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1 Net.Create: Network Visualization to Support Collaborative 2 Historical Knowledge Building

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7 Abstract

8 Students across disciplines struggle with sensemaking when they are faced with the need
 9 to understand and analyze massive amounts of information. This is particularly salient in
 10 the disciplines of both history and data science. Our approach to helping students build
 11 expertise with complex information leverages activity theory to think about the design
 12 of a classroom activity system integrated with the design of a collaborative open-source
 13 network-analysis software tool called Net.Create. Through analysis of network log data as
 14 well as video data of students' collaborative interactions with Net.Create, we explore how
 15 our activity system helped students reconcile common contradictions that create barriers to
 16 dealing with complex datasets in large lecture classrooms. Findings show that as students
 17 draw on details in a historical text to collaboratively construct a larger network, they begin
 18 to move more readily between small detail and aggregate overview. Students at both high
 19 and low initial skill levels were able to increase the complexity of their historical analyses
 20 through their engagement with the Net.Create tool and activities. Net.Create transforms the
 21 limitation of large class sizes in history classrooms into a resource for students' collabora-
 22 tive knowledge building, and through collaborative data entry it supports the historio-
 23 graphic practices of citation and revision and helps students embed local historical actors
 24 into a larger historical context.

25 **Keywords** History education · Network analysis · Activity theory · Knowledge building ·
 26 Representational practices

27 Introduction

28 Students across disciplines struggle with sensemaking when they are faced with the need to
 29 understand and analyze massive amounts of information. This is particularly salient in the
 30 disciplines of both history and data science. While seemingly unrelated, these disciplines
 31 share the need to gather and analyze massive amounts of data. This overlap in learning
 32 goals and norms presents us with an opportunity to think about how an activity system that

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combines data science with history can help support learners in exploring massive sets of data both within and across disciplinary boundaries.

Our approach to helping students build expertise with complex information leverages activity theory¹ (Engeström, 1987) in the design of a classroom activity system integrated with the design of a collaborative open-source network-analysis software tool called Net.Create (Craig & Danish, 2018). The Net.Create software and its accompanying activities were designed with the goal of supporting learners for whom the affordances of network visualization offer insight into a large corpus of data, even if they are novices in the world of network visualization. The tool thus aims for intuitive creation, visualization, and revision of a complex network data set, which in this case is drawn from a large body of historical text. Our focus on humanities classrooms was initially motivated by the need to reconcile the seeming contradiction between the close-reading of a historical source and the birds-eye view across multiple sources that historians use to uncover historical patterns. Data scientists similarly move between these local-detail and aggregate-overview registers as they apply big-data approaches to large datasets and seek to explain outliers. We drew on these similarities to support students as they collaboratively co-constructed knowledge at both the detail and aggregate level drawn from a large corpus of data using both history and data-science practices. Our focus on interactions between students at both the small- and large-group level helps facilitate discovery, discussion, and recreation of historical context (Bae et al., 2019).

The overarching goal that guided our iterative design and analysis effort was an effort to understand the epistemic foundations and disciplinary practices of both digital historians and historians who draw on more traditional analytical means, and how these two traditions might be leveraged to support students in learning historical content through network analysis. To explore this, we first identified features of network analysis approaches that might help encourage student appropriation of historical norms. Then we asked how different modes of interacting with and generating network diagrams affect student understanding of historical information. This allowed us to generate three instructional goals that supported students in: 1) Practicing *consistent citation* and *accurate historical identification*; 2) Using *network concepts and visualizations* to *identify individual significance in a larger context*; and 3) Producing a *network of key players* for the text and *discussing it in groups*. The mapping between these instructional goals and the network analysis features in Net.Create to support them are detailed in Table 1.

Our approach to exploring knowledge building in this context draws on activity theory and involves looking for, and examining the contradictions that exist, and emerge between the various tools, activities, and epistemic goals. This approach helps us better understand how these contradictions drive activity and might be productively resolved by learners. Specifically, we aimed to answer how the design of the Net.Create tool and activities helped or did not help with overcoming:

1. the contradiction between details and context;
2. the contradiction between active learning and potentially passive lecture in a large lecture classroom; and
3. the contradiction between memorizing historical facts and building historical context.

¹ The term activity theory is often used as synonymous with cultural historical activity theory (CHAT). We have opted to use the shorter version to focus our explicit interest in how activity is organized, but we view both literatures as entirely relevant.

Table 1 Instructional goals mapped to learning outcomes, technological features, and data sources

Instructional goals	Learning outcomes (e.g., history disciplinary practices)	Net.Create Feature(s)	Data collected
1. Practicing consistent citation and accurate historical identification	Tie network revision to history disciplinary practice of argumentation ("historiography")	Predictive text; Node/Edge tables with fields for citations, significance notes	Student-produced network creation, revision data
2. Using network concepts and visualizations to identify individual significance in a larger context	See group excerpt in larger whole, moving seamlessly between local, global context ("historical context")	Simultaneous multi-user data entry	Student-produced network creation and revision data; audio log data;
3. Producing a network of key players for the text and discussing it in groups	Seeing individuals in network-analysis-driven historical context ("historical significance")	Live visualization and manipulation of aggregate network	Historical-thinking paper score

Focusing on these questions allowed us to expose and then explore the contradictions in motivation and mediation as we reconciled the barriers to explorations of complete data sets during collaborative learning activities in multi-disciplinary classrooms. In designing the undergraduate classroom activities described below, we used activity theory as a valuable theoretical approach in order to detail how the features of our software and activity design bring network-analysis knowledge building and history knowledge building together to reconcile these contradictions. Our design choices in the activity system support interactions between individual students, small groups, and the whole class. These choices also support students as they shifted between viewing small excerpts of a text and viewing the entire corpus via the Net.Create visualization. Net.Create was, in turn, designed to support productive shifts between different historical perspectives while students worked with the text. This study thus offers both the narrower analysis of the learning outcomes in a specific collaborative historical-thinking activity using Net.Create and the broader exploration of an activity system in which students use collaborative data visualization to build their knowledge of a complex dataset.

Background & objectives

Activity theory and the design of mediators of learning around contradictions in collaborative learning environments

Our work builds on activity theory (Engeström, 2008), a sociocultural theory of learning (Danish & Gresalfi, 2018) focusing on collective activity as a primary site for understanding learning. Collective activity describes situations such as collaborative teams in which a group of people have a shared goal, referred to as the object of activity (Wertsch, 1981). Naturally, people don't always share goals perfectly, and their intentions might change. Attending to the space in which individual and group dynamics intersect helps explain the relationship between individual cognition and learning, and the contexts in which we engage in such work. We have previously found this framework to be particularly valuable in understanding how tools such as Net.Create play a role within coordinated activity in a classroom ecosystem (Craig, Danish, et al., 2020; Craig, Humburg, et al., 2020; Danish, 2013).

In addition to the shared object, activity theory notes that individuals' actions are mediated, or transformed, within activity (Engeström, 1987). In the case of Net.Create, the mediators of activity include rules such as the requirement to work from a set of pages in creating a network, and the division of labor between the individuals within the group (e.g., one student might control the computer while others reference the text). We leverage this perspective to design for specific mediators of students' activity that could change the way they engage with historical analysis and learning (Danish et al., 2016; Danish, 2013). This is different from other approaches as it explicitly draws our attention not only to the tool being deployed, but the ways in which groups of students are organized around that tool (Danish, 2013; Danish et al., 2020; Kaptelinin & Nardi, 2012). We then analyze if and how student activity is transformed, and whether this leads to the kinds of learning we hope to achieve.

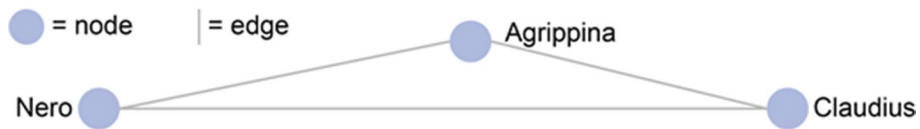


Fig. 1 A simplified network visualization of nodes (individual things) and their connections (edges)

118 **Contradictions and opportunities in history disciplinary practices**

119 One way of designing for, and analyzing, the mediators of activity is to focus on the con-
120 tradictions existing within activity (Yamagata-Lynch & Haudenschild, 2009). Contra-
121 dictions in activity theory address the ways that different mediators may be mis-aligned
122 with each other or the overarching object of an activity. Learning often occurs at the indi-
123 vidual or collective level when solutions to contradictions are proposed and then adopted
124 (Engeström, 1987, 2018). Our activity-theory-grounded design process therefore involved
125 beginning with identification of the key contradictions that we wanted learners to explore
126 within the classroom activity system.

127 **Contradictions between detail and context in historical analysis**

128 One of the most persistent challenges for students who are novices in history is encoun-
129 tering a new detail in a historical text, and yet simultaneously needing to recognize the
130 historical context and significance of that detail (Monte-Sano, 2011; Rouet et al., 1996),
131 especially in complex texts with many details. There is a contradiction between an initial
132 focus on details and an initial focus on context. Professional historians are able to navi-
133 gate the contradiction by recognizing the two as dialectically linked: a detail doesn't make
134 sense outside of context, and contexts don't exist without an accumulation of details. Digi-
135 tal humanities researchers have established alternative resolutions to this tension, one of
136 which is to use network analysis to move between local detail and global context in phe-
137 nomena such as the rise of the Medici family in Florence in the fifteenth century (Gould,
138 2003; Graham et al., 2016; Padgett & Ansell, 1993). The networks digital historians pro-
139 duce aggregate individual nodes (circles representing people, organizations, etc.) and edges
140 (lines showing interactions between the nodes) into a network visualization, simultane-
141 ously exposing local and global context, thus allowing scholars to explore both (see Fig. 1).

142 Our activity system drew on the importance historians assign to citations and proper
143 sourcing as one way of mediating student understanding of these node-edge connections
144 (Shopkow, 2017). Asking student groups to create their own sub-network and then com-
145 bining the networks into a larger whole might help students assess detail and context on
146 a small scale, but not on the scale of a whole historical text. At the same time, working
147 with an entire text at once can make it easy to lose sight of individual details. To help
148 resolve this tension, we harnessed a historical disciplinary norm: citation practices. Asking
149 students to root each edge connection in a citation drawn from the text gives them a way
150 to find, and then move more quickly between, a specific mention of two historical agents
151 interacting in the text and the broader relevance of that specific interaction. We also offered
152 predefined categories and relationships to provide a disciplinary framework to orient the
153 students toward the important historical actors and their historical contexts, and within
154 which students can assess their own and their peers' knowledge-building activities (Lan

et al., 2012; Zhao & Chan, 2014). For instance, our nodes included Person, Group, Place, Thing, and Event, which allowed students to track the interactions of historical actors with each other as well as their involvement in historical events or appearance at particular places. The list of edges included "has peaceful, familial or conversational interaction with", "has martial or adversarial interaction with", "sends written communication to", "is a group member of", "makes visit to", and "participates in". These options emphasize the agency of historical figures as they participate in events and interact with other historical actors. The structure of these categories embedded within the network tool allows size and positioning to be calculated based on quantitative data (e.g., nodes are assigned a size based on the connections to them, known as *degree centrality* in data sciences practices) in order to display the relational features of both nodes and edges individually and in the larger network (Durland & Fredericks, 2005).

Introducing these network analysis tools into a classroom discussion of historical texts has the potential to re-mediate (Cole & Griffin, 1986; Jurow et al., 2018) students' engagement with history by encouraging them to visualize both the significance of individual actors as well as contextualize these individuals within a web of relationships. This shift in mediation is designed to use the process of digital reconstruction to help students open up the "black box", in order to see how professionals generate representations that later become accepted as accurate and true (Silvis et al., 2018). Students engage in an iterative process of knowledge building by creating their own representations of history, exploring those representations with the whole class (Craig, Danish, et al., 2020; Craig, Humburg, et al., 2020; Scardamalia & Bereiter, 2006) and then constructing their own account of the history using that collaborative visualization. In doing so, students gain access to the behind-the-scenes work historians do to generate explanations of historical events, re-mediating their understanding of how historical accounts are created.

Contradictions between active knowledge building and large lecture settings in history classrooms

Tools like Net.Create are successful in part because they provide a shared representational space in which many students can simultaneously and collaboratively build their knowledge about the interplay between local detail and historical context in a live visualization, providing students with a meaningful joint task that allows them to display, repair, and refine their ideas (Danish et al., 2016; Roschelle, 1992; Slotta & Najafi, 2013). However, for this kind of co-construction of knowledge to occur, participants need to engage with each other's ideas, and harness joint attention as they engage in a process of what Suthers (2006) calls intersubjective meaning making. Here lies a second key contradiction: this work is often expected to occur in introductory history classrooms, which are typically large and lecture-based, making it challenging to support students in engaging in meaningful inquiry (Scardamalia & Bereiter, 2006).

Our goal was, therefore, to leverage the benefits of the large-lecture-classroom format for creating a robust network, while supporting students as they move between group work and whole-class discussions (Danish & Gresalfi, 2018; Enyedy, 2003; Hall & Rubin, 1998). Within the local groups, students who are engaged in working collaboratively on meaningful tasks are able to see the key disciplinary nuances, particularly if software scaffolds help to make those differences more apparent (Collins & Halverson, 2009; Lane & Mercier, 2017; Roschelle et al., 2013). In the Net.Create activity, students had the opportunity to actively collaborate and discuss their network additions and revisions while in a

small group. However, teacher-led, whole-class discussions are still valuable for helping students to recognize the emergent patterns in the full visualization, which combines their local ideas, and to have those ideas ratified for use in their subsequent local conversations (Enyedy, 2003; Hall & Rubin, 1998). The Net.Create tool made this whole-class discussion possible. All contributions added by small groups were displayed in a single visualization and data table in real-time, so that students were continuously contributing to, and aware of, the larger context.

By addressing the contradiction between detail and aggregate historical context in our activity design, we also offer some answers to the active knowledge building vs. large lecture contradiction. Because individual nodes and edges are placed into a visually aggregated whole, students can identify how their nodes and edges connect to a larger picture. The citation practices that we identified in the first contradiction allow any user to view and sort each individual interaction sequentially in the data table and look up those interactions in the original text for clarification. At the same time, the contribution of each interaction entered in Net.Create can be easily located in the network graph that visualizes the aggregate context. This in turn supports teachers as they help students connect their small-group inquiry to the efforts of a larger lecture classroom and back again. That is, the small group activities were designed to allow students to construct and represent knowledge about key details of the historical text, while the whole-class discussions helped them connect their small-group knowledge-building back to the larger context.

Contradictions between memorization and building historical context in history learning

These detail/context and active-knowledge-building/large-lecture contradictions contribute to an overarching contradiction that needs to be addressed in tandem with the other contradictions: it is important to recognize that students and professional historians rarely have the same motivations in engaging with the task of historical analysis. Our learning objective was for students to build historical context by understanding the complex interactions shaped by the author of a historical text (Wineburg, 1991, 2001). However, students tend to define history as the memorization of names and dates (Barton & Levstik, 2004; Levstik & Barton, 2008; Shopkow et al., 2012)—in their words, the “chronological history stuff” (Student 1, Group High1, Day 2)—and they are puzzled when that memorization task is not emphasized.

This view of history as a mostly “expository” discipline built on facts results in a view of history as a monologue, a single narrative strand with one textbook or lecture voice speaking for all historical actors. As a consequence, students struggle with the idea of history as a problem-solving discipline. It is a challenge both to see multiple perspectives at work in the primary source material they read and to give voice to their own interpretations of history (Hung et al., 2008; Jonassen, 2000; Saye & Brush, 2002). We wanted to re-mediate this engagement with history so students were more oriented toward thinking about historical context as a construct of many points of view, provided both by primary sources and the many competing interpretations provided by professional historians (Pollack & Kolikant, 2012).

As we noted above in the first contradiction, a key challenge in bridging the gap between memorization of historical details and student agency in reconstructing historical context (Craig, 2017) comes when students simultaneously encounter a new detail and need to understand that detail’s historical context and significance (Monte-Sano, 2011; Rouet et al.,

1996). In this moment, the reading of a historical text requires the student to see two forms of dialogue at play (Enyedy & Hoadley, 2006). One asks the student to see themselves as a modern interpreter of the text itself in order to understand it through the lens of historical thinking. The other allows the student to acknowledge that the primary-source author was in dialogue with contemporary voices with their own set of social and cultural norms. For instance, Tacitus recounts of an affair between Gaius Silius and Messalina, Emperor Claudius's wife:

"Messalina's extravagant behaviour was wilder than ever. Autumn was well advanced, and she was staging a tableau of the grape-harvest throughout the house.... Messalina herself, her hair streaming, brandished a thyrsus, and beside her was an ivy-garlanded Silius, wearing high boots and tossing his head, while all around them rose the din of a dissolute chorus [...] Meanwhile actual messengers — not simply a rumour — were coming in from all quarters to report that Claudius was aware of everything and that he was on his way, eager to exact vengeance. Messalina accordingly left for the Gardens of Lucullus and, to hide his fear, Silius left to take up his duties in the Forum." (Book 11, page 232 from Tacitus).

The excerpt's focus on Messalina's "extravagant" and "dissolute" drinking and partying reflects particular social norms for how women were expected to behave in late-Antique Rome, but Tacitus does not explicitly lay out those social norms. The reader's interpretation of Tacitus' emphasis makes implicit norms more explicitly visible.

Prior research has shown students need a great deal of help to overcome this tension between multiple modern and historical voices, and thus we organized Net.Create's features and activities to help them. Specifically, Net.Create helps make patterns in a primary-source author's historical norms visible, where they might not have been salient before. Furthermore, students are given agency over how they represent the text. They are reminded by the instructor initially, and by the live visualization as they work, that their representational choices help them and their peers to focus on and interpret the text in new ways that may not align with those of the author. The combination of data editing and creation with dynamic visual representation makes visible both what the author wrote and how the students made sense of it, while also affording the instructor an opportunity to explore these contradictions.

Designing Network Visualization Tools and Activities to Overcome Contradictions

In this next section, we highlight how our work in designing the Net.Create tools and activities aims to simultaneously build on prior work with visualizing information for learners, and to resolve the contradictions noted above. Specifically, our goal was to develop a tool that would mediate students' activities in ways that help bring together detail and overview, small group and large lecture, memorization and argumentation, and history and the key data-science practices related to network visualization.

This exploration took place in the context of a larger, aggregated set of complex interactions represented by a shared visualization simultaneously plotting local and global contexts (see Fig. 2). The simultaneous nature of the activity and tool design aim to develop a middle space between individuals and groups that parallel these local and global contexts. In this middle space, students could explore how individual actors represented by nodes (the circles) had interactions represented by edges (the lines between the nodes). In doing so, we present opportunities for multiple levels of dialogic interactions that help students manage the contradictions between detail and complexity in large datasets. To that end, we

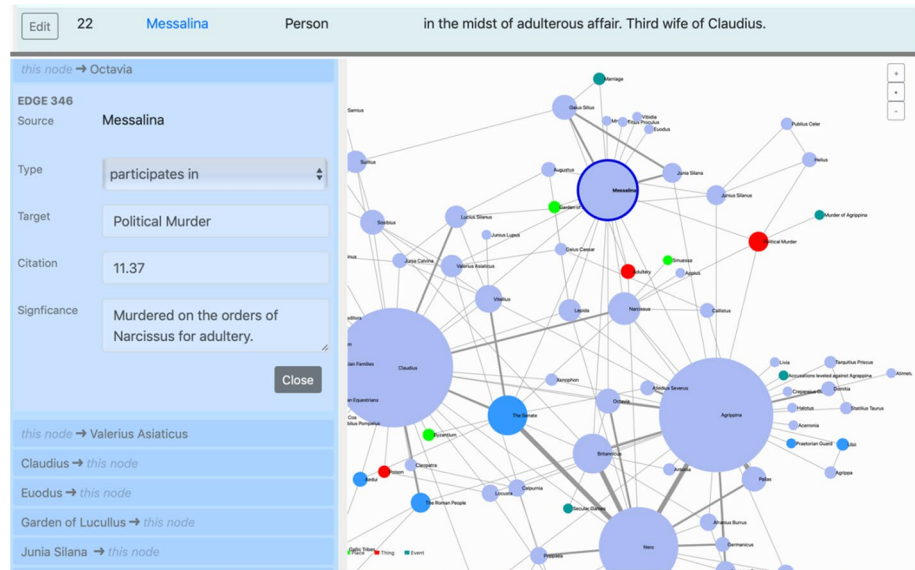


Fig. 2 An overview of the Net.Create interface, with visualization (bottom right), with node description (top) and edge editing (left) **AQ4**

first provide an overview of the basic activity design. We then detail the interplay between Net.Create’s mediating features and the rules and the division of labor in the activity design, so that we can explore the overall effect of the activity system on students’ ability to seamlessly move between the poles of the contradictions outlined above.

As a first step, we divide a large classroom into small groups, each of which has responsibility for tracking the details of one excerpt from a long historical text. The instructor initiates the activity by adding the two most frequently occurring historical figures in the larger text as nodes to a completely blank network in the Net.Create interface. The instructor then adds an edge between those nodes, along with significance entries and a citation for that interaction drawn from the text. Finally, the instructor demonstrates several additional features of Net.Create for students: network-visualization gravity by dragging around a node and seeing how other connected nodes followed it; the tabular-data menus that contain information about individual nodes and edges represented in the visualization (including page-number citations for each edge-interaction, which is an unusual feature for network analysis); and the key and help features of the software. The student small groups are then asked to use the instructor-demonstrated process to enter data about the people and interactions they find in their excerpt. With 15 groups of students working on this, the network emerges quite rapidly. See Fig. 2 for a network after only 25 min of local group work. As students work, their nodes and edges are added to a visualization of the whole network in real time.

To help students find their entries in the network, we pause data-entry tasks briefly after 10–15 min and demonstrate use of the sorting feature in the Nodes and Edges table. Sorting by citation helps student groups identify group entries from their excerpt, and sorting by the nodes students identified in their group’s edges helps them see where else those nodes appear in the text, by way of other student-group citations. This combination of Net.Create feature and instructional design helped students find their own

contributions to the network while also beginning to explore how the larger network made up of their colleagues' simultaneous contributions help define the context of the entire text.

Some of the elements in this activity system—the division of labor that assigns text excerpts to small groups—are independent of the features of Net.Create and can work with other software. Before the development of Net.Create as a standalone tool, for instance, we piloted a study in which students used Google Forms to enter data into a shared spreadsheet and an instructor visualized the resulting network in the popular network visualization tool Gephi, which produced static networks (Bae et al., 2019). We observed several promising behaviors; chief among them were several instances of students noticing, and then using, data relevant to their excerpt that had already been entered by other student groups. At the same time, the pilot exposed several weaknesses in the activity system, which required software features that did not exist in order to overcome them. We then designed Net.Create with these features in mind.

Our first goal was to identify and support effective visualization of the data so that students could immediately and intuitively see connections between concepts that are not immediately obvious in a text or tabular display (Suthers, 2001). In addition to a visualization, our pilot activities showed the value of having the visualization created in real-time so that students could continuously see how the ideas they identified within the text were related to each other, as this could then shape their ongoing thinking about the text as they continued to build the visualization (Solli et al., 2018).

With this in mind, we explored what the ideal visualization would be for this task. Visualizations that map connections between entities, like the one at the heart of Net.Create, take several forms. For example, popular concept mapping tools have consistently proven to support learning by engaging learners in identifying and exploring the relationships between key ideas in a domain as they link nodes to each other (Jonassen et al., 1999; Schwendimann, 2015; Shih et al., 2009). An important aspect of learning with these tools is that learners need to be able to construct and explore their own representation of the underlying content so that they can identify and negotiate the relationships between ideas within a corpus of data (Scardamalia & Bereiter, 2006).

Despite the success of concept mapping tools, they are intended for a relatively specific purpose: constructing and representing one's knowledge. As a result, a good concept map necessarily shows all elements as connected and ideally interconnected (Jonassen et al., 1999; Solli et al., 2018) in order to promote a well elaborated and connected understanding of a target domain. Furthermore, attending to how well connected a concept map is can shed light on how well a learner understands the domain they are representing via the concept map (Schwendimann, 2014). In our context, however, we are not aiming to have students represent their knowledge of a domain. Rather, we want them to engage in an analysis of a historical text by re-representing the people, places, and events as the historical source (author) did, noticing and exploring any outliers or disconnected nodes rather than trying to connect them on principle. When combined with the kinds of automation that network analyses include, the network can help students to see and understand what gaps, disconnects, and unusual patterns tell them about the historical author, text, or context. Furthermore, while common in classroom spaces, concept mapping tools are less visible in the work of professional digital humanists, and we wanted to help students learn techniques that might be applied in the field after graduation. We therefore turned to social network analysis (SNA), an approach that is quite common in the digital humanities (e.g. Ahnert, 2020; Winterer, 2012). A key aspect of SNA and the network visualizations that accompany it is a reliance on statistical information to enhance the representation of information

(Ahnert, et al, 2020; Newman, 2018), potentially helping students to notice relationships or patterns that aren't immediately obvious.

Next, we outline how the network visualization at the heart of Net.Create implements these automated representational features and detail how we anticipated they would support historical reasoning. While we recognize that relying on visualization is the first stage of understanding network patterns and that there are more substantive quantitative approaches to advanced network analysis, visualizing network data offers an entry-level approach to identifying nascent patterns in the data and offering students an entry point into further exploration. Net.Create supports this in several ways. First, the visualization in Net.Create automatically adjusts the representation of each node and edge—and of each node's relative positioning in the aggregate network—based on an aggregate interpretation of the number of connections a node has to other nodes in the network and on how those nodes in turn are connected.

By offering a computationally formatted visualization, we add a computer-generated layer of knowledge-building that bridges the information the students provide in their small groups with the aggregate information built by the whole classroom. Learners often rely on particular kinds of visio-spatial clues as a way to interpret the visualizations they are working with (Lindgren & Schwartz, 2009). The visualization of node sizes is one important way to communicate importance or influence. Network visualizations commonly resize a node or edge based on how many connections it has, combining a network-analysis concept called “degree centrality” with industry visualization best practices that suggest that viewers of visualizations automatically intuit size as representing importance (Carrington, Scott, & Wasserman, 2005; Steele Iliinsky, 2010). As data entered by the whole class trickles in, Net.Create recalculates degree centrality and resizes nodes automatically, so that small groups can see a node growing larger or smaller. Automated node resizing is one computational representation of how the whole class has interpreted the importance of that node in its historical context, regardless of what a small-group excerpt might contain. Similarly, as students add an edge between two nodes that have yet to be connected, the nodes float to a new position in real time as students watch, not only for the student group who entered the edge but for the whole classroom. This helps students keep track of incremental changes, as well as more clearly identify the ways in which the nodes and edges their group has entered relate to the network built by the whole class.

To call further attention to the node-size and edge repositioning, we chose a force-directed layout structure for Net.Create that bases the relative placement of nodes in relationship to each other using a real-time simulation based on physics (see <https://github.com/d3/d3-force> for the plugin we used). Force direction applies physical simulations of force and mass to network analysis data, drawing important (large, or degree-central) nodes to the center of the visualization and applying individual “gravity” to each node. In other words, higher-degree nodes are drawn to the center of the visualization, and higher-degree nodes attract their connected nodes more closely than lower-degree nodes. As such, a node with low degree centrality, but whose primary connections are with high-degree nodes, would be pulled toward the center of the network “universe”, while a cluster of low-degree nodes with connections only to other low-degree nodes would be pushed to the outside of the diagram.

The gravitational analogy behind force direction helped us address a tension we identified in our design process: identifying individual significance within a larger whole. Articulating the gravitational-force analogy to students helped us explain some of the interactions within the network and how force-direction positioning of high-degree nodes might be helpful for students dealing with two issues in complex networks. First, the position of

nodes in Net.Create updates live as new edges are added. From a network-analysis perspective, the movement of nodes as edges are added is not a singularly correct interpretation of the data; however, it does offer one approach to expressing the connections between nodes in the existing network. However, from a student-learning perspective, the node repositioning instigated by the addition of a new edge draws student attention to a new piece of information that drives them to explore how and why that new information affected the visualization. Second, force direction supports looking for clusters of influence in the network. Pulling a high-degree node to the outside of the network also pulls the placement of connected nodes that have no other high-degree connections but leaves behind clusters of other high-degree nodes unconnected to the node being acted on.

Force-directed positioning is a key first step for novices exploring the relationship between individual interaction and larger patterns in a dataset. As students attend to which nodes are pulled toward the center, they may identify network actors who are implicitly influential but not explicitly part of many interactions. Low-degree nodes whose actions tie them to many higher-degree nodes often have otherwise surprising influence on a complex network, as can be the case with nodes with high “betweenness” or “closeness” centrality (Borgatti, 2005; Freeman, 1978). While the Net.Create tool does not explicitly display these betweenness-centrality measurements (which recalculate a node’s centrality based on the degree-centrality of the nodes to which it is connected) force-directed layout does offer helpful automated placement. Low-degree nodes with several influential connections will float to the center of the network, a tendency that we pointed out in discussion after session 1 of data entry. We drew student attention to big nodes that were important, but we also noted the importance of looking for smaller nodes that connected portions of the network and how that reflected the power dynamics in the text. For instance, the influence a freed slave with a low-degree node, Narcissus, had on two very high-degree nodes (Emperor Claudius and a court woman, Messalina) became a point of discussion for one student group (Day 1 High Group 2) as they sought to understand how influence worked in the Roman Imperial court. By comparison, low-degree nodes with low-degree less-influential connections will generally float to the outside of the network visualization. This distinction helps students begin to understand and then assess the contradiction between implicit and broad influence versus explicit by more localized influence.

Computationally calculated placement and sizing of nodes and edges requires a centralized database that tracks and incorporates small-group entries in real time. This treatment of data is not purely a technical benefit, though. Our activity requires small groups first to search the existing data table for an existing entry before entering new nodes and edges. This serves to keep duplicates and ambiguous entries out of the network, reducing unnecessary complexity. It also helps familiarize students slowly with the information made available to them by their peers. The presence of attribute fields, including significance and citations, helps focus the students on more complete details about a specific element in the network. A centralized database updating in real time also allows the display and resorting of every individual node and edge that contributes to the network visualization, giving students easy access to individual nuggets of information as they look for specific information in the large dataset they are building with their classmates in real time.

All of these visualization and data features are supported by the careful treatment of data as *capta* (Drucker, 2011), in which information is gathered with the interpretive lens of a historian. Like earlier CSCL concept mapping tools that helped students connect evidence to aspects of their concept maps (Toth et al., 2002), Net.Create also supports students in linking the course readings to the visualization via a citation field accessible in both the Nodes and Edges data tabs. However, Net.Create also draws on

precedents in the network-analysis community for SNA drawn from a variety of sources at the researcher's preference, rather than automatically scraped data drawn from social networks online. By approaching historical texts as potential sources of *capta*, Net.Create offers students an additional link between history and data science that treats conceptual structures like places and events as historical actors. These places and events are themselves part of an influence network that aligns with the centrality-measurement goals of social-network analysts who gather data by hand (Han, 2009; Padgett & Ansell, 1993) and with the social-network-analysis practices of digital historians who gather, rather than digitally "mine" or "scrape," data from texts of historical sources like diaries and letters (Winterer, 2012). The *capta* approach also allows for, and even encourages isolates or orphans, nodes that are not connected to the main network. These isolates and less-well-connected elements in a social network help provide analytical bases for explaining the causal patterns that result in high-degree, betweenness-central but low-degree, and low-degree or zero-degree nodes in the same network (Forti, Franzoni & Sombrero, 2013).

AQ10

Despite all of these enhancements, a large network visualization still contains a great deal of information, which might be potentially overwhelming for students who don't know where to focus their attention (Mayer et al., 2005). Therefore, we organized our activities to provide students with an opportunity to start with a blank network and build up from there. Starting with a blank network helps students become accustomed to the increasing complexity of the network. Their early encounters as they are learning the text and the network are with smaller aggregate structures. As the network grows over time, so too does their familiarity with both their own local detail and the larger aggregate network.

AQ11

As they work in their small groups, Net.Create also exposes the tension between depending only on close-reading or looking only at aggregate patterns. As students build knowledge about their small excerpt, they can see how their local context, drawn only from that excerpt, differs from and overlaps with the bigger picture. The Net.Create activity draws on this interplay to help students see the difference between the narrower frame of historical agents they encountered directly and the broader context. Historians are then further interested in exploring the mechanisms for how the context led to the observed outcomes. Colloquially, we can refer to these as exploring the who, what, and why of history as related questions (Calder, 2006). In those terms, we have found it helpful to work with students to begin to understand "who" the author was and how this shaped the details they recorded, to then situate that within a broader discussion of "what" was happening in the historical period, to then support a conversation about "why" those events might have happened as they did, and why the historical actors recorded them in that way. Ordering it this way encourages students to explore the idea of historical causality, or the reasons events unfolded the way they did, and see causality as shaped by the social and cultural contexts around the events and historical actors in them. Recreating this historical causality requires students to understand the dialogue in which the author is engaging with their historically contemporary readers; it also requires students to engage in dialogue with their own small groups in order to interpret the details of the text and in the larger-group dialogue of the network visualization and its historical context. Net.Create mediates these interactions by providing a middle space between the student groups' personal data entry within Net.Create and the larger group visualization exposed and externalized by the whole class. This process makes the large-classroom division of labor an advantage, rather than a disadvantage, to individual students learning at their own pace.

515 **Methods**

516 **Participants**

517 This study was conducted over two 75-min class sessions in an undergraduate survey his-
518 tory course at a Midwestern United States university. The 76 students were divided into
519 25 groups of three students in a large lecture hall with tiered stadium seating. Prior to the
520 first day of the two-day activity, we asked students whether they had a laptop and were
521 willing to use their laptop for group work. Each group that did not have one was given a
522 laptop to collaboratively use Net.Create. The laptops were prepared in advance to screen
523 record students' activity. We also asked the instructor for clicker-response data as a meas-
524 ure of course performance to date. Using clicker-response grades, we aimed for roughly
525 equal performance from group to group by putting one high-performing student, one low-
526 performing student and one average student in each group of three. We also made sure each
527 group had at least one student who responded affirmatively to having a laptop and being
528 willing to use it.

529 **The net.create tacitus unit**

530 For this implementation of Net.Create, students used excerpts from a history of the late
531 Roman imperial court written by Tacitus, a historian who lived in ancient Rome, to explore
532 how different generations of historical figures interacted. Here, the nodes represent the
533 complex history of Claudius, the Roman emperor from 41–54 C.E., whose fourth mar-
534 riage to Agrippina brought with it an adopted stepson, Nero, who became emperor after
535 Claudius. The nodes representing these historical figures are connected not simply to each
536 other but in a triangular interaction demonstrating their relations with each other (See
537 Fig. 1).

538 The Net.Create activities in this study were designed around three instructional goals
539 derived from our research questions. These instructional goals tied to learning outcomes
540 oriented toward helping students recreate the historical context in a 60-page historical pri-
541 mary source about the Roman Emperors Nero and Claudius (Tacitus, 2008), which we
542 divided into 1.5-page excerpts. Table 1 maps each of our instructional goals to our desired
543 learning outcomes, the salient Net.Create features, and data collected to assess achieve-
544 ment of learning outcomes.

545 Day 1 began with the first author presenting an introduction to networks as a method
546 for recreating historical context. For this we used a series of slides (Fig. 3) to help students
547 understand the parallels between building historical context and the activity structure of
548 the Net.Create activity itself, so students had some metacognitive tools to reference as they
549 entered and revised data. Such metacognitive tools can support history students in noticing
550 when they hit roadblocks in their reading comprehension and support them in generating
551 explanations for historical events (Poitras et al., 2012). We then introduced them to basic
552 network-analysis vocabulary, in two steps, so we could further emphasize the parallels
553 between network-analysis thinking and historical context building. Slide three introduced
554 some of the simplified “whys” of network analysis in history.

555 After students were introduced to key network analysis concepts, each student group
556 was given a unique excerpt from Tacitus to read and use to enter new node and edge data
557 into the Net.Create tool. For example, the group who read the excerpt about Messalina's

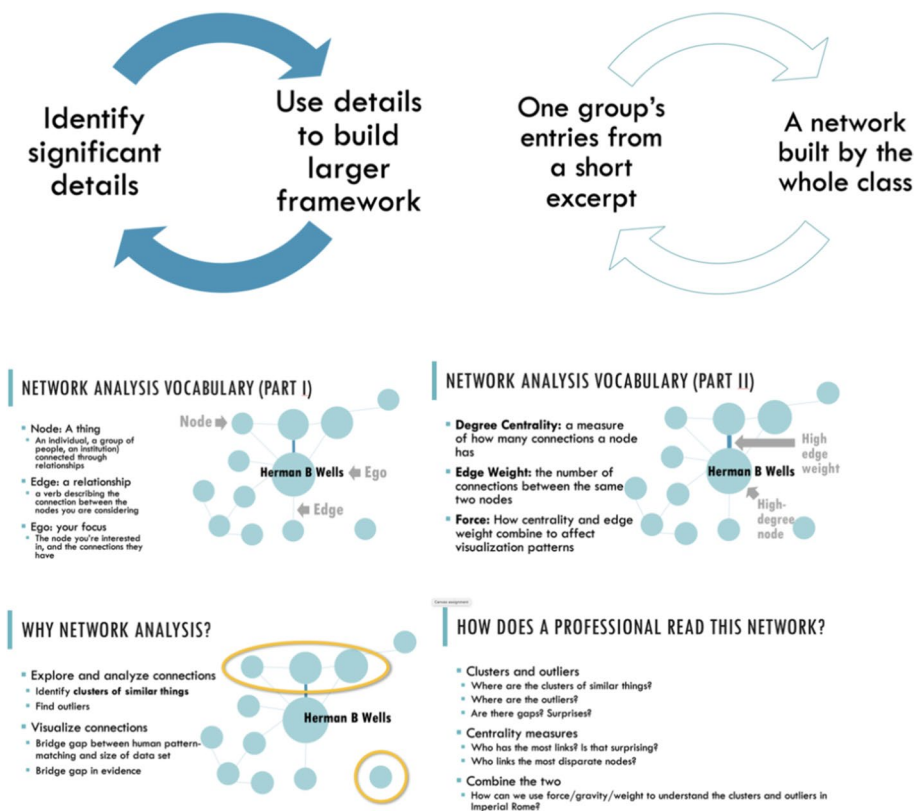


Fig. 3 Slides used to introduce the Net.Create activities to students, explaining key vocabulary and rationale for using network analysis in the context of history

extravagant behavior (see above) added a node for Messalina, added an edge indicating her marriage to Claudius, and then added an additional edge to indicate her affair with Gaius Silius. At the end of Day 1, the class discussed some of the emerging patterns in the network, including an identification of key actors in the network who thus played an important role in the text. After students completed their edits and spent time reviewing the network created by the entire class, we presented one final “introductory” slide (See Fig. 3: “how does a professional read this network”) to reinforce the network visualization vocabulary and process. The course instructor (an expert in Roman history) and Net.Create’s PI (a medieval and digital historian) led the class in a discussion using the concepts on this slide to explore the network students had created, so they could see how their work on Day 1 aligned with, and inspired questions for, experts in the subject matter.

On Day 2 of the study, each group evaluated nodes and edges created by another group previously and revised data to improve accuracy and fill gaps. Data entry prompts within Net.Create encouraged the inclusion of citations and notes on historical significance for each node and edge. These text notes on historical significance provided additional annotation for reference and contextualization. At the end of Day 2, an instructor explicitly demonstrated the use of force-directed layout to explore network “gravity”

and to help students navigate the patterns of influence that had developed out of their collaborative network building.

Data sources and analysis

Data sources included screen-captured recordings of Net.Create in use, audio of small-group collaborations, software log data indicating when each group created or revised a node or edge, and individual student end-of-unit papers that asked students to reconstruct the early Roman Imperial historical context according to Tacitus. The study adopted a mixed methods approach (Creswell & Clark, 2017). We began by quantifying students' final paper performance, and then used these results to inform subsequent analysis about how group interactions with Net.Create supported these outcomes (See Table 2).

To answer our research questions, we focused on how the design of the Net.Create tool and activities helped to navigate the three core contradictions we had identified: between detail and context; between active learning and potentially passive lecture in a large lecture classroom; and between memorizing historical facts and building historical context. To better understand how students navigated these contradictions, we first identified which student groups were more and less successful in their classroom activities in order to explore how they mediated the contradictions that emerged in the different groups in ways that helped them successfully navigate the historical content. To do this, we began by using individual paper grades, assigned holistically by the primary instructor and graded out of 70 points, to construct group averages and identify groups made of individuals with higher-than-average scores on their individual papers and groups made up of individuals with lower-than-average scores. These data sources helped us determine the relationships between a small group's average grade on their individual papers and the ways groups interacted with the Net.Create tool during class.

To further characterize which kinds of historical thinking helped support students in navigating the contradictions they faced within their groups, we developed historical thinking codes that capture the depth of students' reasoning (see Table 2). This allowed us to triangulate more narrowly articulated categories of historical thinking that draw on the research-rating practices of the Net.Create team with the holistic history-grading practices of the instructional staff. To apply the historical thinking codes, two trained historians who had past experience as a paper grading team skimmed the entire paper corpus, and then chose a low, medium, and high paper as examples of what different levels of historical thinking looked like. The team then discussed these paper examples and adapted items 1 ("Build historical knowledge") and 2 ("Develop historical methods") from "The History Discipline Core" (AHA Tuning Project, 2016), an attempt by the American Historical Association to describe the disciplinary skills that students should develop in history programs. We applied the resulting coding scheme on a Likert scale to reflect differences in paper quality, and then coded 20% of the papers (9/46) using the developed coding scheme (See Table 2). The coders agreed on the scores for 8/9 papers (88% agreement) and negotiated the discrepant scores for one paper to 100%. We averaged the instructor assigned scores and researcher assigned historical thinking ratings to produce a holistic group score (see Table 3) and then used that to represent each group's relative historical-thinking performance.

While students' papers are one measure of their historical reasoning, we also wanted to examine whether their networks demonstrated a similar depth of understanding so that we could better understand how creating those networks helped mediate the process of

Table 2 Methods used for analysis mapped to key data sources

Source	Coding Schema	Notes
Log data	<i>Determining the quality of entries (Historical significance):</i> Written annotations in the significance field were coded on a scale (1–5). 1 = no attempt at explaining the historical significance of the node/edge; 5 = a well-constructed explanation of significance that includes the specific situational context of related nodes and edges	Two historians rated 12% of the entries and achieved 90% agreement, negotiating any differences to 100% agreement before coding the rest of the corpus
Individual student end-of-unit paper	<i>Instructor grades:</i> standard A-F grading scale out of a possible 70 points <i>Historical sourcing:</i> Did the student recognize that the historical account in the Annals was driven by Tacitus's perspective? Coded on a qualitative scale (no, sort of, yes) based on whether the student drew on information only from Net.Create significance fields or added additional information from Tacitus not contained in Net. Create notes <i>Historical context (2 questions):</i> Coded on a Likert scale (never, seldom, occasionally, often, or consistently) • Attempted to reconstruct broad historical context • Accurately reconstructed broad historical context <i>Close reading (2 questions):</i> Coded on a Likert scale (never, seldom, occasionally, often, or consistently) • Accurately identified historical actors • Accurately placed historical actors in their individual context	For all but the instructor grades, three members of the research team rated 20% of the entries and achieved 88% agreement, negotiating any differences to 100% agreement before coding the rest of the corpus
Audio & screen-capture recordings	Interaction analysis of groups selected based on weak/strong log-data and paper scores	

Table 3 Group Data and Descriptive Statistics for Tool Interactions and Final Paper Scores

Group # (case study label)	Total Node/Edge Creations and Revisions (Days 1 & 2)	Average Quality Ratings for Node/Edge Entries (Scale of 1–5)	Average Final Paper Scores (70 pts possible)	Average Historical Thinking Final Paper Ratings (28 pts possible)
1	19	2.58	61.7	18.7
2	25	2.64	64.7	19.8
3 (Low1)	35	2.77	57.2	14.7
4	N/A**	N/A**	63.3	17.7
5	24	3.08	65	19.3
6 (Low3)	14	3	58.3	18
7 (High1)	20	3.95	67.3	25.3
8	10	4	66.2	17.7
9	22	4.09	60	20.3
10	20	2.90	60	18.7
11	N/A**	N/A**	64	17.3
12 (Low2)	22	2.95	62	15.3
13 (High2)	35	3.57	67.7	21.7
15	26	3.38	65	17.7
16	28	3	65.7	20.3
17	20	3.50	64.6	20
19 (High3)	21	3.81	68.3	20.3
Group Mean	22.7**	3.28** / 5	63.6 / 70	19 / 28
Standard Deviation	6.68**	0.51**	3.27	2.44

**Groups 4 and 11 were each missing log data from at least one day of activity, so they were not included in correlation calculations or group mean/standard deviation calculations for tool interactions.

understanding the historical text. Analyzing student networks to understand the depth of their understanding as represented is complex for several reasons. First, the network as a whole represents additions and revisions by all of the groups in the class, sometimes including multiple layers of revisions. Second, while historians generally converge on key ideas about the text, there is no such thing as a normative “network” of those events, especially given that many of the key relationships might be depicted in a number of ways.

Therefore, to evaluate student group contributions to the network, we considered all actions visible in the log data. The log data helped us to measure the quantity and quality of Net.Create tool use. Tool use is defined in terms of the nodes and edges that students

GroupNo	EventAction	NodeEdgeID	NodeEdgeInfo
8	insert edge	348	<pre>{ "id": 348, "source": 22, "target": 65, "attributes": { "Relationship": "has peaceful, familial or conversational interaction with", "Info": "", "Citations": "13, 19", "Notes": "They were longtime friends who were driven into conflict over the prospect of Junia Silana marrying Sextius Africanus, creating animosity between the two." } }</pre>

Fig. 4 An example of how log data showed group interactions with the Net.Create tool. The “Notes” field in the log is the significance entry written by students to explain the importance of this edge

created and the information they entered into Net.Create to explain the importance of these nodes and edges. The logs recorded each time a node or edge was added, and each time an existing node or edge was edited, along with the date and time of the edit. Figure 4 shows how along with these action labels (e.g., “insert edge”), the logs contained identifiers marking which group made the edit (“GroupNo”), which nodes/edges were involved in the edit (“source” and “target”), and what information was listed in the node/edge fields when the edit was saved (“Relationship”, “Citations”, and “Notes”).

To measure the quantity of interactions, server logs were organized by group, and the total number of times a group inserted or revised a node or edge were added together. Revision log entries were only counted if the group changed the substance of the node or edge information (i.e., if a group clicked “edit” and then “save” without changing the content of the entry, it was not counted). Quality of interactions with Net.Create, on the other hand, was measured using the average rating given by two raters to students’ node and edge entries (i.e., the “Notes” field, which allowed students to annotate nodes and edges with historical details). As with the quantity measure, a node or edge revision was only scored by raters if it represented a substantial edit. Initial node and edge creations that contained no information in the “Notes” section were automatically given a score of 1.

The two raters drew on their content expertise and previous experience as an instructional team in a large survey history course to create a five-point quality coding scheme to capture the level of complexity students included in their significance entries (see Table 2). 10% of the significance entries (42/424) were coded using a 1–5 scale (never, seldom, occasionally, consistently, always) and the raters initially agreed on 43% of those basic numerical ratings. The raters then generated prose descriptions of each numerical level to clarify what details were needed for entries to qualify as meaningful historical significance at each code level. After accounting for duplicate entries in which students clicked on a significance entry and used the “save” button to close the data-entry screen but did not change the content of the entry, raters ended up training on 42/350 entries, or 12% of the data set. The raters then re-coded this 12% using the clarified coding scheme and achieved 90% agreement.

Spearman’s correlations exposed the relationships between quantity and quality of Net.Create interactions and accurate reconstruction of historical context in student papers. One correlation looked at the quantity of interactions (total node/edge creation/revision) and final paper scores. Another correlation compared the quality of notations with Net.Create to final paper scores, using the ratings trained historians gave to students’ historical significance annotations (see Table 2). To further unpack how students’ interactions with Net.Create mediated their production of the network qualities that we had documented, we next used log data to map event timelines for groups that were particularly strong or weak at reconstructing historical context in Net.Create, as defined by the quality ratings historians gave to the significance-field entries. These significance entries provided a proxy for the quality of student discussion during the in-class activity, because the activity asked student groups to discuss what the contents of their significance entries should be for each node and edge they identified. We also compared entry processes of groups that did better or worse on the final paper, to see whether these differences in scores might be related to groups’ Net.Create data-entry processes. For example, some groups entered many nodes with shallow historical-significance explanations, while others spent more time creating and revising each node and edge, with fewer resulting entries but higher quality connections to the broader historical context. To triangulate log data and analyze the impact of Net.Create features on group collaboration, we conducted interaction analysis (Jordan & Henderson, 1995) on a subset of the screen-capture and audio data. This data exposed the

collaborative practices of students as they entered data and helped us explore how patterns of behavior in groups with fewer entries in Net.Create might account for performance on final papers. Excerpts selected to demonstrate these differences represent broad patterns in interactions we saw across the groups.

Findings

Below, we present our findings organized by how the design of the Net.Create tool and activities helped, or did not help, with overcoming the three contradictions that drove our design efforts: 1) the contradiction between details and context; 2) the contradiction between active learning and potentially passive lecture in a large lecture classroom; and 3) the contradiction between memorizing historical facts and building historical context. In each section, we also aim to illustrate how Net.Create mediated the resolution of the target contradiction.

Exploring quantity and quality of tool interactions: How using net.create mediates the contradiction between details and context

We began our exploration into the data by looking first at quantitative comparisons of groups' interactions with Net.Create, to see if student paper scores and log data could give us insight into whether entering many small details into the visualization successfully supported groups in understanding the broader historical context. The end-of-unit paper required students to interpret the network like a professional, in both historical and data science terms. We asked students to identify influence in the historical network by comparing the node with the highest degree centrality in their excerpt with the highest-degree central node in the entire network. We asked them to provide a similar comparison for the node in their excerpt that appeared less large but seemed to connect important sections of the network together (i.e., betweenness). Students then had to translate these data science practices into historical context, to make sense of which historical figures were influencing the ways that events unfolded and use the visualization and its associated significance notes to explain why the nodes they highlighted were influential. Table 3 shows descriptive statistics for the 17 groups (out of the total 25) who agreed to have their data used in the study (51/76 total students), with shaded rows indicating student groups for whom we will present further analysis below.

Statistical analysis of the log data (e.g., creations and revisions) revealed that groups who added and revised the most nodes and edges in Net.Create did not necessarily score higher on their final paper (as measured by the instructor-assigned scores out of 70 points). A Spearman's correlation revealed no significant correlation between the quantity of interactions with Net.Create (column 2) and performance on the final paper (column 4) ($r_s = 0.11$, $n = 15$, p (2-tailed) = 0.69). This suggests that merely entering large amounts of local details into a network is not sufficient to give students an understanding of broader patterns and context in the data. Thus, analyzing additional features of the activity system beyond data entry was needed to account for differences in the extent to which groups were able to overcome the contradictions of working with large historical datasets.

We next looked at the opportunities Net.Create offered for students to process local details as they entered them (e.g., data entry fields encouraging citational practices and encouraging the interpretive process of *capta* to specify details of relationships). Looking

at the types of details groups entered into the “Notes” field for nodes and edges revealed a moderate, positive correlation between the average quality of groups’ historical significance entries in Net.Create (column 3) and average scores on final paper (column 4) ($r_s = 0.53$, $n = 15$, p (2-tailed) < 0.05). Students who were most successful at reconstructing historical context in their final papers tended to belong to groups whose activities were more focused on *capta* and the construction of more sophisticated explanations of edge and node significance in their data entry. This suggests that the attribute features in Net.Create, which we designed to encourage students to slow down and articulate the importance of small details in relation to the context of their data, may more effectively mediate their ability to move between local and global patterns than reading about and entering large amounts of data more quickly.

This pattern held when we looked qualitatively at how students leveraged the network evidence in their final papers. Students in Group Low1 did not explicitly reference any aspects of the network graph in their papers and only offered vague summaries of historical relationships (e.g., “I think that she really used Nero to try and get Claudius out of the way and then when Nero was too powerful and performing all the time, Agrippina knew it was only a matter of time before Nero did something bad to her”). Students in Group Low2 were a bit more sophisticated in their use of evidence, and they used features drawn from the visualization such as the centrality of nodes and node factions to link their arguments to historical evidence:

“While she may have tried to control him, Nero ends up becoming powerful in of himself as he also has a large node and faction associated with himself. As seen in the readings, Nero eventually turns on Agrippina and he sheds her influence over him. You would think that an emperor turning against you would destroy her whole power base, but as seen in the Net Create, she had access to a large faction of herself. As Agrippina slowly lost the favor of her son, Nero still feared his mother. Nero’s attempts to kill his mother shows that he felt her to be dangerous still.” (Final Paper, Group Low2 Student).

In this paper, the student is beginning to reason about how the Net.Create visualization represents the influence of different historical figures and how their size and positionality indicates how the visualization relates to the actions they took in the text.

Students in higher performing groups made these connections in increasingly sophisticated ways, with more explicit links to evidence from the network visualization, information about historical figures drawn from data entered into the Net.Create attributes, and from Tacitus’ text:

“The network analysis chart reveals several interesting aspects about the extent of Agrippina’s political influence. The first is that Agrippina’s large node, the largest among the represented women, is situated between Nero and Claudius, with whom she has a variety of connections. One might be surprised that her edge with Claudius is not thicker. However, her node has no direct connection to the Senate. Agrippina’s closest connection with it might be with Alledius Severus, who campaigned for marriage between an uncle and a niece simply to pursue his romantic interests with her (12.07). This suggests that while her influence was strong as she grew to be dominant in the imperial household, she may have had less direct influence over the Senate. Also notable is that Agrippina seems to have her own cluster of female nodes, both friendly and hostile, that in many cases lack connection to other nodes. This suggests that Agrippina had her own network of conspirators, such as Aceronia and Halotus, who were otherwise less connected (14.05, 12.66).” (Final Paper, Group High1 Student).

Here, the student makes use of the relative position of nodes, edge weights, and node factions in a historical argument to explain how Agrippina wielded indirect power over

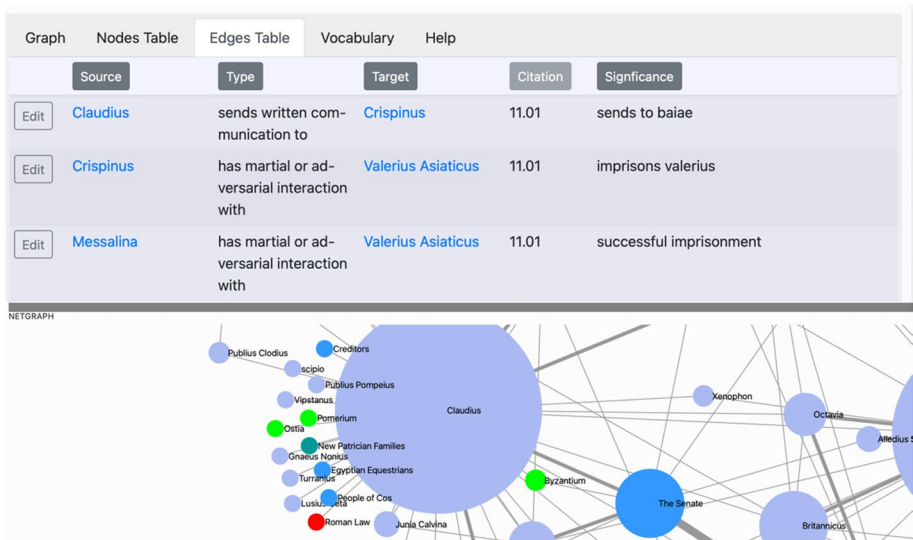


Fig. 5 1: Recreated student view of excerpted edge entries from Tacitus, Annals, Book 11 Chapter 1

historical events. These network visualization features served as guideposts for students during their analysis, encouraging them to notice potential historical relationships and then dive into the text to find evidence to support their interpretations.

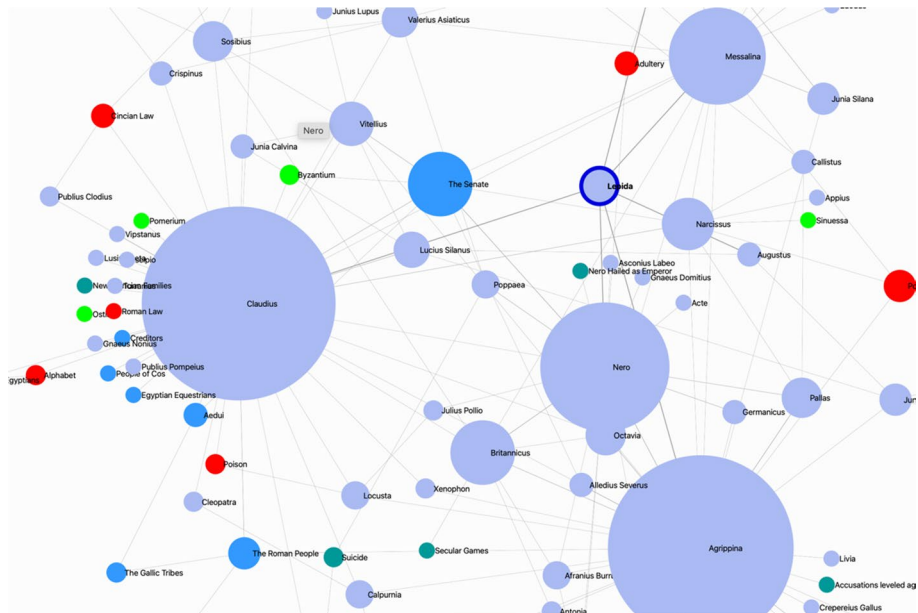
While the network visualization alone cannot give students a complete picture of how and why historical events unfolded, the relative sizes and positions of nodes did encourage students to explore node and edge attributes in Net.Create and link those attribute entries back to the source text. In turn, students used textual evidence from Net.Create attributes and the primary source to make sense of the patterns they were observing in the network visualization. We saw evidence of this pattern-finding and interpretation in groups’ interactions with the tool during class, such as when Group High1 explored the data entered by their peers at the end of Day 1.

This group first scrolled through the edges table (Fig. 5) to look at what edges had been added to the network by other groups in the class. They sorted the table by citation number, which showed them edges that had been added for chapters of the text adjacent to the one they were assigned. This allowed students to differentiate between their own section of the text and the larger dataset that the class was building together, which helped students to navigate the framework-detail tension in the reading of a historical text.

After exploring the edges table and the local details entered by their peers, the group then zooms out on the network graph to get the “big picture” view of the network so far (Fig. 6). One student makes an observation about the way the nodes are currently arranged, saying:

“Claudius doesn’t seem to have much information about figures adjacent to the emperors or their family. Um, like you see all these little bubbles here, they have some relation to Claudius, but they aren’t linked to anyone else.” (Day 1, Group High1).

In this way, the network visualization helped students to notice potential patterns in the data (e.g., that Claudius had many connections to smaller figures who did not have ties to other power players) and also to consider where the network might be missing key



data (e.g., that Claudius likely has more connections to the royal family than are currently depicted).

This attention to the data entered by their peers, documented in both these quantitative log interactions and qualitative video interactions, also appears in our field notes. We hoped, based on our pilot study, that students would draw on the work their peers had done, and our field notes reflect these hoped-for behaviors. Students recognized additional data entry done by other groups while they were focused on one data entry task, represented by edges between nodes or nodes that were not there prior to the start of a just-concluded edge or node data entry task. The resulting attention that other student-group input drew to potential gaps in their knowledge encouraged students to expand the network on Day 2 and fill in the missing information that would give them a more complete picture of the historical relationships in the network.

Exploring quality of small-group contributions: How interactions with net.create mediate the contradiction between active knowledge building and large lecture classrooms

To uncover more detail about the specific features of the Net.Create activities that were mediating students' learning, we highlighted groups with high average scores and low average scores on the averaged final-paper and historical-thinking ratings. Since quantitative results from log data suggested that the quality of entry processes was more central to students' learning than sheer amount of data entered, we mapped out timelines of these low- and high-scoring groups' interactions with Net.Create based on log data, to explore how different data entry methods might be mediating students' knowledge building.

Some groups tended to enter many nodes and edges in quick succession without spending much time exploring the nodes entered by other groups (e.g., Group Low1). Other groups took more time editing fewer entries, with time in between edits where the group clicked between different nodes in the network (e.g., Group Low2, Group High1). While we initially categorized these clicking actions as passive or reference-oriented, analysis of student conversation along with log data indicated that the nodes on which students clicked often reflected the nodes for which the group was discussing and proposing subsequent edits. These edits were not just on their own work, but also revisions to the nodes and edges created by their peers in other groups.

Analyzing the group discourse around these moments of entry and revision helped us link data-entry interaction patterns with the Net.Create tool to conversational patterns in group discussion. This allowed us to triangulate the mediators that supported groups in moving between knowledge-building within their small group and reflecting on findings with the whole class. The stretches of discussion time in between moments of data entry is where particular features of Net.Create, such as force-directed relationships between nodes, mediated students' understanding of which nodes were historically important and why. For example, Group High1 spent portions of their discussion time exploring the Net.Create visualization to figure out how the network was depicting the importance of different relationships through node size and edge thickness. The relative size and gravitational pull of different nodes supported this group in contributing to the whole class discussion about the historical importance of different nodes:

Joe: "Our biggest node contribution was Narcissus, and y'know, he's certainly not the biggest figure connected to Claudius, but nonetheless he's related to both Claudius and Messalina as an advisor, freedman advisor to Claudius, and the one who ordered the final execution of his adulterous wife. And it's sort of interesting to see a freedman, a former slave assume such prominence."

Though such examples hint at the effectiveness of Net.Create for mediating students' interpretations of historical context, not all student groups provided video consent, so we could not directly measure the effects of force-directed layout on student knowledge-building in the middle space between detail and aggregate. Instead, we needed an intermediary process to let us explore conversational patterns from video recorded groups and use those as proxy measures to help explain shifts in Net.Create significance entries for groups we could not record on video. For this, we looked first to the historical significance ratings of student entries. The Net.Create activity design asked students to engage in in-person dialogue in small groups. They then distilled that dialogue into significance entries in Net.Create that mediated a classroom-wide software-scaffolded dialogue. We took these ratings of the typed significance entries as a proxy for the depth of students' small-group historical discussions (See Table 3) as they did original entries on Day 1 and revisions on Day 2.

Overall, the class improved their explanations of the larger context of individual nodes and edges across the board from Day 1 to Day 2. The average rating of the annotations entered into node and edge significance fields in Net.Create, which resulted from their conversations during the in-class activity, started at 2/5 on Day 1 and improved to 3.67/5 on Day 2. We identified three groups whose rating changes across the two days offered a representative picture of the different improvement patterns in the data set. Two of these groups saw considerable improvement; the two groups, however, had very different Day 1 starting points. Group Low1 (no video) started low and saw the most improvement: a jump from 2.21/5 to 4/5 in Day 2's revision activity. Group High1 (video) started high and showed an improvement from 3.85/5 on Day 1 to 4.14/5 on Day 2. A third group showed limited gains from Day 1 to Day 2; Group Low2 (video) started at a significance rating of

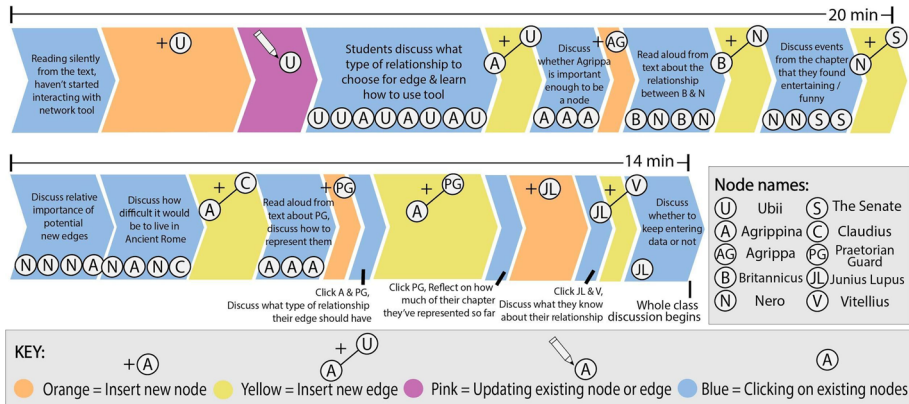


Fig. 7 Group Low2's data entry timeline for Day 1. The average quality rating for their significance entries on this day was 2.91/5

2.91/5 on Day 1, but only increased to a 3/5 on Day 2. Despite these limited gains, Group Low2's log data showed similar tool interaction patterns to Group High1, making them a useful contrasting case study to understand how Net.Create may mediate the learning of groups in different ways, depending on both how the tool is used but also the kinds of conversations that emerge around the tool.

Exploring differences in group goals: How interactions with net.create mediate the contradiction between memorization and building historical context

On Day 1, the log data for Group Low2 (average paper score: 62/70) and Group High1 (average paper score: 67.3/70) had similar features despite the differences in their average significance ratings. The most salient of these features was a pattern of longer, seemingly passive "information consumption"—several minutes clicking back and forth between nodes, presumably comparing information contained in the significance entries of those nodes—and then several faster actions in which groups created edges and wrote significance entries. Analysis of audio and screen-capture data from these two groups reveals three varying levels of depth of historical analysis in their conversation about significance: 1) the "who" of history (e.g., names, dates, events that come up frequently in the text), 2) the "what" of particular people or events, and 3) the "why" explaining the broader context in which people's interactions emerged. These varying levels highlight different goals for historical analysis, with "who" and "what" reflecting the novice historian's emphasis on memorization of basic details, while the "why" of these events better reflects a professional historian's motivation to understand the context from which historical events emerge.

Because the two groups differed in both average paper scores and Net.Create significance entries, we wanted to better understand how these "passive" stretches of time, represented by information consumption but not production or revision, played a role in the knowledge building process. To do so, we visualized their log data in timeline form (see Figs. 7, 8, 9 and 10) for Low2 & Fig. 10 for High1). Segment lengths represent the amount of time students spent on that activity, rounded to the nearest half-minute; segment lengths ranged from 30 s to five minutes, and click icons are spaced out according to when those nodes were clicked. Each timeline begins after

The screenshot displays the Net.Create interface. On the left, a list of nodes is shown: Octavia, Pallas, Political Murder, Agrippina, Statilius Taurus, The Roman People, Ubi, Alledius Severus, Anicetus, and Annaeus Seneca. A dropdown menu for 'EDGE 285' is open, showing a list of interaction types: 'Source', 'Type', 'Target', 'Citation', and 'Significance'. The 'Type' dropdown is selected, showing a list of interaction types: 'has peaceful interaction with', 'has adversarial interaction with', 'sends written communication to', 'is a group member of', 'participates in', and 'makes visit to'. The 'Significance' dropdown is also visible, showing a text entry: 'She dismisses Lucius Geta and Rufirus Crispinus because she wanted the guard under the command of Burus Afranius'. On the right, a transcript of a discussion is shown, with lines 1 through 20. The transcript includes names of participants (Derek, Jason, Quentin) and their dialogue. The dialogue discusses the historical figure Agrippina and her interactions with the Praetorian guard.

Fig. 8 Excerpt of Group Low2’s discussion on Day 1, 30 min into class, with screen capture of supporting Net.Create feature (drop-down menu of edge types makes significance of interaction types more visible to students)

the students have been given their initial instructions for the day’s activities and ends 34 min later, when the instructor signaled for the whole class discussion. We then explored the representations of student timelines together with interactional analysis of the group discussion with screen captures of the relevant Net.Create user-interface features (See Figs. 8 and 9 for Low2; see Figs. 11 and 12 for High1) drawn from video data. These representations together highlight the productive collaborative work these groups engaged in.

Below, we analyze some key representative extracts that show how engaging with the Net.Create tool scaffolded the historical thinking of both high performing and low performing collaborative groups. These excerpts suggest focusing on the “who” is an important first step in deciding what nodes need to be added to the network, but an analysis of who was involved in a historical account without attention to “what” they did or “why” leaves students with memorization-focused goals for activity, rather than the context-building goals desired by professional historians. Thus, we investigate what features of Net.Create, such as historical significance notes, mediated students’ shift from basic to more sophisticated historical discussion practices.

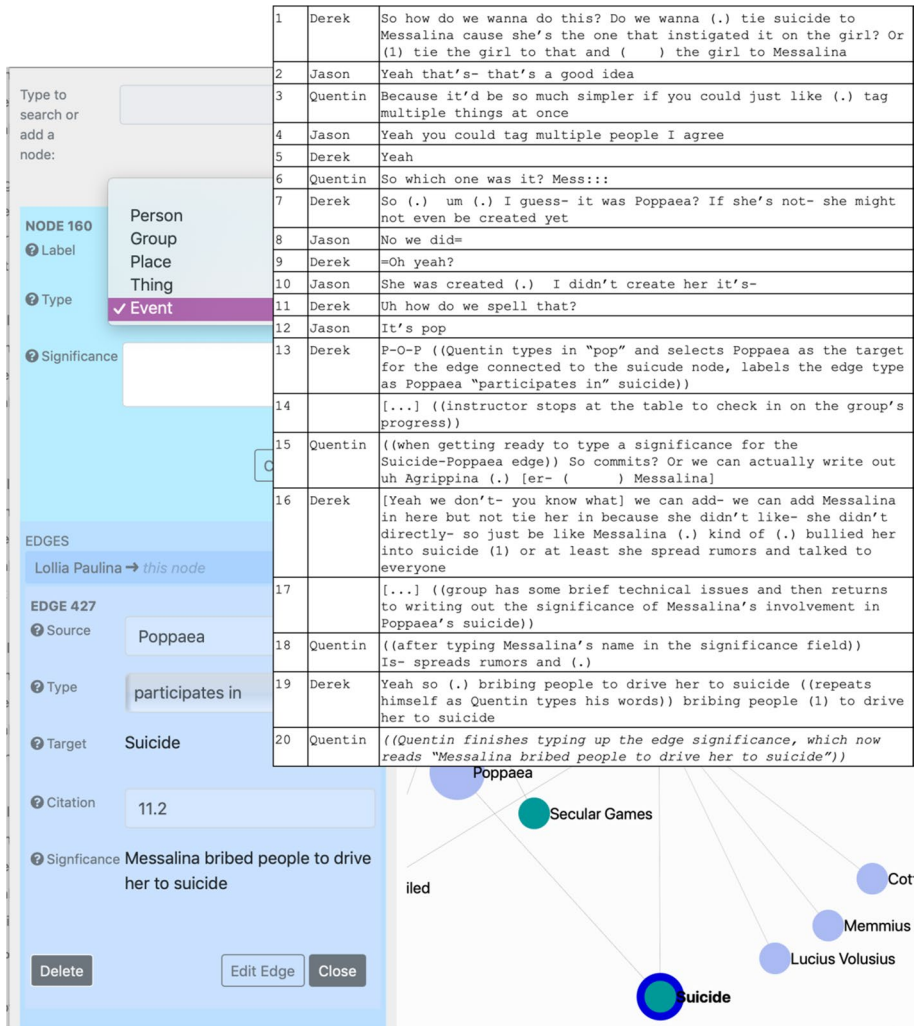


Fig. 9 Excerpt of Group Low2's discussion on Day 2, adding the concept of "suicide", with screen capture of supporting Net.Create feature (drop-down menu of node types prompts students to consider concepts with potential interactions as nodes in the historical context)

916 "Passive" information consumption and the "Who" element of history information 917 gathering

918 In the timeline representation above (Fig. 7), Group Low2 moves between information
919 retrieval—the blue elements of the timeline in which they move back and forth between
920 the nodes they are connecting—and knowledge building—the orange, yellow, and pink
921 elements of the timeline in which they enter new data or revise existing data.

922 A closer look at interactions drawn from one portion of the timeline provided bet-
923 ter insight into the group's contributions to the larger-class knowledge building exer-
924 cise. The conversation analyzed below is drawn from the largest yellow segment in the

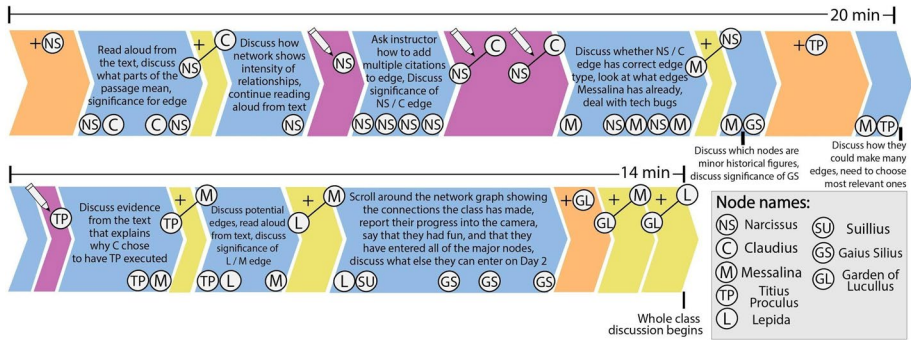


Fig. 10 Group High1's data entry timeline for Day 1. The average quality rating for their significance entries on this day was 3.85/5

Nodes Table	Edges Table	Vocabulary	Help			
Narcissus	has peaceful, familial or conversational interaction with	Claudius	11.34; 11.35; 11.37	Pressures Claudius knowledge Messalina's adultery. Takes C to Messalina's home to discover evidence of infidelity. Orders the centurions and tribune to go through with Messalina's execution.	1	Joe: Oh, you know what this is? ((referring to their assigned chapter of the text)) This is, I think this is relating, so 35 is, is when uh uh Narcissus is, is taking him to uh, to Messalina's home and exposing him to the severity of her uh adultery
Narcissus	has peaceful, familial or conversational interaction with	Claudius	11.30	Narcissus asks C for a pardon for his conduct because he received treachery from Claudius. Also, he helps up the idea that he marries Silius.	2	Ben: And wasn't she, did she kill herself or was killed shortly thereafter?
Nero	participates in	Adultery	11.12	Has an affair with freedwoman (Act)	3	Joe: Well yeah he, Claudius, Claudius was kind of tentative about killing her
					4	Ben: That's right
					5	Joe: So, so Narcissus gave the final order. So we should actually, we might wanna add that actually
					6	Ben: Yeah...((while Joe is editing Narcissus's significance)) Is it Tacitus, I-- that wrote like that um, Claudius like was in mourning or was, like very solemn afterwards I think? In the aftermath of the murder? [Joe has changed Narcissus's significance from "Freedman with Claudius" to "Freedman who advised Claudius"]
					7	Joe: Sorry? Yeah yeah yeah yeah, that's right. Well he was like, he was like, drinking and he was kind of...
					8	Ben: That's right...out of it?
					9	Joe: Out of it yeah
					10	[Joe and Ben go on to edit the significance between Narcissus and Claudius to include more specific details: Joe changes the edge significance from "Pressures Claudius to be truthful; removes his children" to "Pressures Claudius to acknowledge Messalina's adultery. Takes Claudius to Messalina's home to discover evidence of her infidelity. Orders centurions and tribune to go through with Messalina's execution."]

Fig. 11 Excerpt of Group High1's discussion on Day 1, editing the significance of Narcissus as they re-read their section of the text, with screen capture of supporting Net.Create feature (easy visualization of related edges and visibility of edge significance notes supports nuanced discussion)

1	Joe:	[Reads from screen] "Murder of Agrippina. Significance: Penalty for crime she committed." I mean, come on. [sigh] But. We can link it to political murder.
2	Ben:	Yeah, I think so.
3	Joe:	We haven't done that yet, no. Add new edge.
4	Ben:	I mean, they're not wrong, but-
5	Joe:	Yeah, but what help is that gonna be to somebody, you know, wanting to see what the motive of Agrippina was? Okay. [selects edge-type menu] "Participates in", "is a group member of". [pause] "Participates in," I guess...
6	Ted:	It's like marginally better than saying she died...[inaudible].
7	Joe:	Wait, they didn't even have a citation.
8	Ted:	What are you looking for?
9	Joe:	Yeah, the citation where Agrippina gets murdered. 'Cause it would be really fun to have that. [reads] "Nero was in a panic, eager to kill his mother." [inaudible] OK, we're close. Book 14. Agrippina heard the plot. OK. The botched murder attempt [pause] Like the greatest story of all time. I think 14.9. I mean, really, it goes on and on for several chapters.
10	Ben:	There'll be another group.
11	Joe:	Yeah, yeah, I figured I'd just... [types into "Significance" field: "Murders his politically ambitious mother, who tried to institute joint rule and was protected by Praetorian Guard."]

Links to Instructional Goals

Line 1: Students use Net.Create visualization and significance fields to support accurate historical identification.

Line 5: Students use Net.Create edge-type menu to support discussion about how local actor relates to larger network/historical context.

Lines 7-9: Students use Net.Create citation field to critique previous work ("historiography"), revisit text, and resituate individual in historical context.

Line 10: Students acknowledge small-group/whole-class joint task.

Line 11: Students tie 4 details together in Net.Create significance field to reconstruct historical context.

Fig. 12 Excerpt of Group High1's discussion on Day 2 (with Net.Create screen capture), linking students' comments to key instructional goals

925 timeline, labeled as an edge creation between "A" (Agrippina) and "PG" (Praetorian
926 Guard).

927 Just prior to the excerpt presented, the group had added a node "Praetorian guard"
928 with the description "Bodyguards to the imperial family" (see transcript and node-entry

form in Fig. 8 below). The group then decided to connect this node with the existing node for Agrippina. Agrippina is an important historical figure in the imperial reign of Claudius because she brought with her a stepson, Nero, whom Claudius adopted as a way of uniting two feuding families (Julians and Claudians). Nero became emperor after Claudius' death, a suspected poisoning by Agrippina, who Tacitus reports was then herself killed by Nero. Agrippina's courtly intrigue included firing the Praetorian guards whose loyalty was supposed to be to Claudius alone.

As this example highlights, the number of unfamiliar names in a Roman Imperial text can be overwhelming. But the spelling of names is a surface feature and less important for historical analysis. This group spends most of their discussion of the entry negotiating spelling, identifying who was involved in the event, and reading out names (lines 6–10, lines 13–19). They devote scant attention to the significance of the particular individuals or the broader context in which this dismissal of the guards is taking place. The group is largely focused on understanding the “who” of the historical event, but ideally we want students to focus more of their attention on analyzing the “what” of the interactions between people as well as the “why”, or the significance of these interactions to the broader historical context in which these events are unfolding.

“Passive” information consumption and the initial “What” stage of historical context building

Low scoring groups also benefited from activities on Day 2 which explicitly prompted groups to revise and expand on the significance entries their peers had created. For example, the Low2 group began Day 2 by critiquing how few significance notes had been added by the group who had their excerpt on Day 1. As we will see below, Group Low2 revised these entries to add the missing significance, which required them to use citations to engage in reconstruction of historical context.

On Day 1, their tool-use is mostly focused on spelling and clicking rapidly between items in the network. On Day 2, however, near the end of the class, the group begins to engage in a conversation about the significance of the “Suicide” node they entered and how to connect this concept to the rest of the network (see transcript with visualization and node-entry form in Fig. 9 below).

On Day 2, Group Low2 still focuses somewhat on understanding the “who” of historical events (e.g., the spelling question on line 11). However, they also move into a more detailed discussion of “what”. The group discusses events in Poppaea's life that contributed to her suicide, and they offer some contextual details about how Messalina spread rumors (line 16) and bribed others to make Poppaea's life more difficult (line 19). The building of additional historical context around the “suicide” node gives the students a deeper understanding of the deadly court intrigue that drove interactions. The students are not yet engaging with the “why” of these events; there is no mention in their significance entry of why Messalina would want to bully Poppaea or why Poppaea would be affected by the rumors Messalina spread. Nevertheless, the movement from analyzing “who” to “what” shows Net.Create supported low-performing groups in transitioning to more complex forms of historical analysis, even if their network entries did not show a sharp increase in complexity.

972 **“Passive” information gathering and moving toward the “Why” of historical context** 973 **building**

974 Meanwhile, groups that began Day 1 with more complex discussions of the “what” of his-
975 torical events, like Group High1, were also supported by the Net.Create tool to move to
976 even deeper forms of historical analysis. Group High1’s Day 1 timeline below (Fig. 10)
977 shows similar data entry patterns to Group Low2, with the active moments of knowledge
978 building in the network (orange, yellow, and pink) punctuated by long stretches of discus-
979 sion and information gathering (blue). By triangulating the student discussion and informa-
980 tion gathering patterns with Net.Create artifacts, we can get a better sense of how the Net.
981 Create tools and activity design mediated the advancement of their collective knowledge.

982 Though these two groups showed similar data entry patterns at the level of log data
983 analysis, analysis of conversation revealed a difference in focus. As shown in the discus-
984 sion excerpt below, Group High1 spent Day 1 discussing more of the “what” of the his-
985 torical events. They were focused on building the specific local significance of a particu-
986 lar individual’s actions in the context of relationships and attempting to represent that in
987 Net.Create. This discussion falls short of broader context building, but it is nonetheless an
988 important step on the way, and it reflects more depth than spelling concerns. In the excerpt
989 below (see transcript, visualization and edge table reference in Fig. 11 below), students in
990 Group High1 are editing the significance of the node for Narcissus (the first pink segment
991 in the timeline), who pressured Claudius to expose the adultery of his third wife, Mes-
992 salina, and then subsequently to order her execution.

993 The discussion in which Group High1 engages demonstrates a focus on historical con-
994 text and significance in their entries on Day 1. Group Low2 did not begin to engage with
995 questions of historical significance until Day 2. On Day 1, this group is focused on the
996 specific role Claudius plays in court intrigue directly involving Narcissus in Messalina’s
997 death—the “what” of the interaction. The students discuss details such as who gave the
998 final order (line 5), how Claudius felt about the possibility of executing his wife (line 3),
999 and how Claudius behaved after the execution (lines 6–7). This significance building offers
1000 a more complex picture of what was happening as Narcissus and Claudius plotted Mes-
1001 salina’s murder, but it falls short of the more detailed and broader context building that
1002 would explain why Narcissus wanted Messalina’s execution to happen, and why Claudius
1003 went along with it.

1004 Group High1’s conversation on Day 2, by comparison, is about political ambition, and
1005 it offers a focus on the “why” of events that was the ultimate goal of the Net.Create activi-
1006 ties. In this more nuanced conversation about Agrippina as a woman who inserts herself
1007 into a joint rulership, students are forced to contend with the social and cultural norms
1008 restricting women’s direct access to power in this context and why Agrippina’s grab for
1009 power resulted in her death. Figure 12 (transcript, network visualization and edge-entry
1010 form, below) demonstrates how this discussion by Group High1 on Day 2 used Net.Cre-
1011 ate’s edge-type feature to situate more nuanced encounters with details in their historical
1012 context, a practice better supporting success on the final paper.

1013 As Group High1 begins, they first engage with the representations offered by a previous
1014 group in both the main visualization and in the “citation” and “significance” attribute fields
1015 in Net.Create. As they edit the significance for the “Murder of Agrippina” node, they dis-
1016 cuss how the previous group’s entry for this node does not explain the importance of this
1017 event in enough depth. Ben and Joe jointly explain that while the group was factually accu-
1018 rate (line 4), the explanation of significance does not give a reader of the network sufficient

future studies. Some of these groups saw dramatic change from Day 1 to Day 2, so we now turn to a group for which we don't have video data but do have log data and significance ratings, using our understanding of the patterns represented in Groups Low2 and High1 log data and how those patterns are expressed in interactions. Group Low1, with an average paper grade of 57.2/70, exhibited the following tool-interaction pattern on Day 1.

Note the rapid clicking between nodes, the rapid creation of edges between nodes with little reference to the information in the nodes themselves (based on the short time spent on nodes), and the low average significance rating of the nodes and edges entered (2.21/5). As Group Low1's timeline shows (Fig. 13), they spent a significant amount of time linking nodes to other nodes, which is an essential first step in building a reconstruction of historical context through network analysis. Mapping the connections between nodes, noticing which nodes were missing and needed to be added, and adding additional relationships between key nodes allowed students to put the details from their chapter of the text into the larger context of the historical time period.

The high number of node and edge creations combined with the lower significance ratings suggest Group Low1 begins Day 1 at a similar stage of historical analysis as Group Low2, with a heavy focus on who was involved in historical events, and perhaps a bit of focus on "what", but little emphasis on the more complex "whys" that would have earned them higher significance scores on their network entries. Though we do not have access to Group Low1's conversations on this day, their log data and significance ratings tell us this group would benefit from instructor intervention to help them shift their focus to reconstructing why the relationships they entered into the network are important. This group's shift in average significance ratings (2.21/5 on Day 1 to 4/5 on Day 2) suggest the group was able to make some of this progress in shifting towards more complex historical analysis as they engaged with Net.Create, the instructor, and each other.

Discussion

The Net.Create tool and its accompanying 2-day activity structure supports many ways of engaging with complex data at its granular and aggregate levels for students at different levels of skill development in both their historical-thinking and data-science skills. For students who are struggling with the contradiction between moving between small details and broader context-building, Net.Create supports the move from an emphasis on small details to more in-depth discussions of the importance of individual interactions that contribute to aggregate patterns in the network. For these students, the challenge was moving from a focus on the "who" of history to the middle space between detail and aggregate that begins to explain some of the "what" and its significance in complex historical texts. At the same time, the Net.Create activity system also provides support for students who are already engaged with the "what" and need to begin engaging with the larger patterns that help explain "why". By resolving the contradiction between single and multiple voices, students were able to shift from understanding a local detail in isolation to seeing that detail's context in a larger historical framework. These shifts are fundamental to understanding the causal relationships between seemingly discrete historical events—e.g., single assassinations—that are shaped by the many events and relationships making up a broader historical context, like multi-generational multi-faction political power struggles made visible in this network of early Imperial Rome.

In particular, the revision tasks on which Day 2 focused are broad enough to allow for the revision of both the “what” and the “why”. This collaborative process of critiquing and revising edges in Net.Create helped to prepare these higher performing groups for success on the final paper, because they were critically reading a primary source text, critiquing other historians’ reading of that text, and building an understanding of how different historical actors influenced one another in the context of the time period. Developing these skills encourages students to adopt motivations for reading the text better aligned with the motivations of professional historians, rather than surface-level motivations such as memorizing names and dates. These skills, separately and in combination, are key building blocks supporting the historical argumentation and creation of historical narratives history instructors aim to teach in undergraduate classrooms.

Groups interacting with Net.Create were able to produce a shared network visualizing the historical significance of people, places, and events from Tacitus’ history. However, the value of collaboratively producing this network went beyond simply having a shared visualization for reference. As students created the nodes and edges of the network, Net.Create’s shared data and network visualization led them to engage in rich discussions about how to determine which elements of the historical text were relevant. This helped the students to move between local and global context to accurately reconstruct the larger historical significance of individuals, a process that is often a struggle for novice historians.

Students who were less successful in the class based on their paper grades, and whose historical-inquiry practices needed the most support, also saw benefits from the Net.Create intervention. Adding details in the form of nodes (i.e., names of people, places, and events) was still a starting point for students as they their own understanding of Tacitus’ history, but Net.Create encouraged them to tackle one of the barriers to history learning by expanding their focus to the significance of those details. For example, while Group Low2 didn’t focus on significance in their first pass at the network, they appear to have oriented toward this on the second day and were quite critical of the lack of significance previously entered. The activity design that culminated in student revision of peer entries supported them as they began to document the Roman imperial context in Tacitus’ history in exactly the kinds of ways we had hoped. We observed students describing the perspectives of multiple historical actors and the ways different actions and choices built up to influence key events, as evidenced by Group High 1’s conversation in Fig. 11. A goal of our future work is to make this tension between detail and significance more visible for students during the initial data entry portion of the activity by exploring the effects of features that allow for more live annotation and revision practices. Our research team’s experience with the representational practices embedded in other computer-supported collaborative tools suggests one such feature: a pop-up display of significance fields accessible from the nodes in the visualization itself, updated in real time. Exposing higher-performing teams’ work quickly without requiring students to actively explore information in the nodes and edges tables may encourage lower-performing groups to work through more historical context in their first pass as they see other higher-performing groups entering more substantive information. (Craig, Danish, et al., 2020).

Net.Create also supported the inquiry practices of more successful students; it acted as a mediating tool to help them shift away from memorization and toward the active construction of knowledge underpinning the reconstruction of historical significance. When students were tasked with explaining how various historical actors were connected using edge types, they didn’t simply regurgitate the relationships they had read about. Rather, they engaged in rich conversations about how the individual nodes fit into the larger historical context. They did this by using the network visualization incorporated in Net.Create to

explore those relationships while also revisiting and revising the ideas based on referencing the primary source text. This easy transition between the extremes of the disciplinary and learning contradictions we laid out initially, both in terms of traditional historical practices and data science practices, suggests the value of rooting our software and activity design in activity theory. The activity system helped students reconstruct historical context through iterative referencing of sources by drawing on the network-analysis visualizations representations in Net.Create to help visualize, connect, and refine those relationships.

Conclusion

By rooting our design approach to Net.Create and its activity system in activity theory, we were able to connect disciplinary practices in data science and history in ways that make it easier to address the contradictions that pose barriers to student learning in both. In particular, the apparent gap between data science and history becomes narrower when we consider that both disciplines ask practitioners to move between small detail and aggregate overview. This gap was further bridged by using the tools of data science to help students connect those two perspectives in historical texts, drawing on the work of their peers to ease the process. Many students began the long process of shifting away from memorization and toward reconstructing historical context. Net.Create's features, with its integrated activity system, bridge that gap in both conceptual and practical ways that are both relevant for learners and a potential model for linking activities to features in collaborative computational tool design. Our data supports instructor and research-team observations that Net.Create was effective as a mediating tool, pushing even weaker students to engage in the first steps of building historical-context reconstruction skills. Our goal is to use the collaborative patterns of successful groups in this study as a way to redesign and orchestrate future Net.Create activities that help students move even more rapidly toward the reconciliation of contradictions they face in handling complexity in both data science and history activities. At the same time, we view this as a valuable model for engaging large groups of students in powerful knowledge-building activities, offering an alternative to the common assumption that a large format classroom necessarily means passive learning.

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