curation processes: Gather, Assemble, Shift Perspective, Annotate, and Exhibit (Figure 2). Users Gather content from the web browser via direct clipping enabled by a complementary browser extension. The extension also automatically combines clipped content with dynamically captured contextual semantics. Users Assemble elements through spatial arrangement and other visual transformations. Shift Perspective is supported through a zoomable curation space. Users Annotate the curation space...
with writings and sketches. A cloud platform facilitates users exhibiting their curations on the web.

**Gather: Direct Clipping**

Gather is the process of bringing content into a curation. It involves exploratory search and browsing, and then choosing and collecting desired content. By clipping (verb), we mean the act of selecting content in a source context, such as a web page or social media post, and transferring that content to a new context, such as a curation. We also call the resulting object, sheared from its source, a clipping (noun). Hunter Gatherer, WebSummaries [11], and Clui also support clipping web page content.

IdeaMâché supports gathering through a browser extension that transforms encountered web content into material that the user can collect via drag and drop. In its new role as material, gathered web content becomes appropriated and recontextualized through web curation processes. For example, in *Children’s Peter Pan Inspired Room* (Figure 3), Williams recontextualizes curtains and decor from IKEA into scenic backdrops to create the forests of Neverland. The IdeaMâché browser extension transforms a user’s browser into a gathering interface [49]. To the user, the function of the browser as a gathering interface is transparent. It is directly integrated with regular browsing and reading. When a user gathers content through drag and drop it is transformed into a rich clipping.

**Rich Clippings**

In IdeaMâché, each element of curation is represented as a rich clipping—a piece of digital content which has been sheared from its source, enriched by contextual semantics. The browser extension automatically captures the source context from the target web page as a semantic summary. The extension dynamically performs semantics extraction at the start of a drag event. Semantics extraction is supported by a type system, which integrates data models with extraction rules [27, 47]. At a minimum, the contextual semantics include the URL and title of the source document. Depending on their type (e.g., social media post, product, scholarly article, or patent) rich clippings may contain further semantics. Contextual semantics have been shown to support re-finding [23] and reflection on source documents in the context of a curation [60]. Supporting these media types and combining contextual semantics with content aids human cognition and working memory [2]. Rich clippings support multiple types of media—text, image, audio (SoundCloud), and video (YouTube, Vimeo, Twitch).

This present work builds on prior implementation of rich bookmarks [60] by supporting more diverse media types. In SpeedDemon (Figure 1), the author gathered rich clippings of varied media and source types, such as images of motorcycle riding gear from Amazon, news footage of extreme weather conditions from YouTube, and figures of diving safety suits from Google Patents. The author gathers a variety of rich clippings to form a basis for innovation, in this case, a wearable personal vehicle.

**Assemble: Visual Arrangement and Transformation**

While many popular web curation systems use linear feeds, O’Neil articulates the historic role of spatial arrangement in art exhibition design [43]. To bring this artistic sensibility...
into the Assemble process, IdeaMâché enables visually arranging and transforming elements to articulate relationships and compose a connected whole (see example, Figure 1). All elements—rich clippings, sketches, and writings—support the same graphical transformations: position, scale, rotate, layer, crop, and blend. Elements are directly repositioned by click and drag. Layer transformations enable users to position an element behind or in front of others. Blend changes the opacity of an element, enabling elements to overlap and show through. IdeaMâché also supports cut and paste of elements and a rectangular selection tool, enabling users to operate on multiple elements at once.

Scaling elements in conjunction with the zoomable curation space allows authors to create mult-scale curations. Multi-scale curations support organizing elements across levels of zoom, extending the tradition of the Eames’ Powers of Ten [13]. In Children’s Peter Pan Inspired Room (Figure 3), the author has placed a map of Neverland in the center of her curation and arranged details around its perimeter. Depicting the map at larger scale helps it function as an overview.

**Shift Perspective: Zoomable Curation Space**

To support visual arrangement and transformation of large amounts of digital content, we draw from prior work in design ideation. Kolko finds that designers create a physical collage of images, clippings, sketches, and sticky notes to externalize creative thinking during design synthesis [30]. He calls this the ‘big wall’. The big wall enables iterative escape from the mess of content gathered through research. The physical organization of content helps produce semantic relationships.

To support ‘big wall’ design thinking and creative expression on a limited digital display, IdeaMâché provides a zoomable curation space. Zoomable user interfaces (ZUIs) use scale to create a dynamic gradient of detail [3]. Motivated to preserve the inherent rich and dynamic structure of information, Bederson and Hollan designed the zoomable interface to harness human spatial thinking.

The zoomable curation space is a nearly infinite 2½D canvas where users assemble rich clippings and annotations as they engage in web curation. Width and height are not explicitly constrained. Users can pan indefinitely and arrange elements as close or as far apart as they like. There are no predefined layouts, templates, or borders. To aid in navigating the curation space, IdeaMâché provides an overview to compliment the main viewport. This overview-detail technique has been proven effective for supporting navigation in ZUIs [21, 54].

**Annotate: Sketching and Writing**

An important part of curation is to recontextualize by injecting one’s perspective. In concert with choosing what content to gather and how to assemble it, annotation becomes a means for design ideation. IdeaMâché supports annotation in the forms of writing and lightweight sketching. The need for this capability in web curation can be seen in how people create annotations by sketching lines and writing notes in the margins of books to relate and personalize content [38]. Simple lines and short notes are commonly used to help readers make sense of connected information.

**Lightweight Sketching**

Lightweight sketching enables users to engage in visual thinking [1] and express connections among curated elements. Larkin and Simon show how diagrams can be easier to understand than lists of relationships [33]. Benefits include
using position to group information and making inferences easy to perceive. Tversky characterizes glyphs as simple figures, such as points, lines, and arrows that draw from their context to articulate meaning [58]. She emphasizes the role of human interpretation in creating and understanding their meanings in context.

In architecture, early sketches are light scribbles which assist in design reasoning [17]. These early sketches enable a visual exploration of concepts, helping designers imagine patterns, forms, and functions. Instead of drawing independent and complete solutions, their scribbles build on each other, prompting new design considerations. Architects describe intentionally fostering an open mode of thinking, visualizing possibilities which are stimulated by quick and unstructured sketches. Other research observes similar practices of conceptual exploration via lightweight sketching by professional and student architects [55].

Writing
Kolko emphasizes the value of writing in design ideation. He suggests that writing be performed amidst a big wall of information [31]. Designers perform iterative sensemaking by describing and relating insights in writing. Kolko observes that people conceive categories in order to anchor content through organizing and assembling information. While the designer’s wall may look like a mess, it “actually represents the deep and meaningful sensemaking that drives innovation” [31].

In Children’s Peter Pan Inspired Room (Figure 3), Williams created one text annotation to serve as the title for her cura
tion, and others to categorize and elaborate, anchoring sets of image clippings. Williams uses the Neverland map as an indexical overview for Peter Pan inspired interior design. Within the map, subareas correspond to settings from the story. Sketch annotations are used to connect groups of curated elements with particular settings.

Exhibit: Cloud Architecture
Exhibiting involves making a curation available for others to experience. Storing, editing, and viewing content independent of a particular computer has become a requirement for engaging users with Web 2.0 applications. Thus, IdeaMaché incorporates a cloud architecture that handles user accounts and curation hosting.

The cloud architecture enables saving, sharing, turning in, building on, and publishing curations as creative products. Each web curation is assigned a unique permalink. Students use permalinks referring to the cloud in order to share work with their peers and turn in assignments to course instructors. Exhibited curations serve as sources for subsequent works when users re-curate elements. We incorporate exemplary web curations into pedagogy, in order to demonstrate effective practice. The cloud architecture is instrumental in our research data gathering. Through the cloud, each curation becomes connected to user engagement logs, which capture the processes of the author. The cloud supports us, as researchers, in gathering and maintaining a continually growing corpus of curation products.

FIELD STUDY METHODOLOGY
We report on an extended field study. We incorporated web curation into the undergraduate course, The Design Process: Creativity and Entrepreneurship (DPCE). We collaborated with course instructors in an iterative design process.

Our design interventions include the IdeaMaché system, the web curation processes, and course pedagogy. The pedagogy teaches web curation as part of engaging in design, creativity, and entrepreneurship. It includes the specification of assignments, the presentation of lectures, and the operation of a help desk. We find these components necessary for effective design intervention in the classroom.

The goal of the study is to investigate supporting design ideation through web curation in the situated context of the classroom. Understanding how design ideation is potentially supported in a working classroom is a “wicked problem” [48], in that what data to collect and how to analyze it are not obvious. The present research develops a novel mixed methods approach, combining quantitative methods and visual data to observe the impact of our system and our pedagogy.

Study Context
We conducted a field study of IdeaMaché over four semesters—Fall 2013 (s1), Spring 2014 (s2), Fall 2014 (s3), and Spring 2015 (s4)—in DPCE. DPCE students are undergraduates from diverse majors who are charged with the task of functioning as designers, inventors, and proto-entrepreneurs, creating concepts and sketches for new products, services, experiences, and art. They represent a wide variety of majors, spanning architecture, engineering, humanities, and business. The goals of DPCE are to equip students with creative thinking skills in an effort to foster invention.

Our ongoing research collaboration with the instructors of DPCE helps serve the course’s educational goals, directly benefiting students. Through this collaboration, in the situated context of the course, we develop web curation pedagogy in conjunction with creativity and entrepreneurship. Our pedagogy includes the specification of assignments and class lectures that incorporate web curation and its terminology. In each semester, as a first step, we present an introductory lecture about idealeture, web curation, and how to use IdeaMaché.

DPCE students use IdeaMaché for two web curation assignments, Soft Innovations and Imagine a Solution Curation. Soft Innovations (e.g. Figure 1) are new designs for products and experiences made by synthesizing and modifying needs, precedents, and resources. Prior work collections gather examples and media from diverse sources such as patents, nature observations, business models, and social media.

In addition to Soft Innovation assignments, DPCE students submitted an introductory curation assignment called Imagine a Solution Curation. This assignment instructs students to conceptualize, design, explain, and reflect on a solution to a personal need in her/his life. Students’ curations for this assignment address themes similar to those found on Pinterest [35], such as weddings, workout routines, personal health, and redecorating (e.g. Figure 3). For each assignment, stu-
students assemble and juxtapose content to develop ideas. Students expand on their assignments by sketching and writing. Although assignments were required, student participation in the present study was voluntary. We gave students consent forms, in person, that allowed us to gather their curations. We emphasized that participation was optional and that it would not affect grades. For assignments using IdeaMâché, consenting to the study involves having one’s curation data be confidentially collected. While we maintain confidentiality of study participants, we believe artists should be given credit on their work. We appended our study protocol to give students the option to be attributed when we feature their creative work in our publications.

Iterative Pedagogy Design
The IdeaMâché curation system and our pedagogy for teaching it has evolved over the course of the study. We continuously improved the software and added to online documentation. In collaboration with instructors, we iteratively designed instructional materials and assignment specifications over the four semesters of this study.

In Fall ’13, we gave a lecture, supported by PowerPoint slides, which explained curation and prior work collections, relating them to Personal Information Management and bookmarks. Around half of our lecture time was supported by slides and the remaining half contained a live demo and example. Again, in Spring ’14, we used PowerPoint. The presentation began to directly incorporate concepts on ideation and clipping from the web. The presentation also began teaching the use of visual design principles to connect and differentiate elements in web curation.

The evolution of the web curation pedagogy became more pronounced in Fall ’14; instead of presenting slides, we presented in IdeaMâché. The most recent presentation curation is viewable online [http://bit.ly/1Q3g1k6]. Thus, our own pedagogy served as an example of free-form web curation. This new presentation explicitly introduced the processes of web curation, as defined in this paper: Gather, Assemble, Annotate, and Exhibit. We also addressed panning and zooming the curation space, which, in the course of writing this paper, we have named, Shift Perspective. In addition, we incorporated a set of exemplary web curations created by students in previous DPCE semesters, while performing assignments. As the pool of excellent student assignment examples grew, we were able to include them in the pedagogy. This created a feedback loop in which prior student work influenced students in subsequent semesters. Prominent visual design strategies in the new examples included extensive sketching and the use of multiple scales. Among theses example was the Children’s Peter Pan Inspired Room (Figure 3).

In Spring ’15, we increased the integration features of IdeaMâché into the introductory presentation. We developed a depiction of the five processes of web curation, using a diagram similar to Figure 2, which directly juxtaposed illustrations, demonstrations, and examples of IdeaMâché features. At the periphery of the diagram of web curation processes, Gather was juxtaposed with the “direct rich clipping” operation in IdeaMâché, a YouTube video, clippings of prior web curations, and references to relevant prior work in cognition [53, 33, 62, 2, 16, 58] and HCI [9, 56, 29].

Epistemology
Supporting design ideation through software and pedagogy in DPCE is a “wicked problem” [48]. Design problems are considered wicked when they are hard to define and involve complex issues that impact multiple outcomes. There are too many potential solutions to enumerate. There is no way to deductively identify the optimal solution. Alternatively, design research addresses wicked problems by iterative creation of artifacts: prototypes, products, services, and documentation [64]. By situating these artifacts in a particular context of use and users for evaluation, “Design researchers can both discover effects and provide a template for bridging the general aspects of the theory.”

Assessing the impact of a design solution for a wicked problem is difficult. Rittel and Webber [48] assert that wicked problems have “no stopping condition” and there is no definitive test for solutions. In the present research, our design seeks to maximize student engagement and creativity, where there is no upper bound.

Our approach confronts the difficulty of assessing the desired outcome by observing design processes and products throughout the field study. We observe that each semester-based university term constitutes a “one-shot” [48] opportunity to engage students. Students enroll in the course to learn, fulfilling their needs for satisfactory learning experiences is imperative. As design researchers, we have the opportunity to engage in design, contribute to their learning experiences in the situated context of the courses, and collect data in the process.

As a basis for comparing the effects of our design interventions, the present research investigates a sustained series of these one-shot engagements. Each engagement is similar to the last, in that the course assignments and conditions do not significantly change. Of course, some factors in the environment and curriculum, beyond what we report, inevitably do change in ways that we cannot observe.

As researchers, we worked to gain insight into our design intervention’s impact on engagement and ideation. Ascertaining what constitutes meaningful observation is part of our design research. We accomplish this by comparing mixed methods data across semesters, while enumerating changes in the curation system and pedagogy.

The forms of data that we collected and analyzed involve the students’ creative products and their engagement in curation processes. We approach creative products in two ways: (1) we perform a reading of visual data and (2) we use ideation metrics to measure aggregated components of creativity.

Creative Products: Visual Data
As visual data, exemplary student curations, in themselves, represent significant findings. Visual thinking and imagery play key roles in design research and practice [5]. The pictorial, a form of visual thinking, consists of a set of images
and associated textual explanations [8]. A pictorial articulates meaning beyond its individual parts [6]. We define visual data as an extension of the pictorial to encompass visual media beyond images and text, including sketches, maps, and video. Visual data convey direct understanding of experiences [1]. Larkin and Simon showed how diagrams, as a form of visual design expression, play a unique role in thought processes by functioning as external representations of topological and geometric components of a problem [33].

Visual representations are a meta-indexical structure [20]. A visual representation is not self-contained. Rather, it indexes multiple meanings, which become apparent through the process of visual interpretation. Through free-form web curation, students design complex visual and indexical representations. Using observed student work as visual data deepens our understanding of how web curation impacts design ideation. In this way, student work functions as visual evidence, which has been used as a primary form of data in ethnography [19]. While prior work has focused on photographs, this research investigates web curations as visual data.

Creative Products: Ideation Metrics

Ideation metrics are used as a comparative method for evaluating the aggregate effect of conditions on the creative products that study participants produce. Kerne et al. derived quantitative metrics to measure components of creativity in the curations people assemble through engagement in ideation tasks [29, 22]. They took a creative cognition approach [14], extending methods developed for engineering design [51]. These metrics are not claimed as comprehensive measures of creativity, only of components. Another approach is to use microtask workers to perform design evaluations [12]. However, it is hard to align their judgements.

In the present research, we use a subset of prior ideation metrics: Fluency and Variety. Fluency measures the number of ideas [29]. According to Darwinian theories of creativity, the more ideas a person considers, the more likely that one will survive and grow to fruition [57, 14]. We measure this by counting elements in a curation, based on media type and the specific curation process. For the Gather process, Fluency metrics address image, text, and video clippings. For the Annotate process, Fluency metrics address sketching and writing. We derive a Total Element Fluency metric through aggregation.

Variety ( / Flexibility) measures the extent of sources of information explored during ideation [29]. In creative cognition, flexibility in thinking results from drawing from a Variety of different ways of looking at a problem. We measure the Variety of the information sources and links for gathered clippings, at three levels of granularity: (1) Document Variety, (1) web Site Variety, based on domain, and (3) web Site Type Variety (measured using OpenDNS’s site categorization scheme [44]).

Creative Processes: Engagement Measures

Engagement is process oriented. To study this, we collected data about the actions students performed in IdeaMâché. We counted the frequency with which students used different features. In aggregate, this provides measures that describe how users engaged in processes of curation using our system.

RESULTS

We collected curations and logged users’ actions through our cloud service. We logged user actions using IdeaMâché’s undo/redo history stack (like [18]). Log records include event names, timestamps, and curation IDs for all user actions, such as pan, zoom, and drop clipping. We use action data to generate creative process analytics, including the amount of time and number of sessions spent authoring each curation.

<table>
<thead>
<tr>
<th>Semester</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Students</td>
<td>319</td>
<td>296</td>
<td>326</td>
<td>306</td>
</tr>
<tr>
<td>Total Curations</td>
<td>759</td>
<td>876</td>
<td>948</td>
<td>628</td>
</tr>
</tbody>
</table>

Table 2: Average time spent authoring per web curation for each semester, showing mean (\(\mu\)) and standard error (\(\sigma\)). Students spent more time, on average, engaging in web curation in the final two semesters.

To generate our corpus, we began with all curations from students in DPCE. We filtered out insubstantial curations by excluding those with fewer than five elements or less than five minutes of engagement. This resulted in a corpus of 3211 curations. Table 1 shows how may students participated and how many curations they authored in each semester. Students spent a combined total of 6007 hours engaged in the curation process over all semesters. This measurement of active time excludes breaks of two or more minutes (Table 2).

Creative Products: Visual Data

In this research, visual data plays an important role among mixed methods. Visual data convey meaning that cannot be captured by numeric or verbal or verbal forms. We observed visually and conceptually compelling curations authored by students for DPCE, which synthesized diverse and compelling ideas. Figure 1 and 3 are exemplary curations which directly depict the products of students’ design ideation.

Children’s Peter Pan Inspired Room (Figure 3) contains ideas and plans for a personal home decorating project. Williams uses spatial arrangement to create distinct groups of rich clippings. She sketched arrows to show how each group relates to other another and she uses a scaled image of Neverland to connect the groups as a whole.

In the curation SpeedDemon (Figure 1), the author has gathered and assembled diverse content: a video of hurricane weather, patents of airbag related technologies, and images of motorcycle helmets and suits. The author’s writings and sketches explain how these components are combined into a new concept, a smart suit with “air bags all over your body”. SpeedDemon’s rich clippings represent 29 unique source web pages (Document Flexibility), encompassing art, toys, furniture, and do-it-yourself tutorials.
Table 3: Table of Fluency and Variety ideation metrics of creative products, complementing Figures 4 and 5. All ideation metrics, except for Text Clipping Fluency, increased across the four semesters of the study. In bold, we highlight the magnitude of change per semester ($m$), when fit to a linear regression. For example, students tend to gather, sketch, and write 7.4 more elements on average each semester. In addition to the mean ($\mu$) and standard error ($\sigma$) for each semester, we present $m$ (slope), $b$ (intercept), closeness to fitted line ($r^2$), and significance ($p$) statistics of the linear model.

<table>
<thead>
<tr>
<th>Ideation Metric</th>
<th>$\mu_1$</th>
<th>$\sigma_1$</th>
<th>$\mu_2$</th>
<th>$\sigma_2$</th>
<th>$\mu_3$</th>
<th>$\sigma_3$</th>
<th>$\mu_4$</th>
<th>$\sigma_4$</th>
<th>$m$</th>
<th>$b$</th>
<th>$r^2$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Element Fluency</td>
<td>27.0</td>
<td>0.7</td>
<td>34.0</td>
<td>0.9</td>
<td>45.0</td>
<td>1.3</td>
<td>48.0</td>
<td>1.7</td>
<td>7.4</td>
<td>20.0</td>
<td>0.053</td>
<td>1e-39</td>
</tr>
<tr>
<td>Image Clipping Fluency</td>
<td>15.0</td>
<td>0.5</td>
<td>16.0</td>
<td>0.5</td>
<td>24.0</td>
<td>0.8</td>
<td>25.0</td>
<td>1.1</td>
<td>4.1</td>
<td>10.0</td>
<td>0.039</td>
<td>1e-28</td>
</tr>
<tr>
<td>Writing Fluency</td>
<td>7.6</td>
<td>0.3</td>
<td>11.0</td>
<td>0.3</td>
<td>13.0</td>
<td>0.5</td>
<td>13.0</td>
<td>0.6</td>
<td>2.0</td>
<td>6.3</td>
<td>0.031</td>
<td>1e-22</td>
</tr>
<tr>
<td>Video Fluency</td>
<td>0.5</td>
<td>0.0</td>
<td>0.5</td>
<td>0.0</td>
<td>1.1</td>
<td>0.1</td>
<td>1.3</td>
<td>0.1</td>
<td>0.3</td>
<td>0.1</td>
<td>0.023</td>
<td>1e-17</td>
</tr>
<tr>
<td>Sketch Fluency</td>
<td>2.2</td>
<td>0.1</td>
<td>4.4</td>
<td>0.2</td>
<td>4.9</td>
<td>0.2</td>
<td>6.5</td>
<td>0.3</td>
<td>1.3</td>
<td>1.2</td>
<td>0.046</td>
<td>1e-34</td>
</tr>
<tr>
<td>Text Clipping Fluency</td>
<td>2.2</td>
<td>0.2</td>
<td>1.6</td>
<td>0.2</td>
<td>1.1</td>
<td>0.1</td>
<td>1.3</td>
<td>0.1</td>
<td>0.3</td>
<td>0.1</td>
<td>0.023</td>
<td>1e-17</td>
</tr>
<tr>
<td>Document Variety</td>
<td>19.0</td>
<td>0.6</td>
<td>24.0</td>
<td>0.8</td>
<td>40.0</td>
<td>1.3</td>
<td>40.0</td>
<td>2.0</td>
<td>8.4</td>
<td>10.0</td>
<td>0.061</td>
<td>1e-44</td>
</tr>
<tr>
<td>Site Variety</td>
<td>11.0</td>
<td>0.4</td>
<td>14.0</td>
<td>0.4</td>
<td>20.0</td>
<td>0.6</td>
<td>21.0</td>
<td>0.9</td>
<td>3.6</td>
<td>7.6</td>
<td>0.048</td>
<td>1e-35</td>
</tr>
<tr>
<td>Site Type Variety</td>
<td>5.4</td>
<td>0.1</td>
<td>5.4</td>
<td>0.1</td>
<td>6.8</td>
<td>0.1</td>
<td>6.7</td>
<td>0.2</td>
<td>0.6</td>
<td>4.7</td>
<td>0.021</td>
<td>1e-15</td>
</tr>
</tbody>
</table>

Figure 4: Graph showing mean number of elements per curation, across clipping types, by semester of the study, with standard error bars. The aggregate, Total Element Fluency, increases at a rate of $m = 7.4$ elements per semester (see Table 3). The largest increase is between the second and third semester. This increase in Fluency coincides with our articulation of the web curation processes in the pedagogy.

Creative Products: Ideation Metrics

We calculated Fluency and Variety ideation metrics for each DPCE curation in our corpus. We then calculated mean and standard error statistics for each of the four semesters in the study (See Figures 4, 5, and Table 3). In analyzing this data, we hypothesized that students would gather more elements from more diverse sources, and annotate more, as our design intervention proceeded. To test this hypothesis, we fit a linear regression for each Fluency and Variety metric, with semester number as the independent variable and ideation metrics as the dependent. This test yields slope ($m$) intercept ($b$) goodness of fit ($r^2$) and $p$. A low $p$ value indicates a significant relationship between independent and dependent variables. The $r^2$ values represent the ratio of variance predicted by the regression model. Our $r^2$ are relatively low, which indicates that the semester alone, while statistically significant, does not explain most variance. This reflects the nature of the data; student activity is highly variable.

The linear regression provides the slope of a line from the first to last $x$ value. We report the slope ($m$) for each regression, which measures the average change across semesters. For example, $m = 7.4$ for Total Element Fluency means that the number of gathered clippings plus annotations in student curations increased at this average rate per semester.

Fluency metrics (Figure 4 and Table 3, top) show increasing quantity of collected and authored elements per curation. Students became motivated to work more. The exception is text clippings. These fell at a rate of $m = -0.27$ per semester, an order of magnitude smaller than the increase in image clippings of $m = 4.1$ per semester. This might indicate that using image clippings to represent documents is becoming more common socially (e.g. images that link to articles on Facebook). Future research can investigate how to motivate more integration of written and visual scholarship.

Variety metrics (Figure 5 and Table 3, bottom) show increasing diversity of media clippings’ sources. The number of source documents, web sites, and types of web sites grew over the course of the study. This indicates that as the design intervention evolved, students incorporated more diverse viewpoints into their curations.
**Table 4**: Table of engagement measures of creative processes, per curation, complementing Figure 6. There was an overall increase in engagement across the four semesters of the study. In bold, we highlight the magnitude of change per semester \((m)\), when fit to a linear model. For example, scale \((m = 17)\) and zoom \((m = 23)\) increased at a rate of around 20 actions per semester. In addition to the mean \((\mu)\) and standard error \((\sigma)\) for each semester, we present \(m\) (slope), \(b\) (intercept), closeness to fitted line \((r^2)\), and significance \((p)\) statistics of the linear model.

<table>
<thead>
<tr>
<th>Process</th>
<th>Measure</th>
<th>(\mu_1)</th>
<th>(\sigma_1)</th>
<th>(\mu_2)</th>
<th>(\sigma_2)</th>
<th>(\mu_3)</th>
<th>(\sigma_3)</th>
<th>(\mu_4)</th>
<th>(\sigma_4)</th>
<th>(m)</th>
<th>(b)</th>
<th>(r^2)</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gather</td>
<td>Drag and Drop</td>
<td>36.0</td>
<td>1.1</td>
<td>45.0</td>
<td>1.5</td>
<td>68.0</td>
<td>6.7</td>
<td>63.0</td>
<td>2.4</td>
<td><strong>11.0</strong></td>
<td>27.0</td>
<td>.009</td>
<td>1e-07</td>
</tr>
<tr>
<td>Assemble</td>
<td>Position</td>
<td>140.0</td>
<td>5.9</td>
<td>150.0</td>
<td>6.5</td>
<td>240.0</td>
<td>17.0</td>
<td>280.0</td>
<td>36.0</td>
<td><strong>50.0</strong></td>
<td>76.0</td>
<td>.011</td>
<td>1e-08</td>
</tr>
<tr>
<td>Assemble</td>
<td>Scale</td>
<td>39.0</td>
<td>1.6</td>
<td>50.0</td>
<td>2.0</td>
<td>79.0</td>
<td>7.2</td>
<td>83.0</td>
<td>9.5</td>
<td><strong>17.0</strong></td>
<td>21.0</td>
<td>.012</td>
<td>1e-09</td>
</tr>
<tr>
<td>Assemble</td>
<td>Refine</td>
<td>21.0</td>
<td>1.1</td>
<td>24.0</td>
<td>1.3</td>
<td>38.0</td>
<td>2.2</td>
<td>43.0</td>
<td>6.3</td>
<td><strong>7.9</strong></td>
<td>12.0</td>
<td>.010</td>
<td>1e-07</td>
</tr>
<tr>
<td>Shift Perspective</td>
<td>Pan</td>
<td>140.0</td>
<td>6.0</td>
<td>190.0</td>
<td>8.3</td>
<td>260.0</td>
<td>14.0</td>
<td>290.0</td>
<td>17.0</td>
<td><strong>53.0</strong></td>
<td>88.0</td>
<td>.025</td>
<td>1e-18</td>
</tr>
<tr>
<td>Shift Perspective</td>
<td>Zoom</td>
<td>36.0</td>
<td>2.4</td>
<td>73.0</td>
<td>4.0</td>
<td>96.0</td>
<td>4.9</td>
<td>100.0</td>
<td>5.7</td>
<td><strong>23.0</strong></td>
<td>20.0</td>
<td>.037</td>
<td>1e-27</td>
</tr>
<tr>
<td>Annotate</td>
<td>Sketching</td>
<td>40.0</td>
<td>2.4</td>
<td>70.0</td>
<td>3.8</td>
<td>130.0</td>
<td>9.0</td>
<td>180.0</td>
<td>17.0</td>
<td><strong>48.0</strong></td>
<td>-17.0</td>
<td>.039</td>
<td>1e-29</td>
</tr>
<tr>
<td>Annotate</td>
<td>Writing</td>
<td>23.0</td>
<td>0.9</td>
<td>32.0</td>
<td>1.2</td>
<td>39.0</td>
<td>2.6</td>
<td>34.0</td>
<td>1.5</td>
<td><strong>4.4</strong></td>
<td>22.0</td>
<td>.008</td>
<td>1e-06</td>
</tr>
</tbody>
</table>

Figure 6: Graph showing the mean count of actions performed per curation, by semester. In general, students performed more actions per curation as the study progressed. Pan and position are the most common actions, followed by sketch, zoom, scale, gather, assemble refine, and writing. The pronounced increase in student engagement from the second to the third semester corresponds to increases in Fluency and Variety during the same period. See Table 4 for exact values.

**Creative Process: Engagement Measures**

We measure engagement in curation processes by analyzing user actions. Our analysis shows students gathered, assembled, shifted perspective, and annotated as they synthesized and articulated larger ideas (Figure 6). The engagement measures that we derived are: **Gather**, Drag and Drop of content onto the curation space; **Assemble**, Position, Scale, and Refine (aggregating rotate, blend, crop, layer, and delete) of elements; **Shift Perspective**, Pan and Zoom of the curation space; and **Annotate**, involving Write, and Sketch.

We calculated the mean number of times, per curation, that students performed these process actions (Table 4). Again, noticing an upward trend, we fit each process action measure to a linear regression, using the same method as the section above. All engagement measure slopes are positive and statistically significant. This helps us reason the amount of increase in each web curation design process. Pan \((m = 53)\) and position \((m = 50)\), and sketch stroke \((m = 48)\) have increased at around the same rate, around 50 more times per semester. Sketching actions increased by a factor of 4.5 from the first to last semester. Sketch Fluency, the number of sketch elements, only had a 3 fold increase. We interpret this to mean that sketches in later semesters were more detailed.

**DISCUSSION**

Through design research, we iteratively changed the web curation system and associated pedagogy. We observed differences in student ideation work, in response to these design interventions. This section addresses free-form web curation, its processes, and how to investigate through design research in the classroom.

**Free-form Web Curation**

According to Manovich, “In the process of interaction [with new media], the user can choose which elements to display or which paths to follow [37].” Free-form web curation provokes users to continuously resituate themselves, and so constitutes new media. Free-form web curation is inherently multi-scale. Users repeatedly shift perspective in the course of authoring and viewing experiences.

Through process measures, we observed that students continuously increased their engagement in free-form web curation during the course of our design research. Specifically, among these, Sketching and Shift Perspective constitute visual thinking and, more broadly, an artistic sense of curation. There was a particular increase in sketching as the study progressed. Further, we observed an increase in the Shift Perspective actions of pan and zoom. These actions are integral to spatial arrangement. These findings show that students engaged in visual thinking, through an art-inspired form of web curation, to perform their design ideation assignments.

Because the amount of useful content is increasing, new techniques for managing and understanding are necessary. Kolko shows that creating a ‘big wall’ of clipped content, annotation and connecting ideas, is a common practice of designers, who engage in synthesis [32, 31]. Curation media need to support big wall design processes, creating ways to gather, organize, manipulate, prune, and filter diverse and extensive forms of content. The visual data and ideation metrics show that free-form web curation supports design ideation by functioning as a digital ‘big wall’, enabling users to synthesize diverse and extensive content. Synthesis in students’ web curations manifests everyday design [59] and mini-c creativity [24].
Free-Form Web Curation Processes
The identified processes—Gather, Assemble, Shift Perspective, Annotate, and Exhibit—provide valuable framing for web curation. The identification of these processes came about through our design research, as we developed ways to teach web curation. Our mixed methods analysis shows that students engaged in these processes of free-form web curation. As a component of 21st century media literacy, knowing and understanding processes of free-form web curation has the potential to be valuable for students, educators, and practitioners across disciplines and levels.

We assert that these processes are inherent to curation, arising in diverse contexts. Like the observed student curators, professional museum curators engage in similar processes of gathering pieces, placing and arranging them in a gallery space, writing label texts, and overseeing exhibitions [10]. Pinterest users also engage in the Gather and Exhibit processes of web curation, but the Pinterest board de-emphasizes the Assemble process. In Pinterest, Assemble is performed automatically, based on the order of gathering clippings.

Incorporating free-form web curation processes into curriculum apparently stimulated students’ engagement in them. Both ideation metrics and engagement metrics increased most between semesters two and three. This timing coincides with substantial changes in the evolving pedagogy. Specifically, as described in the Iterative Pedagogy Design subsection, we (1) presented using free-form web curation, with IdeaMâché; (2) integrated the articulation of web curation processes; and (3) incorporated exemplary student work from assignments (exhibited) into our presentation.

Design Research in the Classroom
We address the process of conducting on-going design research in the classroom, how the classroom is a useful context for design research, and the role of pedagogy. Supporting student design ideation is a wicked problem, which must be studied in a real context. While we do not claim that our study methodology is the best way to investigate student ideation, it constitutes a real context, in which students and instructors are stakeholders.

Our study context is a university classroom, not a laboratory environment. Conducting research in this context enables and requires us to foster a close relationship with the course instructors. There was significant risk involved in our field study. Poor performance of our research software could jeopardize students’ educational experiences, as well as our relationship with the course. This level of risk instantiates the wicked problem of ‘one-shot’ studies [48]. We argue that our field study procedure of repeated one-shot engagements constitutes a methodology contribution for the wicked problem of how to conduct design research in classroom contexts.

We used quantitative data as one of our lenses for understanding the effects of articulating and supporting the web curation processes. We recognize that our field study features no control condition. The quantitative data does not prove that this method works. Rather, our analysis, which makes comparisons across four semesters, presents one portrait of our process of engagement with DPCE students. Specifically, we see increases in both the extent of the creative products created by students and in their engagement in processes of free-form web curation. Maximizing student engagement and creativity has “no stopping condition” [48], yet our approach and findings address assessment. The increases suggest that our articulation of the web curation processes, as articulated through the IdeaMâché system and associated pedagogy, stimulated and sustained student design ideation. The importance of the iterative design of pedagogy in design research in the classroom cannot be overstated.

Using quantitative measures over time served as an effective lens for observing the impact of design interventions in this situated context. We thus argue for the place of ideation metrics and engagement measures in the design research toolbox, along with visual and qualitative data.

We drew from the work of previous participants to support teaching new ones. Through this process, student participants had lasting impact on pedagogy and future undergraduate designers. As our intervention improved, student work examples improved, which fed back to stimulate further improvements in student work.

CONCLUSION
We conducted design research to investigate supporting student design ideation with free-form web curation. Free-form web curation involves collecting and organizing information, emphasizing visual thinking and artistic sensibility. We developed IdeaMâché, a free-form web curation system. We conducted a field study, situated in the context of an undergraduate course on creativity and entrepreneurship. Over the course of the study, we identified the processes of free-form web curation—Gather, Assemble, Shift Perspective, Annotate, and Exhibit—and articulated them in pedagogy.

Our field study addressed a wicked problem, supporting student design ideation, through a series of one shot semester engagements. This enabled us to assess changes across semesters. These semester comparisons are valuable in understanding the effects of design interventions in the non-controlled environment of the classroom. We combined visual data, ideation metrics, and process measures to understand the impact of our design interventions. Our results show that students performed free-form web curation as part of design ideation. Student ideation and engagement increased over the course of our study. We attribute these increases to the identification and articulation of the processes of free-form web curation.

In the course, undergraduate students from diverse backgrounds, with no particular training, used free-form web curation as a means to draw on the information resources of the internet to engage in design ideation through visual thinking. While these findings are situated in one particular course, they suggest the potential for free-form web curation to support ideation in diverse intellectual contexts.

REFERENCES
11.


