Collaborative Live Media Curation:
Shared Context for Participation in Online Learning

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ABSTRACT

In recent years, online education's reach and scale have increased through new platforms for large and small online courses. However, these platforms often rely on impoverished modalities, which provide limited support for participation in social learning experiences. We present Collaborative Live Media Curation (CLMC), a new medium for sharing context and participation in online learning. CLMC involves collaborative, synchronous collection, creation, and assemblage of web media, including images, text, video, and sketch. CLMC integrates live media including streaming video, screenshares, audio, and text chat. We deploy and study LiveMâché, a CLMC technology probe, in four situated online learning contexts. We discovered student and instructor strategies for sharing context and participating including creating curations in advance, sketching to illustrate and gesture, real-time transformations, sharing perspective, and assembling live streams. We develop implications through live experience patterns, which describe how spatial and computing structures support social activities.

ACM Classification Keywords

H.5.3 Group and Organization Interfaces

Author Keywords

live streaming, curation, participation, context, online learning

INTRODUCTION

This research addresses the need for shared context [21, 46] and participation [51, 30] in online learning experiences by synthesizing two recent forms of new media—live streaming [27, 73] and free-form web curation (FFWC) [56, 41]—to create the new form of *collaborative live media curation (CLMC)*. In recent years, massive open online courses (MOOCs) have expanded the reach and scale of education. There has also been an emergence of small private online courses (SPOCs), which rely more on small group learning experiences [20, 80]. Both MOOCs and SPOCs draw on prior media, including

asynchronous forms, such as pre-recorded YouTube lectures [26] and student discussion forums [10]. Some are starting to also employ synchronous media tools, like chat rooms [8] and Google Hangouts [49]. Alas, these modalities provide limited support for participatory learning experiences, in situated social contexts, which have been shown to be critical for learning [51, 31]. Research in communication has shown the importance of shared visual context for conversational grounding in collaborative tasks and distance learning [21, 46]. To address these needs, we develop a new medium for creating online contexts for participatory learning experiences.

We incorporate live streaming, an emerging form of social media, because it has been found to afford sharing rich experiences and participating in them [27]. Platforms such as Twitch [27], Periscope [73], and Facebook Live [55] have enabled new live streaming practices. These platforms combine streaming audio/video of live action with other synchronous and asynchronous communication modalities. This combination of modalities has been shown to provide shared context, which supports online community formation [27].

We build on the the medium of free-form web curation, which has been show to help students engage in visual thinking [56] and creatively engage with prior work to conceive, synthesize, and express new ideas [41]. In art, curation means the creative conceptualization and design of an exhibition context [61]. Curators arrange and interpret elements in an exhibition space, to stimulate active engagement and produce cultural meaning. *Free-form web curation* is a computational medium that enables multimedia elements to be spontaneously collected from the web, written about, sketched amidst, manipulated, and visually assembled—in a continuous zoomable space—in order to create conceptual and spatial contexts [56].

Collaborative Live Media Curation extends free-form web curation. CLMC integrates live streaming modalities—e.g., webcam video, screenshares, audio, and text chat (see Figure 1)—to support participating in shared learning experiences. Further, where prior implementations of FFWC only supported a single user at a time [56, 41], CLMC incorporates *collaborative and synchronous* collection and assemblage of media elements, which becomes a new live communication modality. Through this work, we explore the following research questions: How do students and instructors use CLMC to support and engage in learning activities? How can we further support participation in online learning experiences?

To explore these research questions, we design and develop LiveMâché [50], a technology probe [33], for collaborative live media curation. We deployed the LiveMâché probe in four situated online learning contexts to provoke and collect data about new experiences. During these situations we observed emergent strategies for sharing context and participating in learning activities using CLMC. We also develop implications through live experience patterns, which describe how spatial and computing structures support social activities.

PRIOR WORK

To frame the present research, we weave together prior work across fields, including participation and media in online education, participation in live streaming, and sharing visual context for conversational grounding. Finally, we incorporate the medium of free-form web curation, and its strategies for contextualization, which we extend to form collaborative live media curation.

We draw on Cohen's articulation of the terms media and modalities [11]. He uses the term "medium" to refer to the holistic "production, storage, and transmission by the machine of signals" [11]. Alternatively, he uses "modality" to "concentrate on the syntactic, semantic, and pragmatic properties of the signal" [11]. We use *medium* to refer to holistic tools (e.g live streaming or CLMC), while using *modality* to refer to specific communication channels (e.g. text chat or screenshares).

Participation and Media in Online Learning

According to Lave and Wenger, "Learners inevitability participate in communities of practitioners... the mastery of knowledge and skill requires newcomers to move toward full participation in the sociocultural practices of a community" [51]. In this way, learning, as a process, is not simply individual. It takes place in inherently social situated contexts. "Learning, thinking, and knowing are relations among people in activity in, with, and arising from the socially and culturally structured world" [51]. Much recent online learning research holds that participation and social engagement are at the core of learning processes [12, 72, 63, 31]. Hrastinski develops a theory of online learning as participation, synthesizing social and constructivist views on learning [31]. Other researchers have studied the effects of asynchronous and synchronous media on learner participation [32, 30]. Asynchronous media, such as wikis, blogs, and forums, have been shown to afford student reflection and discussion, but discussion can be hard to initiate [29]. Synchronous media in online courses, such as video conferences and text chat, foster more overall dialogue, addressing task planning and social support [29].

In a few MOOCs, instructors have deployed live media forms to foster student participation. Cambre et al.'s Talkabout system enables small-group discussions of 4–6 students in MOOCs using Google Hangouts [6, 52]. Talkabout randomly assigns students to small group discussions based on their availability. Other work has explored the use of synchronous text chat in MOOCs [9]. CLMC goes beyond the separate windows of text chat and Google Hangouts, enabling participants to assemble and interact with media to create more integrated situated contexts for online learning activities.

Live Streaming for Participation

Live streaming has emerged over the past decade as a new form of social media. Platforms have ranged from the now defunct Qik and Bambuser [39], to Twitch [27], to Periscope [74], and now Facebook Live and Instagram [55]. We observe that live streaming practice [27, 55] and research has shifted towards shared experiences [59, 34, 66, 57]. Live streaming shared experiences has led to the formation of new online communities through participation and shared histories [27, 55]. In the present research, we support shared participatory learning experiences using a new form of live media.

Prior research has explored how new modalities support participation and agency in live experiences. Jo and Hwang [35] explored viewpoint control and direct sketching on video to support viewer communication during video calls. Kim et al. [44] found that providing contextual information, such as maps and high resolution photographs, enabled viewers to participate by pointing out things to a remote streamer. Yonezawa and Tokuda [78] found that enabling remote viewers to control the light and camera angles of live music performance broadcasts engaged viewers and helped connect performers and their audiences. Webb et al. prescribe new modalities for feedback and participation between audiences and performers [75]. Hamilton et al. explored how live streaming modalities, such as push-to-talk audio and Periscope-style hearts, afford new forms of participation in multi-stream experiences [28].

Other work has investigated collaborative production of live media experiences. Engström et al. explored systems supporting the collaborative production of mobile live streams [15, 17, 18]. Juhlin et al. reported on the practices of amateur [38] and professional [16] broadcasters. Finally, Sa et al. designed an application supporting collaborative mobile broadcasting by providing awareness of nearby streams [68]. CLMC is a new medium for collaborative live production and participation.

Conversational Grounding: Shared Context

Prior research has investigated the role of shared visual context in collaborative work [21, 48, 47, 24]. Fussell et al. argue that developing virtual co-presence through shared visual and linguistic context is critical for establishing common ground, information that all participants in an activity are aware of [7, 21]. Conversational grounding is the iterative process by which participants exchange information to frame shared understanding [7]. Kraut et al. later showed that media providing shared visual context enables participants to more effectively complete complex tasks using deixis [48]. Deixis is the use of deictic language, i.e. language dependent on context, such as other language, gestures, or images, e.g., pointing at "that". In the present research, we show how CLMC enables participants to perform deixis to ground discussion around complex ideas through shared visual and linguistic context.

Others investigated the use of remote gesturing in collaborative work [62, 45] and instruction [46]. Fussel et al., in work investigating pointing and sketch gestures on live video to support collaborative tasks, argue that gestures facilitate grounding by enabling participants to simultaneously communicate multiple pieces of information [22]. Kirk et al. found remote gesturing benefits remote instruction and learning [46]. Citing Clark

[7], McNeill [58], and Kendon [40], they argue that the performance of gesture, to contextualize language, supports the construction and communication of meaning [46]. Much prior work on shared visual context and gestures focuses on performance and the efficiency of physical collaborative tasks [21, 48, 46, 45, 47, 24]. In this work, we do not focus on physical tasks, but report on emergent use of CLMC for sharing context and performing gesture in online learning activities.

Free-form Web Curation: Creating Context
Free-form web curation (FFWC) is a visual medium for collecting and assembling media, in order to support creative cognition and the emergence of new ideas [56, 41]. FFWC is inspired by *curation* in art—the conceptualization and creation of a *context*, in which works are found, collected, interpreted, and arranged—to stimulate active engagement and visual thinking [60].

Strategies of free-form web curation were articulated based on diverse artistic and scholarly practices: Collect, Assemble, Shift Perspective, Sketch, Write, and Exhibit [41]. Students made extensive use of the strategies in creative engagement with prior work [41]. FFWC was also shown to support students in visual thinking [56]. To support participation in learning activities and other CSCW, this research extends FFWC to develop a new collaborative and social medium, with synchronous support for multiple users and live streaming media.

Collect is the gathering of content elements. The diversity of collected elements promotes ideation [71, 77, 42]. Central to the collect strategy is the *found object*, a conceptual technique in which one takes an ordinary article, exhibits it with a new title, places it in a new context, and so transforms its meaning [54]. The current probe enables diverse media types to be collected from the web.

The *Assemble* strategy involves visual organization of elements to express relationships and convey meaning. In art, *assemblage*—the process and means of fastening found objects together—is used to highlight duality and tension between the original and resulting contexts of found objects [70]. In FFWC, this has been shown to promote creative cognition of relationships among collected media elements, supporting ideation [43, 53, 41].

Shift perspective involves navigating a curation space to different views. Here, this is accomplished with a zoomable user interface [5]. *Sketch*, which involves making marks depicting abstract or concrete relationships or ideas, has been shown to be a generative means for design ideation [25]. *Write* is the articulation of ideas through text; shorter writing involves labeling categories; longer writing involves exposition. *Exhibit* involves sharing, experiencing, and engaging in discourse.

LIVEMÂCHÉ PROBE
In order to explore the use of CLMC in online learning contexts, we designed and developed LiveMâché [50] for use as a technology probe. LiveMâché is a cloud based web application implementing collaborative free-form web curation. The probe integrates typical live streaming modalities including text chat as well as streaming audio and video. Finally, LiveMâché

supports participant roles and sharing perspective. We present here the design motivations and resulting capabilities of the LiveMâché probe.

Collaborative Free-Form Web Curation
To enable the collaborative creation of media curations, for supporting live learning activities, the LiveMâché probe brings synchronous collaboration to the FFWC strategies: collection, assemblage, sketching, writing, shifting perspective, and exhibiting [41]. Users can collaborate both synchronously and asynchronously to collect a wide range of media from the web and their personal devices. They assemble collected elements in a shared, near-infinite zoomable canvas. They use visual transformation, updated in real-time, to further relate and synthesize elements. Collaborative sketching and writing help users think about and communicate ideas.

Real-time Collecting and Assembling
In order to support flexible collecting of content, the LiveMâché probe enables gathering and transforming media elements—including images, text snippets, videos (YouTube and Vimeo), Google Docs, and Google Maps—from the web. Users collect content directly from their web browser or file system by dragging and dropping it into the zoomable curation canvas (Figure 1). The canvas is a near-infinite zoomable space in which the user can pan and zoom their viewport using the mouse or keyboard. Each curation begins as an empty space with no predefined or suggested structure. As soon as an element is dropped onto the canvas, it immediately becomes visible to all other users. Users assemble their curation as they gather and arrange elements.

In order to support the development of ideas and construction of new meanings, LiveMâché enables expressive visual assemblage through graphical transformation of media elements, e.g., position, scale, rotation, and layer. Any element can be repositioned by clicking and dragging it to a new location. When collected, an element's initial scale is determined by the zoom level of the user's viewport. Elements can be scaled larger or smaller at any time. Scaling elements, in conjunction with the zoomable user interface, enables users to create arrangements which span multiple levels of scale. Layer transformations enable users to position elements behind or in front of others. All visual transformations are synchronized, in real-time, across all instances of a curation.

Real-time Sketching and Writing
To support authoring and annotation of ideas, the LiveMâché probe supports collaborative sketching and writing. Users can freely sketch within a curation. These sketches can be on empty sections of the canvas or they can overlap other elements. Users can adjust the size and shape of the sketching brush and select a color from a preset palette. While a user is sketching, other users see the partial sketch, in vivo, as it is drawn. Our motivation for supporting lightweight sketching, is to support visual thinking [3] and the expression of the images and forms in the minds' of the users [25].

Similarly, collaborative writing supports exposition, which involves labeling, explaining, expounding, and verbally illustrating. Within the curation, users are able to create, edit, or
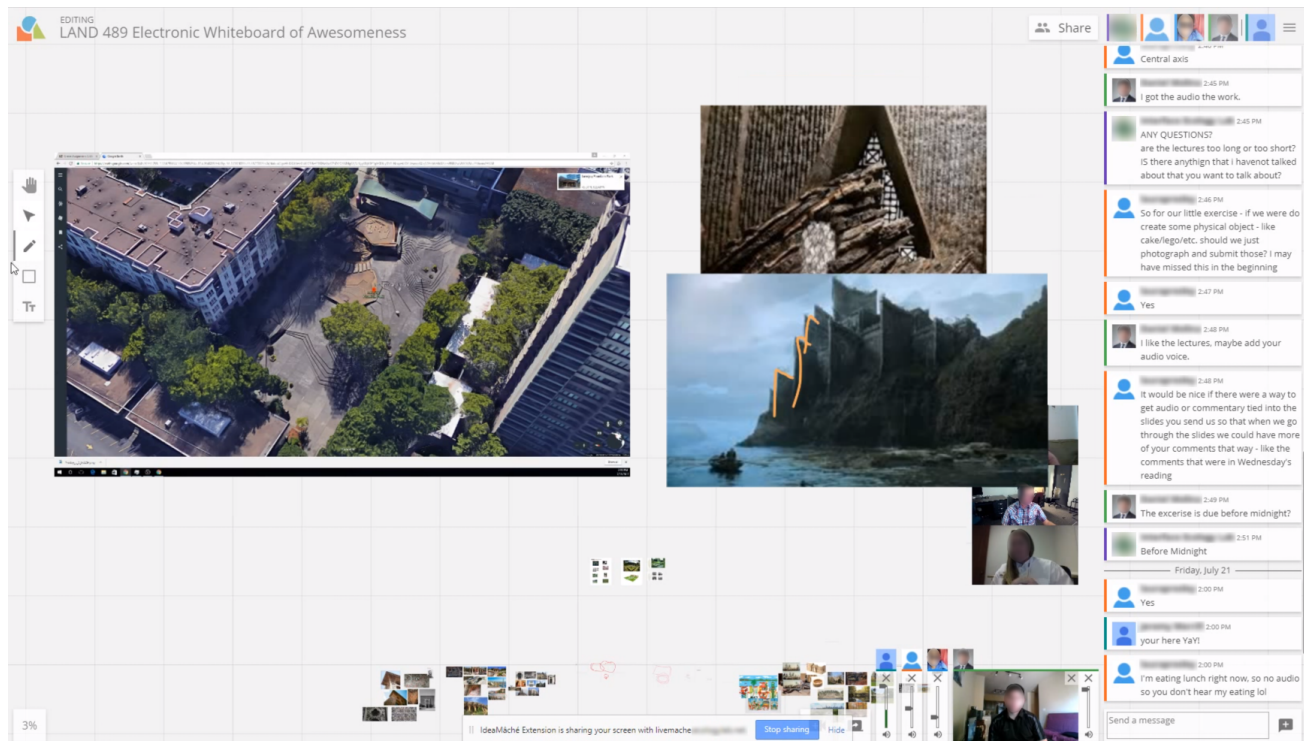
Figure 1. The LiveMâché probe implements CLMC, providing a synchronized media assemblage space (center). It also integrates live modalities including text chat (right), live streaming audio and video (bottom right, and middle right), and screensharing (center left). In this observed example, C4I is discussing the landscape architecture of a park using a screenshare of Google Earth on the left. He asks his students if the park's architecture reminds them of other contexts they have seen. C4S1 responds that it reminds her of Dragonstone from HBO's popular television show Game of Thrones. She then collects two images of the fictional castle to ground her point. C4I proceeds to sketch on and discuss the castle's architecture.

paste in text elements. Text can be created, layered, and manipulated in the same manner as as all other curation elements. By default, the initial font size of a newly created text element will automatically scale in relation with the current viewport zoom level. As a user edits a single text element, changes are continuously synchronized in real-time. While only one user can edit a text element at a time, different text elements can be edited simultaneously by different users.

Viewport Following

To support sharing perspective in collaborative curations' exhibition experiences, we incorporate tools for following viewports in LiveMâché. The viewport is the mechanism that controls what each user sees. In FFWC, users engage in the shift perspective strategy to situate their view of a curation. We developed *viewport following* to enable users to continuously shit perspective with another user. To follow another user, a participant simply clicks on their avatar in the upper right of the interface (see Figure 1). While following another user's view, the user's viewport is continuously centered on the same point as the followed viewport. A minimum zoom level, encompassing the followed user's viewport, is then used. During continuous perspective shifts, such as zoom and pan, the following user's view is updated at approximately 20Hz. In order to stop following another user's perspective, a user directly retakes control, moving their own viewport by panning or zooming. If a user tries to follow a user who is currently following a third user's viewport, they automatically start following the third user.

Live Media Modalities

In order to support sharing experiences and participating in learning activities, the LiveMâché probe integrates communication modalities that have become typical in live streaming: e.g., synchronous text chat, video, and audio. These modalities have been shown to support shared context, communication, and participation in live experiences [27, 28].

Text-Chat

Text chat has been shown to serve as a light-weight, non-intrusive communication modality, supporting participation by large numbers of users [37, 27]. LiveMâché incorporates persistent text chat, overlaid on the right side of the curation space (see Figure 1). Messages are displayed with the sending user's avatar and a timestamp. Chat messages can be collapsed to provide a greater view into the curation space.

Live Streaming Audio and Video

In order to support real-time discussion and views of activity, LiveMâché enables adding live streaming audio, webcam video, and screenshares into shared curations. Audio and webcam video streams are added to a curation using a modal dialog, allowing the participant to select and preview the desired video and audio source (not shown). Once added, webcam video thumbnails and audio stream controls are shown in an overlaid, fixed dock in the lower right hand (Figure 1).

In the dock, audio streams are represented as small meters. These meters include a slider knob for adjusting each respective audio stream's volume. Audio volumes are synchronized

for each client, enabling participants to control the shared volume mix of the curation. Each meter also displays a dynamic green bar representing the audio activity for its respective audio stream. Video streams in the dock are rendered as small video thumbnails alongside each participant's audio meter. Each participant's streams in the dock are displayed together along with their avatar and name on hover (Figure 1).

In early testing, we found it is often is more appropriate for webcam video and audio to be situated independently of a user's shifting perspective. A participant's facial expression and speech is often important for the whole activity context, not at a location in the curation. For this reason, webcam video and audio tools are initially placed in the dock. However, if a participant wants to situate a webcam view within the media assemblage of the curation, LiveMâché supports simply dragging live video streams directly into the shared curation space. The video is then directly embedded in the curation and can be transformed like other media elements. Video elements can be moved back to the dock using an on hover button.

Participants can add live screenshare streams into the curation (Figure 1). To do so, they must install a browser extension, to meet security requirements. In early deployments, we found that screenshare streams are most likely to be used for sharing views of activity. Thus, LiveMâché automatically adds screenshares into the composition space instead of the dock, where they can be readily assembled with other media elements.

To capture and broadcast participant audio and video streams, LiveMâché uses the open source Jitsi Videobridge project [65]. Jitsi Videobridge enables web clients to send and receive media streams using WebRTC, an emerging web standard for real-time communication [1]. By using Jitsi Videobridge and WebRTC, LiveMâché functions as a collaborative web-based live media curation space, the first we are aware of.

Prior work found that combining multiple video streams—particularly video streams of people and views of activity—effectively supports sharing, participating, and collaborating in live experience [76, 34, 27, 28]. We modified Jitsi Videobridge to support multiple video streams from a single client. Low latency in communication modalities is critical for efficient communication and grounding in collaborative tasks [23]. LiveMâché is able to transmit video and audio streams with sub-second latency. LiveMâché also utilizes Simulcast, a WebRTC feature for on the fly adjustment of video resolution for balancing quality and bitrate [13].

Permissions and Roles
In live streaming practice, in order to organize participatory experiences, streamers often make decisions about when and how their viewers can engage through modalities, such as gameplay, text chat, or voice [27]. Thus, we wanted to support instructors and students in making decisions about how other participants can engage and applying structure to their curations and activities. To this end, LiveMâché implements a basic permissions and participant roles system, drawing from observed practice and capabilities in other collaborative tools.

Similar to Google Docs, curation authors are able to make their curations public or private. Public curations can be viewed by anyone who has the link. Meanwhile, private curations are only shared with users who are explicitly assigned a role.

Authors can assign users one of three predefined roles: *viewer*, *commentator*, and *editor*. We model these on roles observed in live streaming practice, on platforms such as Twitch [27]. Viewers can see everything that happens in a curation space, but are only able to engage with other participants through the text chat modality. This role models that of a live stream viewer. Commentators can additionally add video and audio streams to the curation, enabling them to comment on activity. This is like how a video game commentator, or remote player, participates in a stream on Twitch. Third, beyond the commentator live modalities, editors can engage in collaborative FFWC. Editors may also assign roles to other participants and control or remove others' media streams. The editor role models that of 'streamer' in live streaming practice. In addition to assigning roles to specific users, editors may choose a default role for all other participants in a public curation. We note that LiveMâché interface elements dynamically change, or are removed, as a participant's role changes.

STUDY DESIGN
In order to observe emergent use of CLMC, we deployed LiveMâché as a technology probe. Technology probes are functional technologies that are deployed in situated real-world contexts [33]. They are intended to field test, provoke, and collect data about new experiences.

We deployed LiveMâché in four different situated online learning contexts. These include a local human-centered computing graduate seminar, a MOOC on edX, an informal perspective drawing tutorial, and an online undergraduate landscape architecture history course. The activities conducted in each of these situations was different. Instructors worked with us, in advance, to conceptualize and setup learning activities. We video-recorded participant curations during each situation.

We also conducted semi-structured post-interviews with students and instructors regarding their experience participating in probed learning activities. In total, we interviewed ten students and two instructors. Interviews lasted 20-50 minutes. Interviewees were compensated with a 15 USD gift card.

Our analysis of the interview and learning activity recordings follows the critical incident approach, in which analysis is focused on significant or pivotal activity [19, 67]. Two of the authors identified critical incidents from observation notes taken during the learning activities. Critical incidents included points where emergent behavior relevant to our research questions or significant breakdowns occurred. We targeted questions about these incidents during interviews. Focusing on these incidents, we transcribed and categorized interview and activity data using open coding to form a grounded set of emergent themes. Initial themes included multimodal interactions, deictic interactions, avoiding interruptions through text chat, annotating other participant's elements, social cues, following other users, is anybody watching me, awareness of other participants, collaborative audio adjustment, and organizing activity. We discuss some of these as findings.

In the following subsections, we describe each probed situation including its participants, content, and use of LiveMâché. We refer to each of the situations using the identifiers C1–C4. We refer to participants by their situation's identifier followed by either an I or S<N> to denote the instructor or a student respectively, where N is a number identifying specific students. For example, C1I is the instructor in the first situation, while C1S3 denotes that situation's third student.

C1: Human-Centered Computing Graduate Seminar
We deployed LiveMâché in a graduate seminar course offered at a local university. This first deployment was intended to be formative in nature. Authors of this paper were among the participants. The seminar focused on the theory and design of human centered media experiences. It required that students work on research projects. There were a total of 12 students, involved in 3 group projects of 2-3 students, while 4 students worked as individuals. Throughout the course, students presented and discussed their work in informal presentations to the class. Presentations normally occurred in a classroom.

In one class session, students were asked to present and discuss their projects using LiveMâché. Participants used a single shared classroom presentation curation, with designated spaces for each project group. All participants were assigned the role of editor. Students prepared their presentations, in the curation, by collecting, authoring, and composing media including images, YouTube videos, GIFs, text, and sketches.

The students and instructor added live webcam, screenshare, and audio streams to the curation, in order to present and otherwise participate in the live curation as seminar classroom. Project group members presented together, fluidly alternating who spoke and demonstrated. Presenting students referenced their prepared media. During and after each presentation, students fielded questions and comments from the instructor and other students. We interviewed the students C1S1–C1S5.

C2: Mobile Application Experiences MOOC
For the second situation, we deployed LiveMâché in "Mobile Application Experiences" a popular edX course. The online course addresses the design, usability, implementation, and evaluation of novel mobile applications. We targeted the course in order to explore how to support engaging visual design education tasks in software development education.

The instructor asked students to volunteer to use LiveMâché to create a digital poster explaining their final project, a mobile application prototype. The digital posters were prepared in advance. Students were asked to present their projects to the instructor and other students during one of two poster sessions. Sessions were scheduled 12 hours apart to accommodate international students' varying time zones. Six students signed up to participate. However, only 3 students were present during the scheduled times. These 3 attended both sessions.

One hour prior to each session, we hosted a green room curation, in which all of the students were assigned the editor role. Students were encouraged to join and ask us questions about LiveMâché as well as test their video, audio, and screenshare streaming settings. In the green room, we posted the list of the participating students, with links to their poster curations.

At the start of each session, C2I and students met in the green room. C2I would then chose one of the students to present their poster, following the link to the presenter's curation. In poster curations, the presenter and C2I were editors, while other students were viewers. The student typically added audio and a screenshare of their mobile application running in an emulator. The instructor added a webcam and audio stream of himself. We note that, in one of the presentations, C2I wasn't able to add his audio stream, and used chat instead. Presenting students explained their application, referencing their poster and screenshare. Following their explanation, C2I and the student engaged in a short discussion about the project. Other students gave feedback via text chat. This process was repeated for each student. We interviewed C2S1 and C2S2.

C3: Perspective Drawing Tutorial
For the third situation, we deployed the LiveMâché probe to support an informal drawing tutorial. The tutorial was presented by a local student, listed as a coauthor of this paper. Participants were recruited using the researchers' and the instructor's social media networks. The tutorial was attended by 4 students collocated with the instructor and 3 remote students.

The tutorial took place in a lab space instrumented with three webcams oriented to provide close-up shots of the instructor's and students' drawings, a webcam providing a wide shot of the room, and a large display showing the instructor's view of the tutorial curation. Local participants sat around a large table, where they could easily watch the instructor work through the tutorial curation on the large display. The room was also equipped with a condenser microphone to pick up and broadcast the instructor's and local participants' discussion.

The condenser microphone audio stream and webcam views of the physical tutorial space were added into the shared live curation. Remote participants were assigned the role of commentator, so they were able to interact with the local participants by adding their own video and audio streams to the curation. We observe that 2 of the 3 remote participants chose to engage using a live audio stream.

C3I began by discussing basic concepts of perspective drawing. To illustrate his points, he sketched over (using the LiveMâché sketching capability) photographs and sketches he had collected prior to the tutorial (Figure 2). After going over these concepts, he switched to demonstrating and narrating the discussed techniques, by drawing with a pen on a sheet of paper. This was captured and broadcast by one of the webcam views in the live curation. During this time, C3I encouraged both local and remote participants to follow his view and attempt to sketch their own perspective drawings. Additional webcam views in the room were added to the curation to capture and broadcast the local participants' efforts. Next, C3I viewed and discussed the local participants' drawings using his desk webcam. Later in the tutorial, C3I made students editors and encouraged them to share pictures or live videos of their drawings, but none did. We interviewed C3I, C3S1, and C3S2.

C4: Landscape Architecture History
For the final situation, we looked at how LiveMâché would be used over an extended period. We deployed the probe in

a SPOC on the history of landscape architecture. The course was taught over 5 weeks during a summer semester. It had 4 enrolled students. The instructor is listed as a coauthor of this paper. C4I used LiveMâché to conduct 4 weekly live chats to supplement the course's other content. Each week, C4I would send out two sets of slides, which constituted the main content of the course. Then, during the live chats, C4I and the students discussed important content covered in these slides.

Prior to each live chat, the instructor would collect media (usually images of landscapes) illustrating the concepts he planned to cover. In the final two weeks, the instructor also used screenshares of Google Earth, through which he explored examples of landscape architecture from around the world. He also incorporated slides into the curation, using screen-sharing. The instructor frequently sketched over assembled media elements as he discussed them. During each live chat, the instructor assigned students the role of commentator. He required that they add audio streams and, optionally, webcam views of themselves to the curation. This enabled the students to easily ask questions and engage in the live chat. In the sec-ond week, C4I had students present assignments. To support this, he added student submitted images of their assignments to the curation, which they then referenced during presentations. In the third week, C4I also made his students editors in the curation for a short time, so they could collect and assemble media to discuss during class. We interviewed C4I and C4S2.

FINDINGS AND DISCUSSION

We present and discuss findings from deploying the LiveMâché probe in these 4 situated online learning contexts. The findings and discussion are presented together, in order to ground our discussion with description of observed phe-nomena. We first report on emergent strategies we observed participants using to share context and ground their collabora-tive learning activities. We then discuss how the synchronous capabilities of CLMC function as a new participatory modality. Finally, we identify patterns of live experience that emerged during the probed situations and discuss resulting implications.

Collaborative Live Media Curation Strategies

In each situation, we observed participants using CLMC to establish shared context supporting their learning activities. Participants engaged in deixis, using language to reference collected content, grounding discussion in the shared context defined by their curation. Kerne et al. articulated *strategies* of free-form web curation, each of which addresses methods and techniques that artists, curators, and scholars employ—and which in many cases have been investigated by creative cog-nition researchers—in creative acts [41]. We extend their strategies to collaborative live media curation, by identify-ing how participants share context, ground conversation, and perform deixis.

Creating Shared Curation Space in Advance
In each probed situation, participants worked to create cura-tion spaces before the actual live engagement. Participants, students in C1 and C2 and instructors in C3 and C4, collected media, wrote text, sketched, and assembled curations prior to each activity. For example, prior to his tutorial, C3I collected

Figure 2. Prior to presenting his tutorial, C3I collected photographs and drawings exemplifying perspective. During the tutorial, he sketched over these images to illustrate perspective drawing techniques.

images exemplifying perspective (Figure 2). He subsequently used the context of these collected media elements to ground his early instruction, by referencing and sketching over them.

Participants found it valuable to asynchronously assemble cu-ration spaces in advance, then engage in synchronous curation, on the fly, during the learning activity. By collecting and assembling content, they established context for upcoming activity, where they subsequently created shared meaning.

Sketch: Illustration and Gesture
Participants in C1, C3, and C4 used sketching over other media elements in order to ground their descriptions of a particular concept. Sketching was used to directly articulate ideas re-lated to other curation elements. We observed participants not only using sketch to illustrate concepts, but further, as deictic gesture to call attention to particular features of other elements as they discussed them. We give examples of both uses here.

C3I started his perspective drawing tutorial by explaining concepts of vanishing points and lines. In order to do this, he collected exemplary images, including photographs and drawings, before the tutorial. During the tutorial, he then sketched over these images, to illustrate, by sketching dots at the vanishing points and lines along the vanishing lines of the image (Figure 2). Using this approach, C3I was able to ground his discussion of vanishing points and lines by illustrating the concepts using his previously collected media. C3I left these sketches in place, throughout the tutorial, as a reference.

C4I also extensively used sketching to facilitate discussion of landscape architecture examples. He would often sketch over elements depicting landscape architecture sites, e.g., pho-tographs or screenshare streams of Google Earth. While he used sketching to illustrate concepts, he also used sketch ges-ture to focus students' attention on particular design features of the sites. He described the architecture of a particular park, while sketching over a Google Earth screenshare (Figure 3):

> C4I You can see the building right over here [draws a quick circle in orange around the building behind some trees]. Right through those trees there. Now Kiley has given us this meandering path. [draws curvy line along a bricked path through the park]. Because this part is separated by all of these trees... [scribbles green lines over trees] So all of these trees are screening the building. So you don't have that neoclassical influence on your

Figure 3. C4I discusses the design of a park. He sketches over a Google Earth screenshare as deictic gesture to ground his description.

aesthetic experience anymore. Now you are in a different type of park. Now you are actually in part of, you are in a different sculpture garden, because look at that [circles a sculpture in red]! That is a very modern art piece...

In this case, C4I uses sketch as deictic gesture. To indicate the trees in "all of these trees", he sketches over the trees in the screenshare. C4I is not directly illustrating a concept. He is using sketch to reference and ground his vocal explanation of the site. After making these quick sketches, C4I usually deleted them, since they lacked continued illustrative purpose.

Real-time Element Transformations
One of the primary strategies participants used to engaged in deixis was the dynamic transformation of media elements. Since element transformations are synchronized across participants' views of a shared curation, participants were able to express complex ideas through language contextualized in gesture performed through media transformations.

In one salient example, C4I was discussing the work of Antoni Gaudí, a well known Catalan architect. He described Gaudí's practice of modelling architecture, using upside-down force models, with hanging weights and string. To do this, he started by collecting a picture of one of Gaudí's hanging models from Google Images. After briefly describing the construction of the model, C4I then used the rotate transform tool to flip the image of the model upside down (see Figure 4), while explaining:
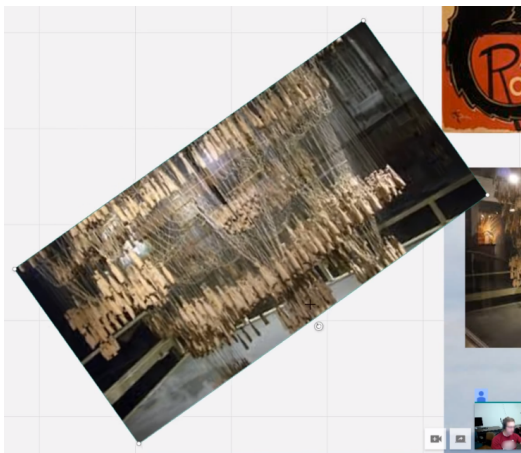
Figure 4. C4I explains Gaudí's use of hanging models. He performs a rotation transformation on an image of a model to ground his explanation.

What he did actually though was, he designed a building. So now you can see, these strings... He was making a physical model of showing how the forces of gravity were going to pull on these archways.

By rotating the image to invert it, C4I was able to ground his explanation using the image of the model. He used the act of rotating it as gesture to explain its inverted nature. He then used the inverted image as a shared visual context for himself and his students, to ground his explanation of the model's purpose. He went on to sketch over the image, highlighting the arches and weights composing the hanging model.

Sharing Perspective
The viewport following capability was used by participants, in every situation, to ground conversation through shared visual context. Viewport following was used by participants watching a presentation made by the instructor or peers. While other participants followed his viewport, the speaker would discuss a concept, while shifting perspective, to focus on a particular set of media elements in the curation. In turn, other participants would see the speaker's visual context changing, grounding his points with media curated into the participant's viewport.

The FFWC strategy of shift perspective is a means through which an individual reorients their view in a curation [41]. A compelling aspect of the shared viewport capability is that when a participant shifts their perspective, others literally follow, in the space, and so dynamically share their changing visual context. Participants in C1 reported that while they made extensive use of viewport sharing, they hardly thought about how their audience was viewing the curation. However, we did find that sometimes more purposeful consideration motivated perspective shifts. When asked about how he thought about shifting perspective during his live chats, C4I reported:

I didn't want it to fill the screen. I wanted you to be able to see the things on the periphery, so that you would know that it was connected to other things. When I laid things out, I wanted them all the same size, but I wanted them to be organized in a sort of structure that talked about [how] these things are related. So when I zoomed in, I wouldn't try to fill the whole screen with one thing. I liked a little bit of white space around it, and just a little touch of other things. So there is this idea, this thing doesn't exist in a vacuum. It is actually related to other things.

Here, C4I explains how he deliberately shifted his perspective to ensure that media elements remained contextualized within the broader curation for his audience.

Assembling Webcam and Screenshare Streams
Live streaming video was used extensively in all the situations to contextualize learning activities. Participants primarily accomplished this by adding screenshares of applications they were using or demonstrating. Webcam streams were also used to share views into activity. Since LiveMâché supports directly embedding live video streams into the curation canvas, streams can be assembled, sketched on, and transformed, like any other element, to construct context. We briefly describe some instances of participants assembling live streaming video.

During the student poster presentations in C2, students were asked to demonstrate their final project mobile applications. In addition to discussing their prepared posters, students would assemble a screenshare stream of their application running in an development emulator, in the curation, next to their poster. This enabled students to ground their discussion by connecting live views of their application with prepared poster materials.

C3I used a live webcam stream to show himself demonstrating perspective drawing techniques. The stream provided an overhead view onto his desk, where he was drawing, using pen and paper. C3I used the stream to ground his explanation of perspective drawing techniques, for local and remote participants. The stream was assembled into the curation, with other video streams of the room, providing multiple views of the activity. These streams were augmented by images, which C3I sketched over, to illustrate perspective drawing concepts.

In the C2 and C3 examples, participants contextualized activities by situating live stream activities by assembling other media. They engaged with the live media using the above strategies for sharing context. For example, C4I sketched over screenshares of Google Earth, which he used to explore landscape architecture sites.

Collaborative Curation: A Participatory Modality
CLMC integrates prior live streaming modalities such as video, audio, and text chat, each of which affords participating in live experiences [27]. However, prior work has shown that new modalities can support new forms of participation [79, 36, 44, 28]. Beyond existing modalities, CLMC enables participants to engage by collaborating in the assemblage of shared media curations. Participants with the editor role can collect media, assemble it, share their perspective, sketch, and write in the shared curation. Each of these synchronous capabilities can serve as a new modality for participation.

For example, in C1, each team assembled a curation for the discussion of their project. During class, each team described their work, referencing their previously assembled media. Students who were watching the presentations participated by authoring text and sketching to annotate the presenters' collected media to give feedback, pose questions, and make suggestions.

During the third week of C4, a student collected images to contribute to and participate in live chat discussion. While discussing the architecture in a particular park, C4I asked the students if it reminded them of anything else they had seen. C4S1 responded that it reminded her of architecture she had seen in the popular HBO television show, Game of Thrones. At this point, C4I made all of the students editors of the curation and suggested that C4S1 try to find some images of the building she was thinking of. C4S1 went and found two images of the fictional castle Dragonstone, and added them to the curation (see Figure 1). C4I commented on Dragonstone's asymmetry and sketched over the collected images to highlight the castle's lines, noting their repetitive style.

In both of these cases, we see students engaging in learning activities by collecting, authoring, and assembling media using CLMC. Thus, collaborative curation served as a new modality for participating in social learning activities.

Live Experience Patterns: Structure Supporting Activity
During the probed situations, we observed the emergence of recurring structures of live experience and social activities. We refer to these here as patterns of live experience, drawing on Alexander's notion of patterns, which are recurring forms of spatial organization that support particular types of experiences and events [2]. WWhere Alexander referred to spatial patterns in architecture, the patterns we discuss here describe organization of modalities and computing resources to support live social activities. We note that these patterns are not limited to CLMC. They may be found in other live social media forms, such as Twitch, Periscope, Facebook Live, Skype, Google Hangouts, etc. Live experience patterns we identify include include small team, broadcast, and touring. We present examples of how these patterns were manifested by users, and abstract from examples, focusing on how the affordances of CLMC contributed to their structure. We also address how the patterns are invoked in other live media forms.

In the *small team* pattern, we typically observe a curation shared with two or more participants given full editing access. Workflows and roles are then worked out through ad-hoc articulation between participants. An example of the small team pattern arises in C1, in which everyone had equal access to the curation. Who presented when, who was speaking, and where participants prepared their presentation was established through informal social articulation. The small team pattern is typified by prior tools, such as Google Hangouts and Skype.

The *broadcast* pattern is more asymmetric, with one or more core participants broadcasting live media and editing the curation. All others participate using limited, peripheral modalities, like text chat. We specifically observed this pattern of use in C2, where the poster presenter and instructor had a live video / audio discussion, while other students observed the presentation and discussed through text chat. In CLMC, the broadcast pattern can be organized by assigning a few participants high impact roles like editor or commentator, assigning all others the viewer role. The broadcast pattern is typical of live streaming forms such as Twitch or Periscope.

Finally, in the *touring* pattern, participants move together between social activity contexts. During the student presentations in C2, we observed touring, where participants moved between and interacted across several different curations. In our study, touring was supported by providing links to each poster curation in the green room, with the instructor directing participants to move between them. We note that the touring pattern can also be observed in other live streaming forms. For example, Twitch streamers can "host" other streamers, effectively shifting their audience to another stream. Future research that explores how to support maintaining social context while groups tour live media contexts would be beneficial.

In prior live media forms and in CLMC, live experience patterns are collaboratively established through explicit system enforced roles, ad hoc articulation of social roles, and the assemblage of modalities. This curation of roles and modalities is performed by organizers, i.e. streamers or instructors, to control the media's content, how it is perceived, and how others may participate. A poorly assembled media curation may

result in limited participatory opportunities or cognitive overload. CLMC enables curators to freely assemble modalities and roles to create media contexts that supports the needs and requirements of their situated social activity. In the following, we discuss issues and approaches that we hypothesize may support structuring live experience through curation.

Structuring Live Experiences Through Roles
The LiveMâché roles system provides a flexible mechanism for structuring how curations and their respective activities are viewed, edited, and participated through. These roles specify what modalities are available for participants to use. Existing live forms like Google Hangouts (small team) or Twitch (broadcast) implement static media structures and roles. In contrast, CLMCs can be restructured by moving participants dynamically between roles. This enables organizers to fluidly transition between patterns like small team and broadcast, or to organize experiences somewhere in between.

For instance, during most of C4 a broadcast pattern was assumed. Students were able to commentate, but C4I was the only participant able to actively compose media in the curation space. However, at some points C4I would change the students' roles to editor, shifting the experience to more of a small team pattern. LiveMâché only currently provides 3 distinct roles. Future work could explore a more diverse, nuanced set of roles that could lead to new patterns of live experience.

Live Experience Pattern Templates
While the roles provided by LiveMâché support structuring live experiences, some participants reported difficulty in thinking about how to assign roles. As C1S5 noted,

> The whole experience could get out of hand rather quickly, because it [is] such a creative system. In which, it is so open-ended, and there are is not lot of structure. [...] My thinking is that at a high level it would benefit from a little more structure in some situations. Like possibly, different templates with varying degrees of structure.

Assigning roles to support a particular pattern of experience requires significant forethought and collaboration from participants. A potential solution we plan to explore is *live experience pattern templates*, as mentioned by C1S5. For example, when a participant creates a curation, they may be given the option to use a broadcast template. This template would have preconfigured role assignments, so the creator could edit and broadcast video and audio, with a default role of viewer for other participants. Templates would support thinking about roles and scaffold the work needed to organize activities.

Territories
Another approach that emerged for structuring live experiences was the use of territories within a curation associated with a specific participant or group. In C1, each group was given an area in which to prepare media for their presentations. These territories were implicitly agreed upon and denoted via a grid of text elements of participants' names. Given that the territories were not computationally enforced by LiveMâché, we did observe instances of participants manipulating others' elements or revealing intentionally hidden content in others' territories. While these interactions were mostly beneficial

and sometimes playful, it is easy to imagine situations where these interactions would be less acceptable.

This suggests that enforced territories in a curation might help structure shared activities. Territories would support spatially defining how curation space is assembled and seen. This could help participants articulate their roles and define social context. We note that the use of territories for coordination in tabletop systems has been investigated [69, 64]. Future work investigating the use of territories in zoomable collaboration spaces like CLMC, may lead to unique considerations. For instance, a territory defined within a infinite zoomable space also provides infinite, ample room for participation.

CONCLUSION
Collaborative live media curation is a new medium for live CSCW. Prior live streaming forms do not afford collaborative, free-form assemblage of live modalities. By extending free-from web curation with synchronous collaboration and live media, CLMC enables a new contextualization of live experience. By deploying the LiveMâché CLMC probe in four online learning situations, we provoked new participatory online learning experiences.

We observed how participants invoke new collaborative live media curation strategies for sharing context, grounding collaboration, and constructing meaning through the assemblage of media and performance of deictic gestures. Like others, we found that shared context is based on common understanding of framing [14] and social construction of mutual understanding [4]. The strategies—creating shared curation space in advance, sketching to illustrate and gesture, real-time element transformations, sharing perspective, assembling web cam and screenshare streams—contribute new, concrete means for promoting collaborative meaning making through shared visual and social context. Collaborative free-form web curation afforded new modalities for participation. Prior forms limit most participants to limited modalities, such as text chat. CLMC's open-ended integration of media and modalities affords new opportunities for any participant to engage in the collection, broadcasting, and assemblage of media.

Finally, we articulated patterns of online live experience. Prior live media platforms typically support a single activity pattern. For example, Google Hangouts supports the small team pattern, while Twitch supports broadcast. CLMC is more flexible, enabling participants to assign roles and assemble media to form small-team, broadcast, and touring patterns of live experience. Participants can shift between patterns, using roles, to support dynamic social contexts. Future work has the potential to provide value by exploring how new strategies for assembling and structuring media will support new forms of participation and shared context in situated live experiences.

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