Redistrict: Online Public Deliberation Support that Connects and Rebuilds Inclusive Communities

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Public deliberations are often a staple ingredient in community decision-making. However, traditional, time-constrained, in-person debates can become highly polarized, eroding trust in authorities, and leaving the community divided. This is the case in redistricting deliberations for public school zoning. Seeking alternative ways of support, we evaluated the potential introduction of an online platform that combines multiple streams of data, visualizes school attendance boundaries, and enables the manipulation of representations of land parcels. To capture multiple stakeholders' values about the potential to enhance public engagement in school rezoning decision-making through an online platform, we conducted interviews with 12 participants with previous experiences in traditional, in-person deliberations. Insights from the interviews highlight the several roles an online platform could take, especially as it provides alternative means of participation (online, synchronous, and asynchronous). Additionally, we discuss the potential for technology to increase the visibility and participation of multiple community actors in public deliberations and present implications for the design of future tools to support public decision-making.

CCS Concepts: • **Human-centered computing → Collaborative and social computing**; *Empirical studies in collaborative and social computing*.

Additional Key Words and Phrases: policy, education, user study, socio-technical trust, geospatial deliberation

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1 INTRODUCTION

Public school districts occupy a pivotal role in the way that national education systems function [7, 19, 43]. However, fluctuations in population cause a recurrent need for school districts to redraw school attendance boundaries, especially in regions with high growth [72]. This is known as *rezoning* and is accomplished through community-scale decision-making processes. These processes give different stakeholders the opportunity for participation and aim to support more sustainable and

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holistic solutions [20]. Data-driven strategies based on accurate, current, and predicted data are crucial for supporting these efforts. Maintaining good relationships with diverse stakeholders is important [65] and necessary for success [54]. However, the datasets are often large, stored in obscure file formats, or restricted from direct processing by public stakeholders due to privacy (e.g. Family Educational Rights and Privacy Act (FERPA) [64]) or security (e.g. infrastructure) concerns. Additionally, even when such data are collected and available, community members can still struggle to piece it together [2] and fully understand it. Thus, interactions with complex data from different domains (e.g. geography, education policy, information technology, etc.) bring a new level of difficulty to the problem and require more advanced means and skills to manipulate and make sense [26].

In this context, school district planners need to establish a shared understanding, often called *common ground* [70]. They work earnestly to produce optimal documentation that communicates the constraints under which the district must operate. This process often entails myrid conversations among multiple stakeholders with, often, conflicting points of view [20]. Indeed, James Bohman defines public deliberation as "a dialogic process of exchanging reasons for the purpose of resolving problematic situations that cannot be settled without interpersonal coordination and cooperation" [13]. However, community members might not feel comfortable or have the time to attend and speak out in public deliberations. Agitated debates or disagreements can cause anxiety [82]. When collaborative spaces are not adequately established, communication breakdowns occur, making public deliberations more challenging [33]. Thus, social tensions and issues around trust are often manifested in public deliberations [33]. For example, community members often express frustrations about the lack of transparency and limited visibility of public proposals, highlighting the need to create meaningful and trustworthy spaces for collaboration [33].

In response to school planners' lack of dedicated tools, we took a human-centered design approach and created an online public school rezoning platform to address several design challenges we identified in this context. Through an interview study with 12 different stakeholders, we captured the perceived value of the platform and its potential to visualize boundaries. The platform builds on previous research in text analysis scaffolding [3] and trial-and-error learning [84] using a novel *try-and-see visual scaffolding* method to present geospatial data. This method considers multiple constraints (e.g. complex policy, geographic and educational data, available facilities, etc.) and makes use of visual representations that combine diverse background information [87]. Our findings highlight several roles an online platform could have, such as the ability to create informed opinions, visually validate participants' points of view, and act as a common information space to store, access, and exchange comparative scenarios guided by real constraints. Based on our findings, we discuss the potential for technology to increase the visibility of multiple community actors in public deliberations.

2 RELATED WORK

2.1 Civic Technologies: Challenges and Opportunities to Support Community Deliberations

Supporting and improving public deliberations is a central endeavor in civic computing research [6]. Previous HCI and CSCW research has considered the ability of technology to support and increase citizens' participation in the provision of public services [14, 33, 56, 86]. Previous studies have investigated how data [54] and collaborative spaces [33] can provide insights into multifaceted problems, or how trust and distrust [28] can be mediated through community engagement [31]. Indeed, establishing trust between different stakeholders requires an active role in service planning [44] and delivery of civic engagement activities [49]. How to empower community members, support trust, and increase community engagement are significant challenges for HCI and CSCW research [4, 33, 74], especially in the effort of involving low-resource communities and organisations into the design of civic planning [28, 38]. In particular, a recent review highlights how previous research "has mostly studied civic technologies that do not have a deliberative or binding outcome" [74]. In highly deliberative processes, there is a need to further understand the trust-distrust dichotomy [88] (e.g. building trust and responding to distrust [28]), elicit feedback from diverse constituents [56, 61], and facilitate shared understanding and common ground to support and strengthen civic engagement [74], especially in sensitive contexts [28, 60]. Burkhalter et al. [17] explains how a shared language, understanding, and common ground are needed from the outset (or even in anticipation of deliberation) to support community participation.

In addition, crowdsourcing mechanisms have been used to build trust and support community understanding, without requiring large time commitments for simple tasks and micro-activities [61]. For example, these mechanisms have been used in complex sense-making problems by helping to create a taxonomy of items [27] and supporting a bottom-up analysis of a large corpus of qualitative data [3]. Considering that civic processes are prone to conflict due to the involvement of multiple stakeholders that often have different perspectives, competing values, visions, and motivations [8, 22], careful attention has been paid to supporting collaboration between community members and authorities [35] in terms of information dissemination [40], presentation of constraints [50], and ways to diversify community participation [75]. With the need for gathering contextual knowledge about civic problems [8], community members can serve as important sources of local knowledge which broaden, deepen, and even challenge common perceptions [58]. For example, previous research employed algorithmic techniques to leverage human experience and judgment towards better rezoning alternatives [30]. Indeed, leveraging human analytical strengths within information visualization tools can amplify the cognitive abilities of community members to understand complex datasets. Using their strengths in human cognition and computation [34] supports reflection and discussion of otherwise latent issues.

2.2 Socio-Technical Challenges to Support the Advancement of Public School Deliberation

Educational Challenges. Education is a prominent focus of state and local governments [80]. Best practices may include allocating additional funds to low-income communities in an effort to ensure impartial access to education for all children [71]. Fair access to resources is difficult to ensure due to continual shifts in school populations, restrictive geography, neighborhood composition, limited school space, shrinking public school budgets, troves of specialized data that require advanced knowledge, and lack of policy consistency across years. Education policies aim for fairness [85] and inclusivity through balanced and contiguous geographical student planning areas proximal to schools for students to attend.

The Need for Geospatial Data. School space is limited and allocated to students living near [90] to each school. Each neighborhood is considered an indivisible *student planning area* (SPA) or *planning unit.* These SPAs are the smallest indivisible neighborhood parcels that traditionally have been kept unified by planning officials. Their boundaries are often restricted by geographical constraints such as highways, rivers, neighborhood contiguity, or for the sake of efficient resource allocation (e.g., transportation). Subsequently, the SPAs geography seeks to keep together communities or traditional neighborhoods. Decision-making about SPAs involves the processing of geospatial data and often requires dedicated, proprietary software and advanced skills (e.g., information technology, geospatial information systems (GIS), educational policy, etc.) in addition to specialized domain knowledge since each SPA has specific and cultural student population characteristics (i.e., community, demographics, accessibility).

Multi-Disciplinary Constraints. In the space we investigated, the Standard Attendance Zone Change Process (see Figure 1) involves detailed planning and communication, with yearly reviews for adjustments that reflect changes in costs, enrollment projections, school capacities, transportation, and county population trends. These are communicated in the Public School Capital Planning and Budgeting priorities document, usually a part of the long term Capital Improvement Program and Capital Asset Preservation Program budget released by the superintendent. An Action of Changing School Attendance often takes 1–2 years of thorough preparation prior to being presented to the community as an Attendance Zone Change Process (Figure 1, left circle). The County Administrator and Public School Planning Department review such Actions for inclusion in the county's Proposed Fiscal Plan. Yearly, the Board of Supervisors releases Capital Facility Planning Guidelines as a long-range capital building program to support adequate public schools and facilities in the county (Figure 1, middle circle, the focus of this study). Awareness of all these socio-technical considerations adds the context of a massive net of interconnecting constraints that must be considered in every public school rezoning effort.

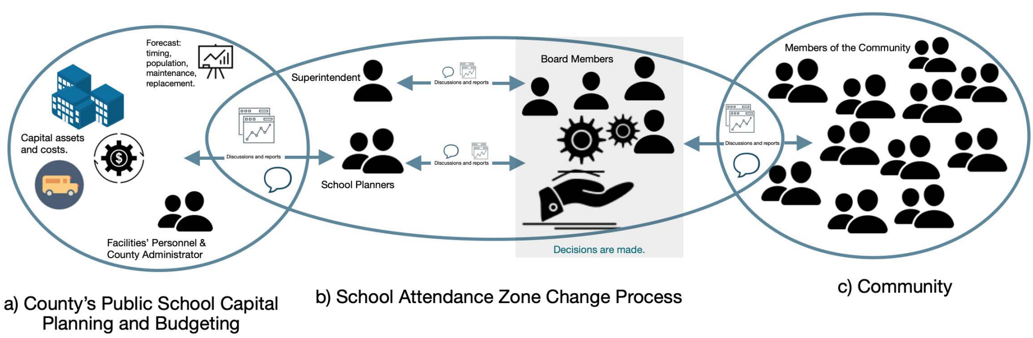


Fig. 1. School Redistricting Mechanics: The County and Public School Officials work years in advance to project long-term resource allocation. A Capital Improvement Plan is written and reviewed annually. It informs many decisions about schools' needs, including the possibility of initiating an attendance zone change process.

3 BACKGROUND: PUBLIC SCHOOL REZONING COLLABORATIVE SPACE IN THE US

Our work builds on prior HCI and CSCW research [33, 74] and contributes an example of understanding and designing collaborative spaces in public school planning. This work leverages "new ways of supporting deliberation and decision-making in local planning" [54]. A schematic description of how the collaborative space of public school rezoning looks and its diverse actors is shown in Figure 1. On the left are (a) the public school offices which are directly responsible for monitoring this process. On the right hand side (c) is the community, which benefits from the change. In the middle we illustrate (b) representatives of both groups (e.g., school planners, superintendent, board members) that work together to facilitate the deliberation process. The Board Members are elected representatives of the Community. They volunteer to serve in official capacity for a set term and to conduct deliberations on planning and other similar sensitive matters concerning its constituents. The School Planners are representatives from the Facilities Department, which is both the initiator of the change and responsible for implementing the agreed-upon modifications to school boundaries. The Superintendent's Office oversees deliberations and can mitigate conflicts at times.

Some of the authors were first exposed to this collaborative space as community members, specifically as parents of young children attending public school in fast-growing part of the US.

At that time, our own families were included in frequent school boundary changes, sometimes as often as every other year. Our own experiences ignited the interest for research in this area [63]. Consequently, we formed a common interest team and attended in-person public school community meetings about boundary adjustments, aimed to decrease school overcrowding, between 2017–2019, in the surrounding counties. At these events, the public's comments often oscillated between questions about the use of factual data and expressions of emotional, concerned, or adverse viewpoints. Regardless of the outcome, after every rezoning effort, a part of the community was upset with the planning department and the changes in boundaries, often making the headlines of local news [68, 69]. This situation seemed to erode trust in public officials and divide communities in these counties. The public school rezoning efforts we witnessed were contentious in nature [69].

3.0.1 Current public school rezoning practices. As some of us are educators as well, we had a secondary perspective. We could appreciate how planning departments were tirelessly trying to meet the school district's exponentially growing needs by juggling geographical constraints, limited resources, and overcrowded schools. Due to budget limitations, planning departments are small — sometimes teams of only two to four people — in school districts that can have, in some cases, 100,000 students, over 100 school facilities, and over 10,000 employees [37]. Although planning officials often have advanced training in geographic information systems (GIS), in most cases even the enterprise software they are using is not attuned to solving the complex problems of education boundary assignment [21, 90]. The small planning team is tasked with identifying and optimizing current resource allocations. Planners must analyze, inform, and organize meetings with community members, prepare briefings to the school board, and produce several possible rezoning scenarios, in which each land parcel in the affected area is accounted for. Frequently, public school planning employees organized meetings to discuss rezoning scenarios that would help mitigate school overcrowding [52]. External factors would often cause delays requiring information to be re-communicated several times until a majority vote could be reached. Each time, new plans are printed and communicated through multiple channels and adequate preparation time is necessary to reach members of the community [67]. We observed how the continuous increase of the school population was a growing concern for school planners because once a rezoning effort was finalized in one part of the county, another area needed their attention.

3.0.2 Attending co-located meetings is challenging. For parents and students, participation in the planning process can be an overwhelming challenge. Co-located planning meetings are often held on a school night, in local school cafeterias since public schools do not often have rooms that are large enough to host such gatherings [67]. These meetings often push the limits of the building's occupant capacity. Some families have children of all ages and, with working parents, it is difficult at best to fit a three-hour school board deliberation meeting into a family's schedule. Considering the current demographics in the US, where single parents account for 23% of the population [23], 15% are shift-work employees [83], and 8% have multiple jobs to support their families [24], it is no wonder that the constraints of family life impede participation in public school deliberations. Even families that are not under the same constraints bring their children to long public deliberations to learn, understand, and express their viewpoints. It is, therefore, not rare to hear children crying during a spirited debate.

3.0.3 Current use of technology. The technology available during community meetings is, at most, a projector with a slide presentation [36]. Student population forecasts and school capacity calculations are displayed on the screen (Figure 2, left, 2017 picture from a traditional rezoning) communicated verbally, posted on the school's website as static files (Figure 3), or distributed on sheets of paper (Figure 2, bottom-left, 2018 paper map from an actual rezoning).

If more than one scenario is available, the map, supporting documents, and projection numbers are printed in enough copies to allow review from the entire audience (at times 200–400 people). Often, the audience asked about the impact of small changes to a current proposal. Yet, members of the planning department do not have the technology and resources in the locations where public meetings are held to compute the effects of such “what-if” scenarios on the fly during the meeting [89]. We often witnessed planners recording comments to be followed up on later [14]. Yet, the community, often immersed in technology and able to "Google" any question and get instant responses, seemed to engender annoyance and growing distrust when faced with planners’ inability to produce instant answers to questions they perceived as easy.

4 DESIGN PROBLEM: MULTIPLE CONSTRAINTS AND PROJECTIONS IN THE REZONING PROCESS

After observing the traditional rezoning process, we researched ways to enable more productive and inclusive discussions. We seek to investigate the design problem: how hands-on testing of scenarios, given multiple constraints and projections of school overcrowding, can raise civic understanding of the problem and support the rezoning process towards a more cohesive deliberation process and broader stakeholder participation.

To achieve this objective, we undertook a human-centered design approach [15, 66], in collaboration with a head planner and two education policy professors with expertise in traditional school rezoning, to explore the potential role of technology in helping address rezoning challenges. Our interdisciplinary team brought together expertise in advanced geographical data science, education policy, constraint optimization, and human-computer interaction to provide essential feedback and knowledge to the human-centred design process. Exploring the design space across multiple domains [79] helped crystallize the idea of the design and development of an online platform that helps visualize and test scenarios with multiple constraints and projections. Between August

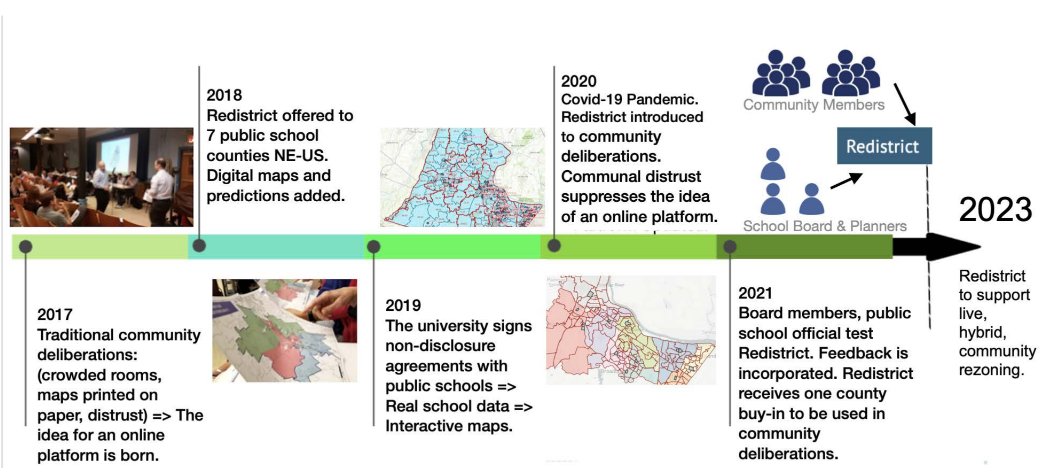


Fig. 2. Development timeline of Redistrict. Online support to unify maps, projections, and community feedback. User are able to construct their own “what-if” scenarios for possible school boundary changes.

2017 and January 2021 (Figure 2) our interdisciplinary team iterated on the design of our platform, Redistrict. During this process we held discussions with seven public school systems in Mid-Atlantic USA, signed non-disclosure agreements with two of them (The public county schools our team was in communication with include: Loudoun County Public School, Prince William County Public School, Arlington County Public School, and Fairfax County Public School in Virginia, U.S.; and Washington, D.C. Public School, U.S.). The team further evaluated policies from numerous other jurisdictions around the country. Based on the identified socio-technical challenges in school rezoning (see above), we set out to address the following design challenges: a) integration of multiple sources of information and visualization of constraints, b) difficulties understanding diverse sources of zoning information including how these are presented to the user, c) lack of readily available projections of student population, d) lack of mechanisms to explore school assignments and what-if scenarios.

Our collaborators gave feedback on early versions of the platform. about both the interface and functionality for computers and mobile devices. The focus of our iterative design work was on exploring potential use cases, initial concerns regarding user perception, identifying limitations, and uncovering socio-technical practices [39]. We aimed to provide a visualization platform with fast computation that could help balance possible constraints (Figure 2, 2019–2020). As soon as Redistrict was functional, we presented the interface to the community in public deliberation meetings. It was offered free of cost and was intended to test virtual interaction as adjacent means of participation to traditional rezoning.

Hoping for broad user feedback from constituents and policymakers, we stood up Redistrict in support of several active rezoning efforts. But, due to several factors, including lack of official support from school boards (despite support from planning departments), we met with mixed success and less than ideal participation levels. As a stepping stone towards broader constituent participation, we invited stakeholders to assess the interface during a time without active rezonings. This step eventually resulted in this current user study wherein the participants are represented in Figure 1 (middle, "Decisions are made"). The ways in which county officials and the community are presented with information in traditional rezonings and on the Redistrict platform are illustrated in Figures 3 and 4. In the first case, all materials are on paper and displayed as static screen images in synchronous presentations. In Redistrict's case, the map is dynamic, for use in synchronous presentations and asynchronously on personal devices. Users can reconfigure SPAs via mouse interaction and in cases where there are proposed changes to school assignment, SPAs are displayed with hashed white diagonal lines. The student projections and SPA assignment tabs for any user-created allocation are computed and displayed in real time.

4.1 High-Level Overview of the Platform's Functionality

Here we present the overall functionality of the platform. Details of the system and geospatial optimization algorithms based on it have been presented elsewhere [9–11, 76–78]. The current paper focuses on how the users interact with the platform.

Redistrict is hosted on our university's servers and seeks to address the aforementioned design challenges through the use of interactive maps and participant feedback. It allows users to manipulate parcels of land and provides immediate calculations of future student population predictions and facility utilization for each given plan configuration. The interface has four main functionalities: a) the plan viewer, b) the plan editor, c) a survey page, and d) a list page for reviewing all submitted plans. The initial design was inspired by printed documents produced by the Loudoun County Planning Department for distribution at public planning meetings (Figure 3). The printed paper map used color coordinated zones for each attendance area with the SPAs affected by a rezoning process marked by a hash pattern. In addition to the map, printed tables display the number of students attending each school involved in the school boundary zone change and projections for those schools of student population growth over the next few years. The system uses geospatial data to populate an interactive map and follows the same color convention: each school pyramid has a distinct color and proposed changes are hashed (see Figure 4). The interactive map displays information about the number of students in each SPA and each school building's capacity, utilization, and projections. As users reassign SPAs, the interface provides a dynamic re-calculation of school population projections and school capacity utilization across the affected regions. This data-driven approach enables the users to experiment with their own "what-if" scenarios. The interface uses *try-and-see visual scaffolding* to support hands-on learning through trial-and-error, aiming to build healthy premises for cohesive communal collaboration [29, 54].

5 STUDY DESIGN

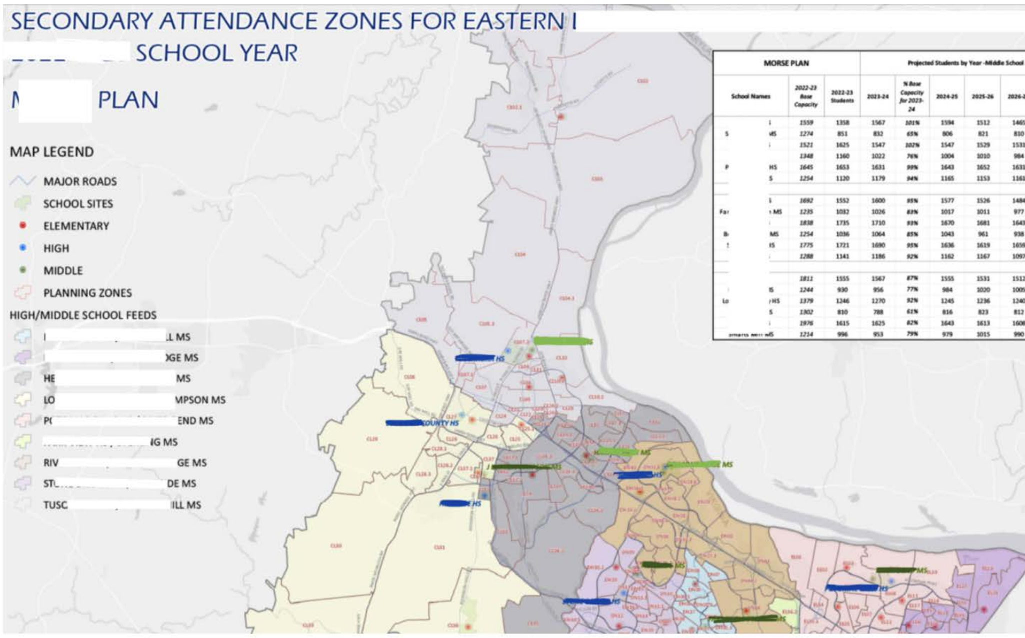
To further inform our design methodology , we conducted an exploratory qualitative study of the Redistrict online platform's utility using real geospatial data and current student projections. However, in an attempt to avoid the emotional responses common in actual rezoning efforts, we did not use an actual boundary scenario. Instead, we composed a plausible, yet hypothetical boundary rezoning exercise. This hypothetical scenario allowed users to test the platform's capabilities and envision potential acceptability. In this manner, we sought to minimize, if not eliminate, the undercurrents resulting from real boundary dispositions that we previously experienced while attempting such testing during live rezoning efforts. Consequently, this study was performed during a time with no active rezoning efforts in the school district. This district had nine School Board Members, four planners, 96 principals, a few facility management personnel, and around 60 bus drivers. Our pool of possible participants was relatively small for this endeavor, especially given additional inclusion criteria: individuals who (a) performed a double function as both public school officials and community members; (b) previously participated in traditional rezoning process in one or more capacities (Figure 1); and (c) had never seen Redistrict.

5.1 Study Participants

Aligned with typical sample sizes for qualitative HCI research methods [18][81], we recruited 12 participants for our exploratory study. Eleven participants were from the same county, and the twelfth participant was from an adjacent county. His input contributed towards an understanding of whether prior familiarity of the geographic distribution of the county would make a difference in the ability to understand the proposed changes. All participants had at some point lived in the county and had experienced the rezoning process in some or multiple capacities (see Table 1) and either have or have had children in the public school system. . The participants confirmed an ability to use a computer and had internet access. Seven participants identified as women and five as men. Eleven participants identified as white and one participant did not self-identify their race. Although participants were not racially diverse, they were representative of the county's employee base, around 90% white [1]. The participants were recruited based on their availability for an online interview and because they had never been exposed to the platform before. All participants were allowed to withdraw from the study at any time without any consequence. Participant interest and availability determined the interview time length ranging from 40 minutes to two hours.

5.2 Feasibility Evaluation Procedure

Each interview had two parts: a) a task-based, self-guided exploration of the platform ; and b) an exit questionnaire. The interview protocols were reviewed and approved under a Memorandum of Understanding and Non-Disclosure Agreement. Our university's Institutional Review Board (IRB) reviewed and approved the user study design. Consent and disclosure were obtained from all participants before presenting them with a brief overview of our research and collaboration with the public school districts. All participants were exposed to the same initial starting screen and had no prior training with the platform.



[redacted] ATTENDANCE ZONE ASSIGNMENTS BY RESIDENCE			PLAN ZONE	[redacted] PLAN		[redacted] PLAN		[redacted] PLAN [redacted]		[redacted] PLAN 860	
ELEM	MID	HIGH	2022-23	MID	HIGH	MID	HIGH	MID	HIGH	MID	HIGH
LUC	SMM	THS	CL01	SMM	THS	SMM	THS	SMM	THS	SMM	THS
LUC	SMM	THS	CL02	SMM	THS	SMM	THS	SMM	THS	SMM	THS
LUC	SMM	THS	CL02.1	SMM	THS	SMM	THS	SMM	THS	SMM	THS
LUC	SMM	THS	CL03	SMM	THS	SMM	THS	SMM	THS	SMM	THS
FHR	SMM	THS	CL04	SMM	THS	SMM	THS	SMM	THS	SMM	THS
FHR	SMM	THS	CL04.1	SMM	THS	SMM	THS	SMM	THS	SMM	THS
KWC	SMM	THS	CL05	SMM	THS	SMM	THS	SMM	THS	SMM	THS
FHR	SMM	THS	CL05.1	SMM	THS	SMM	THS	SMM	THS	SMM	THS
KWC	JLS	LCH	CL06	SMM	THS	JLS	LCH	JLS	LCH	JLS	LCH
FHR	SMM	THS	CL07	SMM	THS	SMM	THS	SMM	THS	SMM	THS
FHR	SMM	THS	CL07.1	SMM	THS	SMM	THS	SMM	THS	SMM	THS
FHR	SMM	THS	CL07.2	SMM	THS	SMM	THS	SMM	THS	SMM	THS
FHR	SMM	THS	CL08	SMM	THS	SMM	THS	SMM	THS	SMM	THS
LEE	SMM	THS	CL09	SMM	THS	SMM	THS	SMM	THS	SMM	THS
BAL	SMM	THS	CL10	SMM	THS	SMM	THS	SMM	THS	SMM	THS
BAL	SMM	THS	CL10.1	SMM	THS	SMM	THS	SMM	THS	SMM	THS

Fig. 3. Printed material from a traditional redistrict process. The top table shows student population projections. The bottom table displays a list of SPAs with their school assignment (e.g. Elementary, Middle, or High School), the corresponding name/label of each SPA on the map, and the SPA assignment in four plans

The interviews were conducted as semi-structured Zoom video/audio interview interactions over a period of approximately one week. Participants were informed that the study uses real geographical data, but that the rezoning effort and associated proposal scenarios were hypothetical, constructed specifically for the exploration and discussion of the platform in this study.

Participants were given short prompts and asked to "think-aloud" [41] while navigating and using the platform. The participants chose for themselves how to approach each of the following tasks: understand what the public officials are proposing, determine which schools are impacted,

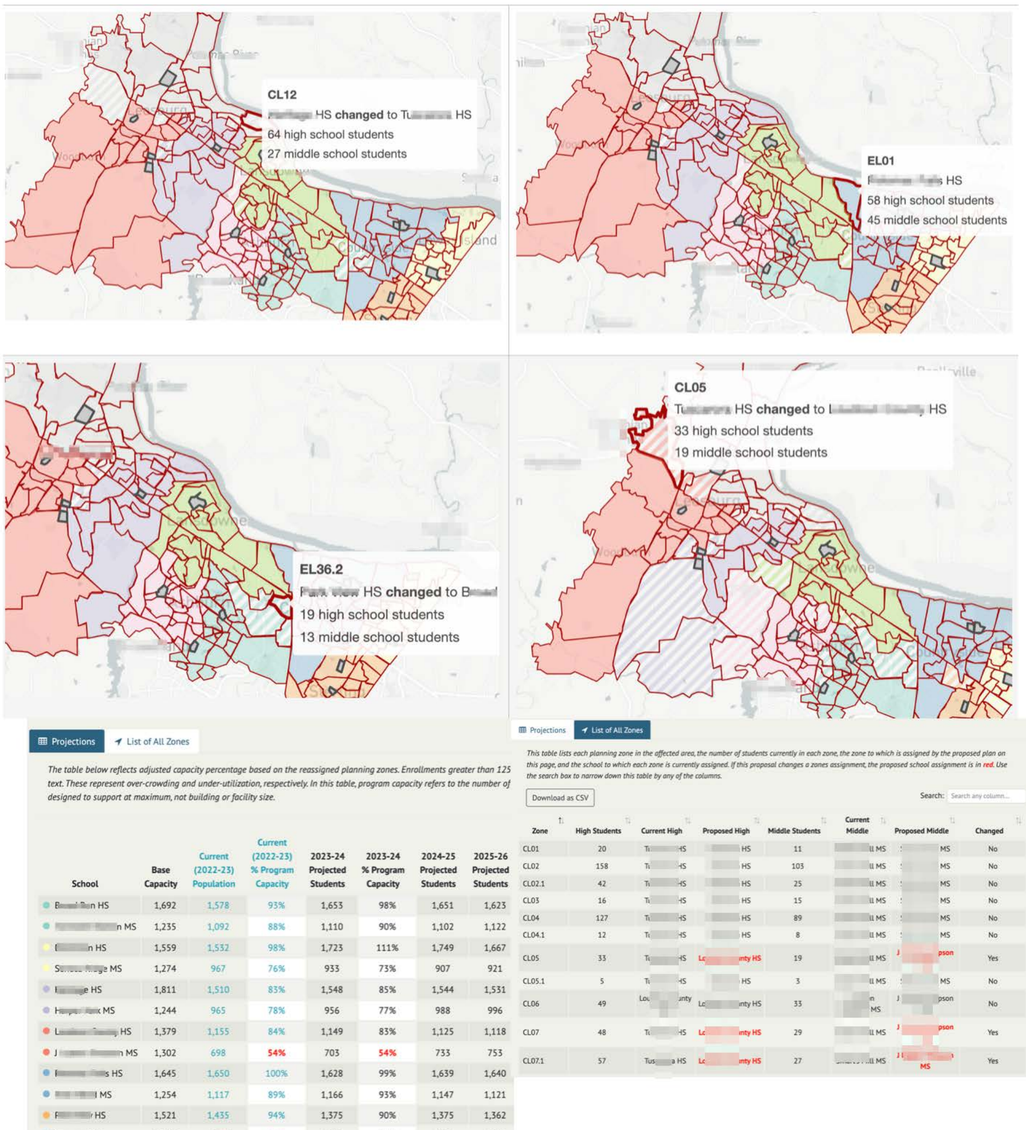


Fig. 4. Redistrict screenshots of four proposed plans. SPAs proposed to change have hashed lines over the color of the proposed assignment. Hovering over SPAs displays their names and school assignments. Below are tables with student projection and assignments. These update dynamically with any change to the map.

develop an opinion about the proposals, and communicate their thoughts. When the site was loaded, the participants were first presented with the plan viewer interface (see Section 4.1), which displays our hypothetical boundary rezoning exercise plan. After familiarizing themselves with the plan, participants commented and most tried to propose changes.

Exit survey: After each participant spent as much time as desired manipulating the online platform's features (plan viewer, plan editor, survey interface, list of plans), we administered an exit survey intended to measure participants' opinions in three areas: comprehension, experience, and demographics. All participants correctly answered the comprehension questions (e.g., *"How many schools were involved in the rezoning process?"*). The demographic responses provided the information used to describe the participants (as presented in previous sections). All participants chose to take the exit survey, even those few that had exceeded the agreed-upon time limit.

Data Analysis: Data collected through the interviews added up to approximately 15 hours of recorded time. After cleaning and anonymizing, the resulting transcripts constituted the material for analysis [73] following six-step thematic analysis, as described in Braun and Clarke [16]. This was performed in a virtual collaborative environment (www.miro.com) by five members of the research team. The analysis session ran for about two hours to develop the initial codes and themes.

Each interview was split into short snippets of text, then further analyzed and labelled. Most interviews exceeded 100 virtual notes. Throughout the session, researchers took turns expressing their thinking. To learn about participants' perceptions, an inductive approach was followed to allow the data to guide the themes [25]. The labels were deducted from the analyzed snippets of text. The codes were largely consistent when labeled by different researchers despite a diverse range of familiarity with the interviews and the content from researchers.

For each participant, a different color was assigned. Empty placeholders were created for codes. As the team analyzed each interview, the notes were assigned to related buckets/codes. Each note was labeled using the semantic meaning of the text, affording subsequent discovery of latent themes if the text indicated an indirect correlation. In this manner, each text snippet was assigned to one or more categories based on explicit or implicit meaning. Once the familiarization and coding of our interviews was finalized, the themes were further reviewed for global meaning.

Table 1. Self-identified participants' prior experience in traditional rezoning process

User	Previous involvement in traditional rezoning - capacities:
$R1$	Parent/non-parent, community member, planning official, school personnel
$R2$	Parent/non-parent, community member, school official, principal
$R3$	Parent, principal multiple school districts/states
$R4$	Parent, advocate, community member, school personnel
$R5$	Parent, community member, school official, principal
$R6$	Parent/ non-parent, community member, school official, principal
$R7$	Parent/ non-parent, community member, school official planning
$R8$	Parent/non-parent, community member, transportation management
$R9$	Parent/non-parent, community member, school transportation - bus driver
$R10$	Parent, community member, facility management
$R11$	Undisclosed/non-parent capacity, community member, school board official
$R12$	Non-parent, community member, teacher, professor

6 FINDINGS

The following sections summarize the findings from our qualitative study, presenting excerpts from the interviews and an overview of the results from the exit survey. We present the most salient themes in relation to the perceived potential of Redistrict to support understanding of multiple types of data, reinforce existing knowledge, enable participation of stakeholders with different expertise and perspectives, and provide educational value.

6.1 Interview Findings

6.1.1 Beyond novelty: Supporting comprehensibility, shared-understanding, and leveraging existing knowledge. Given the perceived novelty of the tool, participants were unsure what to expect. At first, some participants indicated feelings of pressure and a lack of confidence in their technical abilities. For example, participant R2 commented that *"[another] user would do this much faster"*. R6 and R9 indicated their jobs did not require computers in daily activities. They did take a bit longer to start manipulating the virtual conference software in which the interview was conducted. The written instructions on Redistrict's interface were minimal, yet participants did not read them.

For example, we received questions such as: "*what do I do now?*", "*shall I press on this item?*", "*shall I look at the first item, shall I click on this?*", "*do you want me to press on this menu?*". The researchers treated these questions as rhetorical, as part of the initial familiarization of the platform.

However, the potential utility of the platform seemed to play an important role during this exploratory process to support comprehensibility of multiple sources of information. For example, a participant commented, *"it is good [because] people who did not go to college, or are not part of the parent-teacher organizations need to understand [too]"* (R8). In particular, the platform interface supported exploration as showcased by the following participants that took the initiative: "*I am going to read this menu here*", or "*I am going to press on this link here, I hope that is OK*". In addition, participants appreciated the features of Redistrict as they discovered them and in particular the simplicity in the language. For example, participant R11 stated, *"I really liked [the] language [added in to describe] the policy"* and *"I was really happy that I could find that information readily"*.

Some participants perceived value in the platform to increase community participation. Participant R6 mentioned, "*I think anything that can give parents and community members input into the zoning process will be a good thing*." Further, they considered Redistrict's ability to support multiple stakeholders' perspectives as a benefit. For example, (R7) was impressed *"to see all the possible choices"* and that the two-way ability to submit plans *"would allow for multiple points of feedback. Because each of us [. . .] has different perspectives"* (R2) and *"everybody can understand it"* (R8). The feedback option *"[has] a lot to say, [because it] kind of gives people that initial reaction to it."* (R2).

Once the participants learned their way around, they used their newly-gained knowledge to discover the functionality of the platform and create meaning, often employing prior knowledge of the traditional process and local geography. Participants that were able to identify geographical elements of the maps, such as roads and water streams, used that knowledge to identify the boundaries of the SPAs and had an easier time manipulating the interface through this perspective. As R6 explained, to understand the projections *"more carefully [. . .] I will have to get back in and look at the maps."*. R7 discovered, "*. . . many of the zones are not affected during this particular process. Oh, okay, if I go back in and read, I can see it [now].*" Participants in an active learning state, who allowed themselves to read and process the information, consequently had fewer confused comments. For example R8 said "*Yeah, I don't know what district that is if that is what you are asking me*" in contrast to R11: "*well, I know that. That is the airport, [that's why] there are no students [in this SPA]*".

The researchers noticed a change in perceptions as participants' ability to understand the data improved. Prior knowledge of the geography is implicit because the intended users work, live, or both work and live in the county. Participant R5 navigated the interface, stating, "[*The application] was [. . .] new, [but] some of my background information that I knew about the process [helped].*" Their experience highlights the importance of the interplay between prior domain knowledge and interactive visualizations tailored to a specific task.

6.1.2 "Aha!" Moments: Supporting Reflection, Discovery, Planning, and Comparison. With a hypothetical scenario and limited instructions, participants manipulated the plan editor interface in an investigative manner, exploring and discovering how to create a better hypothetical plan within a short time. As their familiarity with the interface improved, they were able to understand the potential impact of an allocation, setting the stage for reflection and future planning. A participant mentioned, *"I know they're just projections, but it's kind of nice to see because it gives you a sense of comfort to know [the impact]"* (R3). Thus, the change between novelty and familiarity with the online platform was marked by an "aha" moment. For example, a participant commented "*... so I could go in here and move all kinds of things around — Oh, wow!*" (R9). Indeed, each interview session had a point when the participant understood the basic functionality and started using the platform to gain information, test ideas, and convey their opinions.

The task of assigning SPAs to different schools, while watching how the projections change, deepened participant's understanding of physical invariants involved in rezoning processes; i.e., real estate and building capacity. This came as a surprise to some: "*Am I reading that right?*" (R8), or "*So I would kind of wonder 'why that [lack of space] is?'*" (R5). Most participants manipulated the map to gain information about projected impact of changes and read others' feedback. The participants with a better understanding of the process, mostly principals and school board members, spent their time attempting to create the "perfect plan."

Some of the interviews ran past the maximum scheduled time (60 minutes) going up to 90 minutes, with participants keenly trying to create a better allocation, despite knowing that it is a hypothetical scenario. For example, R5 explained:

> "*I understood how it works, but it was entertaining. I [tried to] figure this out, forgetting the fact that this is completely invented. Made up. And it's not gonna make any impact whatsoever.*" R12 referred to it as a "*highly intriguing process*", "*addictive*", and "*almost like a mind game, on the computer.*" Participant R10 mentioned, "*I could see parents spending a lot of time playing with this...*"

R5 synthesized the overall experience: "*Once I sort of understood, how the numbers and the actual changing of various districts work together. I mean, you can see, I was like, oh yeah, this is great!*"

Once participants became comfortable using the application, they often expressed a belief that it could help resolve significant pain points in the traditional rezoning process. Most showed a keen desire to understand how their opinions and ideas compared against proposed plans. Some admitted to expressing opposition in past rezoning efforts, including strong opinions on how the process could be approached better. For example, one participant, R4, shared previous experiences and described their family's quest during a prior rezoning effort, one of several they were subjected to. Their family was part of a group of residents who strongly disagreed with the county's proposal and felt a better distribution of resources could have been devised. Yet, they had neither the tools to articulate their view nor the data to support their points. So, participant R4 "*actually came up with my own map*", spending over a month working in Microsoft Excel spreadsheets. Their group participated in the traditional rezoning process where they "*used to go into work and print these engineering sheets*" with papers that would cover the whole table and fall off to the floor:

> *I would sit at my kitchen table with a highlighter [into the night] and compare the Excel calculations against every SPA. I would have a draft one, because [I] would mess up and then redo it nicely and take it into the school board meeting. I would show them my big spread-out map with a highlighter — and this was just few years back, not that long.* (R4)

Participant R4 and the group of parents they were a part of went in front of the school board with R4's plan and were able to present a convincing argument. As a consequence, the group had the particular SPA split up: "*I really I did get my way. I'm happy I did, and it turned out way better than I thought it would be*" (R4). This participant actually spent so much time learning the process that they quit their (then) job and found employment with the county:

> *I spent my time at work doing school rezoning — it was not my work — but it looked like I was working because I was in my cubicle doing Excel work, all of this Excel stuff because of this work [with the rezoning process]. I realized that I did not even like my job. So this is how decided to work for the school… This tool would have made the [past] rezoning much easier, I probably would have kept my other job!* (R4)

6.1.3 "This is hard": The Importance of Visualizing Complex Scenarios. The participants' familiarity with the tool advanced over the first 20 minutes of the interview and seemed an appropriate time interval. Because of their exposure to the traditional rezoning process, they had some preexisting understanding of the difficulty of such rezoning efforts. But as they became the drivers of the process via Redistrict, they began to realize the full extent of the challenge. R10 explained their thought process while trying to find a better allocation for the proposed hypothetical plan:

> *So, […] I'm happy with the progress that we have here, trying to get these numbers down, but I'm still… realizing, there is a real challenge. Now I'm recognizing that, alright, I'm starting to bring [enrollment in school 1] down and [enrollment in school 2] down over time. But now I've got like 124% in [enrollment in school 3], up 115% over at [school 4], I'm already at 100% in [school 5]… I can see there's a lot of slim margin for error.*

As participants tried to propose better plans, their demeanor ranged from excitement to deflation, and even surrender, as they realized how difficult is to satisfy the constraints within the confines of available real estate. For example, R10 found the experience valuable for communicating to others the difficulty of the process: "*[Redistrict will] give them [parents/community] a good insight as to how challenging this actually is for staff and the school board when they're making decisions.*" Other participants expressed a feeling that the optimization task was essentially endless. R12 said, "*[I] would continue doing this for few hours.*" Similarly, R5 asked after a while, "*So, you want me to still try to get to a solution here?*" Given participants' previous involvement in districts' decisions, the time voluntarily spent reinforces how the tool facilitated realizations about previously intangible constraints. R11 put it succinctly: *"This is hard."*

Apart from highlighting how complex the exploration of solutions can be, participants listed many aspects of the platform they found meaningful, such as how it raises awareness of unseen constraints of the given scenario, and how happy they were to be able to see their proposal and compare it to the proposed plan. R5 elaborated on comparing the "*hypothetical proposed [plan] and then my plan. Great! So I can go [here to] see my plan. See how amazing it is! Oh, that's 'The genius plan!'*" Participants suggested several improvements to the interface to support the exploration of complex scenarios. Most of them preferred seeing the information side-by-side, as R3 explained:

> "*Just double checking [if] they are under- or over-[capacity]. So what I would actually prefer at this point [is if] I could see this chart [showing utilization and capacity] right next to this map. It would save me from going back and forth.*" R7 agreed that, with a side-by-side view so, "*I can see how many students I'm affecting.*"

The online platform facilitated visualization of multiple constraints and immediate feedback. These seemed to play a role in participants' confidence while evaluating not only problems, but also potential solutions. For example, R1 observed, "*[If I] move [children from school 1] [to school 3] it under-utilizes [school 4]... still, most kids will be affected*" due to the need to move SPAs around. Without prompting, participants described looking at the situation from a new angle, beyond personal stance. For example, many participants mentioned their frustration that the *stability* constraint (i.e., avoiding many rezonings over a short timespan) was overlooked by the planning department: "*This [rezoning] happens every year*" (R4) and "*Two years ago, the students [in this neighborhood] were moved, knowing that they had to be moved again in two years*" (R6). However, as the session progressed, participants realized it is hard to make a perfect proposal: "*So now I'm thinking to myself, I'm starting to go away from [initial thought] then I'm realizing that I actually need [to build] another school (laughing)*" (R5).

6.2 Exit Survey

After interacting with the online platform and finishing the prompted tasks, we administered a standard exit survey which usually lasted about 5 minutes. These survey questions gave participants an additional opportunity to verbally reflect on the rezoning process in general and the possible support the inclusion of an online platform might bring. In closing remarks, participant R12 mentioned, *"You might wonder, how did these things [planning department decisions] come about? [But in Redistrict,] you zoom in and you see features that explain it, [because] there's a lot going [in the geography] that influence what would otherwise be a typical student or family commute to school."*

The exit survey responses are presented in Figure 5. Questions related to the value added by the online platform scored highest. Participants agreed unanimously that the interface provided valuable support in the decision-making process, while the relevance of the platform scored high for current impact. Future implications registered highest across the board.

Figure 5 shows encouraging feedback around the benefits of providing an online platform, such as Redistrict, as a part of a school rezoning deliberation process. The survey responses complemented the interview findings, clearly showing that participants see Redistrict as a valuable platform to support the School Attendance Zone Change Process. In addition, participants were also asked a multiple-choice question: *"What was the most useful aspect of the interface?"*, with choices: (1) visual display of maps, (2) ability to select and reassign SPAs, (3) ability to see enrollment projections, and (4) the ability to see other users points of view. Eight users chose (1), (2), and (3) as having equal impact. Three selected (2) of the (3), and one chose (1) to be the single most important feature.

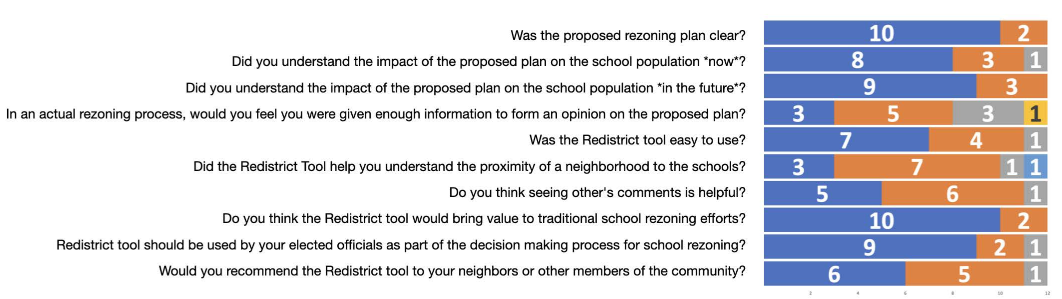


Fig. 5. Exit Survey responses, on a Likert scale, showing positive feedback from the evaluation. Color representation is as following *From left to right*: (blue) Strongly Agree, (orange) Agree, (gray) Neutral, (yellow) Disagree, (light-blue) Strongly Disagree

7 DISCUSSION

School rezoning is a particular example of an interdisciplinary context that opens up many opportunities to support community participation, collaboration, and innovation for civic technologies. The users' input elucidated aspects of trust and the potential of learning through visualization (*try-and-see*) as well as how this could facilitate a common ground development process for expanding previous work. This investigative discovery revealed an ability to understand complex geospatial data and multi-domain constraints using learning as a scaffolding process [27, 40, 61]. Based on the themes described above, we present three opportunities for designing technology to support the school rezoning process: (1) Designing to Support Active Participation in Public Deliberations, (2) Designing to Support Reflection, Shared Understanding and Potential Common Ground, and (3) Designing for Rebuilding Trust, Shared Expectations, and Fostering Credibility, along with the limitations of our study.

7.1 Designing to Support Active Participation in Public Deliberations

Previous research has highlighted the need for civic technology to improve the quality of public deliberations beyond the level of informing and consulting community members [74]. Indeed, there is a need to increase citizens' active participation in public deliberations [59]. Beyond face-to-face interactions, technology [47] has become an a nearly ubiquitous alternative to synchronous virtual participation in deliberations [45], yet has shown minimal impact on the planning process [46].

On the one hand, our study demonstrates the complexity of the school rezoning process which requires both active participation from disparate stakeholders (e.g., school planners, superintendent, board members, community members, etc.) and making sense of multiple constraints in an ongoing dialog before, during, and after deliberative discussions that can involve disagreements or latent, long-running conflicts. On the other hand, designing socio-technical systems to support active participation in public deliberation can strengthen community engagement efforts and has the potential to support a more inclusive decision-making process. Our findings show how Redistrict was able to make a complex planning exercise more engaging and entertaining, as some participants continued trying to make better plans. This goes in line with prior research [59]. Additionally, our participants used the platform not only to try out the plan editor, but also to provide and collect feedback from other user-made plans. The extant asynchronous / synchronous support of an online interface shows potential advantage, not only to help different stakeholders to build knowledge in advancement of the deliberation, but also to reinforce the motivation to participate [17], increase the visibility of community members, and sustain community engagement [47].

7.2 Designing to Support Reflection, Shared Understanding, and Potential for Common Ground

Supporting reflection is important in public deliberations [56], especially to "move citizen participation beyond isolated transactions" [48] and to facilitate the establishment of common ground [56, 57]. Johnson et al. highlighted the need to develop platforms to support community decision-making [55], helping community members to reflect before even engaging actively in direct discussions [56]. For complex decision making processes, visualization tools have proven to be useful to support comparisons and highlight disagreements [62].

Our findings highlight the added layer of complexity when civic deliberation requires understanding of multiple data sets in order to reach common ground. The scaffolding approach to learning, in which our participants created plans during their first exposure by manipulating the interface without instruction, allowed participants a convincing first hand-exposure to the complexity of rezoning. Concomitantly, they discovered constraints, looked for relationships, used projections, and compared plans, bridging multi-domain knowledge [53] in the process. It was evident in our study that the visualization of multi-criteria complex scenarios helped participants to build confidence through many planning iterations and to explore not only the problems but also potential solutions, thus reinforcing the contextual knowledge needed for face-to-face public debates [17].

Our study shows the potential of an online platform, such as Redistrict, to serve as a common information space [51] enabling the shared understanding between multiple stakeholders and as a tool for thinking together [17]. Finally, this study elucidates how multi-criteria scenarios were useful as lens for setting the stage for future action, based on reflection of the scenarios at hand [12].

7.3 Designing to Rebuild Trust, Share Expectations, and Foster Credibility

Building trust along with supporting credibility and transparency are critical components in public deliberations and necessary for meaningful participation [5, 28, 31, 32, 38, 74]. Since public deliberations involve multiple stakeholders, it is not surprising to find conflicts or disagreements [14]. Communication can accomplish successful cooperation between diverse actors [42]. Conversely, lack of transparency and delayed communications increase communities' distrust [38]. During our study, many participants brought up previous debates and tensions between public officials and the community as a sour-spot in public deliberation. In particular, frequent rezonings and overcrowded schools were acknowledged to erode trust within community, and the motives for these actions were not understood by even the school system employees that we interviewed. Our study shows how an online tool, such as Redistrict, enabled not only a greater understanding of the difficulty of producing a good rezoning proposal but also an awareness of other perspectives. These were used in the creation of a participant's proposals and can increase participant's ability to engage in future discussions [17]. In addition, the opportunity to read other users' comments within the online platform allows participants to gauge how others are feeling and reflect on their own perspectives. If participants had remained unable to understand the exercise, they would not have been able to realize that the building school space was insufficient for the amount of students present in certain areas, and that a perfect rezoning plan may be impossible with regard to student distribution and demographics.

Thus, participants' positive reactions hinted at the possibility that a dedicated tool, such as Redistrict, could help build relationships among various stakeholders. Online platforms could become enablers for a shared understanding throughout the rezoning process, making the process more transparent and in turn creating the premises for rebuilding trust in multi-stakeholder decision-making processes over time. Leveraging information credibility [58] and providing an adjacent online modality to explore diverse types of information expands proximity-based deliberation, broadening the channels of participation in communal decision-making to build trustworthy relationships among different stakeholders. Going through this process promoted participants' mutual respect for school planners' work, enhancing their credibility. While the perception of school rezoning as a low-room-for-error process was not fully understood until participants attempted to create a better-than-proposed plan, participants realized how infeasible it was to satisfy all constraints simultaneously by comparing the school and attendance projections with their own expectations. Therefore, sharing expectations through Redistrict could support the coordination of multiple scenarios of planning for school attendance zones.

7.4 Reflexivity and Limitations

In the spirit of small-group reflexivity, the first author was a high school teacher and three of the authors have previous experiences as parents of young children in a growing city on the US East Coast, during the course of the research. As part of the community, we grew increasingly intrigued by the mechanics witnessed during the time our own families were subjected to the school redistricting processes. We understood some of the existing challenges including the competition in securing a family home, the suspense of learning about the process, and the frequency of disagreements in the community. Four of the authors are based in an academic institution in the US and cumulatively were able to participate in fifteen traditional public deliberations. As researchers, we struggled to make sense of the disconnect in perspectives between public school officials and the community members present at the debates. The experiences of research team members, held over the years (parent, community member, school employee, and researchers), offered different perspectives, to further understand what stood in the way of uniform realization of the hard work and good intentions invested by each group in public debates. All authors appreciated the potential that interactive visualizations could provide, due to exposure and background in applied sciences and human-computer interaction. These experiences motivated our research aiming to support public school rezoning deliberations through technology.

We further acknowledge the qualitative nature of our study whose results, as with most qualitative studies, are not intended to be entirely generalizable. Redistrict and its evaluation presents a different perspective and rich description of the space and sets the stage for a broader work into online tools for promoting civic collaboration addressing wicked problems. In addition, our participants all self-identified as North American adults and mostly as white. The results mostly pertain to this particular demographic group and geographic location. Future studies can address these limitations by engaging with racially diverse communities in other counties, as well as conducting long-term studies with a larger group of participants to learn about the challenges for adoption and the community's perceptions over time. In addition, comparative evaluation could be conducted in other school districts that are recording a decrease in school population. Such evaluations could further extend to other geographical areas and jurisdictions around the globe to test perceptions, reactions, and further develop the methodology of virtual geospatial civic deliberations.

8 CONCLUSIONS AND FUTURE WORK

During this work we qualitatively evaluated the potential for an online platform to extend and supplement in-person, live public school zone boundary deliberations. Addressing the study's design problem was the first step in the process of rebuilding assurance. In practice, we have noticed that the community is reluctant to adopt new technology when trust in authorities is compromised. But, this can be somewhat mitigated by transparency in the form of access to data and relevant calculations, as shown on the Redistrict platform. Socialization and user testing with public school officials was a necessary and important step towards large-scale testing (Figure 2).

The interactive map supported the ability to see an immediate shift in the attending and projected school populations and helped participants learn more about the constraints of the process. Attributing different parcels of the map to various schools, in an effort to create a better-than-proposed mapping, gave a hands-on understanding of the very limited possible rezoning choices. This helped participants realize the difficult situations position planners find themselves in, with such limited school space. By using Redistrict, participants report increased awareness of the complex problem of resource allocation (in terms of stability, compactness, etc.). This activity has the potential to enable transparency and shared understanding of the difficult and often compromising decisions that go into supporting continuous school population growth.

Redistrict's online interface was perceived as a fast, reliable, easy-to-learn platform with the potential to enable information dissemination. Additionally, participants mentioned wishing to see the interactive map and student projections side-by-side. This was not implemented by us during the course of this study; however, we appreciate the benefits of this potential display and encourage further research to follow this suggestion.

Future research should expand participation to a more diverse group to include people of different demographics and abilities to assess the broader suitability of Redistrict and to support more inclusive public school rezoning deliberations. There is a need to conduct similar qualitative user studies for areas experiencing long-term decrease in population, such as areas that need to rezone because schools have closed, causing students from further away to be grouped together to form classes and run a school. Additionally, quantitative studies of a larger number of participants would provide a valuable complementary perspective to the positive effects suggested by our qualitative evaluation here.

The geo-supported online interface should be thoroughly tested during live rezoning efforts to observe the extent to which our findings are preserved and what other concerns might appear over time through its adoption and appropriation. In this context, the premises would potentially shift, as people would be personally invested in the process. Engagement could be measured in terms of the time it took users to submit a plan, how many plans were submitted, differences between submitted plans, the number of participants, number of comments, and many other aspects. Lastly, based on our findings, we provide design opportunities to frame a new socio-technological medium to extrapolate to other subject-specific decisions on complex geospatial data, for instance, electoral districts, city planning, or law-enforcement deployment.

This research further expands on previous work that seeks to establish common ground and shared understanding in community deliberations and opens a perspective for community co-operative work on highly interactive, data-driven visualizations in a civic, multi-disciplinary context. Given limited research in this space, we hope to invigorate discussion on design considerations towards broader, more diverse studies.

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REFERENCES

[1] AACP. 0. *U.S. Census Bureau Demographics.* https://www.census.gov/.

[2] AL. 2014. *Public Rezoning Meeting.* Over the mountain journal.

[3] Paul André, Aniket Kittur, and Steven P. Dow. 2014. Crowd Synthesis: Extracting Categories and Clusters from Complex Data. In *Proceedings of CSCW 2014.* unknown, unknown, unknown.

[4] Pablo Aragon, Adriana Alvarado Garcia, Christopher A. Le Dantec, Claudia Flores-Saviaga, and Jorge Saldivar. 2020. Civic Technologies: Research, Practice and Open Challenges. In *Conference Companion Publication of the 2020 on Computer Supported Cooperative Work and Social Computing* (Virtual Event, USA) *(CSCW '20 Companion).* Association for Computing Machinery, New York, NY, USA, 537–545. https://doi.org/10.1145/3406865.3430888

[5] Mariam Asad, Christopher A. Le Dantec, Becky Nielsen, and Kate Diedrick. 2017. Creating a Sociotechnical API: Designing City-Scale Community Engagement. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) *(CHI '17).* Association for Computing Machinery, New York, NY, USA, 2295–2306. https://doi.org/10.1145/3025453.3025963

[6] Tene C Barber. 2011. The online crit: The community of inquiry meets design education. *International Journal of E-Learning & Distance Education* 25, 1 (2011), 1.

[7] Patrick Bayer, Fernando Ferreira, and Robert McMillan. 2007. A unified framework for measuring preferences for schools and neighborhoods. *Journal of political economy* 115, 4 (2007), 588–638.

[8] Nelson HF Beebe. 2022. A Complete Bibliography of Digital Government: Research and Practice. *unknown* unknown (2022), unknown.

[9] Subhodip Biswas, Fanglan Chen, Zhiqian Chen, Chang-Tien Lu, and Naren Ramakrishnan. 2020. Incorporating Domain Knowledge into Memetic Algorithms for Solving Spatial Optimization Problems. In *Proceedings of the 28th International Conference on Advances in Geographic Information Systems* (Seattle, WA, USA) *(SIGSPATIAL '20).* Association for

Computing Machinery, New York, NY, USA, 25–35. https://doi.org/10.1145/3397536.3422265

[10] Subhodip Biswas, Fanglan Chen, Zhiqian Chen, Andreea Sistrunk, Nathan Self, Chang-Tien Lu, and Naren Ramakrishnan. 2019. REGAL: A Regionalization Framework for School Boundaries. In *Proceedings of the 27th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems* (Chicago, IL, USA) *(SIGSPATIAL '19)*. Association for Computing Machinery, New York, NY, USA, 544–547. https://doi.org/10.1145/3347146.3359377

[11] Subhodip Biswas, Fanglan Chen, Andreea Sistrunk, Sathappan Muthiah, Zhiqian Chen, Nathan Self, Chang-Tien Lu, and Naren Ramakrishnan. 2020. Geospatial Clustering for Balanced and Proximal Schools. *Proceedings of the AAAI Conference on Artificial Intelligence* 34, 09 (Apr. 2020), 13358–13365. https://doi.org/10.1609/aaai.v34i09.7058

[12] Susanne Bodker. 1999. Scenarios in user-centred design-setting the stage for reflection and action. In *Proceedings of the 32nd Annual Hawaii International Conference on Systems Sciences. 1999. HICSS-32. Abstracts and CD-ROM of Full Papers*. IEEE, unknown, unknown, 11–pp.

[13] James Bohman. 1996. Public deliberation.

[14] Alan Borning, Batya Friedman, Janet Davis, and Peyina Lin. 2005. Informing public deliberation: Value sensitive design of indicators for a large-scale urban simulation. In *ECSCW 2005*. Springer, unknown, unknown, 449–468.

[15] Guy A Boy. 2017. A human-centered design approach. In *The handbook of human-machine interaction*. CRC Press, unknown, 1–20.

[16] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative research in psychology* 3, 2 (2006), 77–101.

[17] Stephanie Burkhalter, John Gastil, and Todd Kelshaw. 2002. A Conceptual Definition and Theoretical Model of Public Deliberation in Small Face—to—Face Groups. *Communication Theory* 12, 4 (2002), 398–422. https://doi.org/10.1111/j.1468-2885.2002.tb00276.x arXiv:https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1468-2885.2002.tb00276.x

[18] Kelly Caine. 2016. Local Standards for Sample Size at CHI. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '16)*. Association for Computing Machinery, New York, NY, USA, 981–992. https://doi.org/10.1145/2858036.2858498

[19] David Card. 1999. The causal effect of education on earnings. *Handbook of labor economics* 3 (1999), 1801–1863.

[20] Kelley D Carey. 2011. School district master planning: A practical guide to demographics and facilities planning. *A* b (2011), 5.

[21] Felipe Caro, Takeshi Shirabe, Monique Guignard, and Andrés Weintraub. 2004. School redistricting: Embedding GIS tools with integer programming. *Journal of the Operational Research Society* 55, 8 (2004), 836–849.

[22] Andrene J. Castro, Mitchell Parry, and Genevieve Siegel-Hawley. 2022. "All schools are not created equal:" An analysis of public comments on school rezoning. *Education Policy Analysis Archives* 30 (Feb. 2022), (13). https://doi.org/10.14507/epaa.30.6984

[23] U.S. Census. 2019. *Household statistics*. https://www.census.gov/newsroom/press-releases/2016/cb16-192.html.

[24] U.S. Census. 2019. *Household statistics*. https://www.census.gov/library/stories/2019/06/about-thirteen-million-united-states-workers-have-more-than-one-job.html.

[25] Kathy Charmaz. 2006. *Constructing grounded theory: A practical guide through qualitative analysis*. sage, unknown.

[26] Xin Chen, Jessica Zeitz Self, Leanna House, John Wenskovitch, Maoyuan Sun, Nathan Wycoff, Jane Robertson Evia, and Chris North. 2017. Be the data: embodied visual analytics. *IEEE Transactions on Learning Technologies* 11, 1 (2017), 81–95.

[27] Lydia B. Chilton, Greg Little, Darren Edge, Daniel S. Weld, and James A. Landay. 2013. Cascade: crowdsourcing taxonomy creation. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13)*. ACM, New York, NY, USA, 1999–2008. http://doi.acm.org/10.1145/2470654.2466265

[28] Rachel Elizabeth Clarke, Jo Briggs, Andrea Armstrong, Alistair MacDonald, John Vines, Emma Flynn, and Karen Salt. 2021. Socio-materiality of trust: co-design with a resource limited community organisation. *CoDesign* 17, 3 (2021), 258–277.

[29] Gregorio Convertino, Helena M Mentis, Mary Beth Rosson, John M Carroll, Aleksandra Slavkovic, and Craig H Ganoe. 2008. Articulating common ground in cooperative work: content and process. In *Proceedings of the SIGCHI conference on human factors in computing systems*. unknown, unknown, 1637–1646.

[30] Gregorio Convertino, Helena M Mentis, Mary Beth Rosson, Aleksandra Slavkovic, and John M Carroll. 2009. Supporting content and process common ground in computer-supported teamwork. In *Proceedings of the SIGCHI conference on human factors in computing systems*. unknown, unknown, 2339–2348.

[31] Eric Corbett. 2018. Trust and community engagement in digital civics: exploring opportunities for design. In *Proceedings of the 2018 ACM Conference Companion Publication on Designing Interactive Systems*. unknown Press, none, 367–370.

[32] Eric Corbett and Christopher Le Dantec. 2019. Towards a Design Framework for Trust in Digital Civics. In *Proceedings of the 2019 on Designing Interactive Systems Conference*. unknown Press, unknown, 1145–1156.

[33] Clara Crivellaro, Rob Anderson, Daniel Lambton-Howard, Tom Nappey, Patrick Olivier, Vasilis Vlachokyriakos, Alexander Wilson, and Pete Wright. 2019. Infrastructuring public service transformation: Creating collaborative spaces

between communities and institutions through HCI research. *ACM Transactions on Computer-Human Interaction (TOCHI)* 26, 3 (2019), 1–29.

[34] R Jordon Crouser and Remco Chang. 2012. An affordance-based framework for human computation and human-computer collaboration. *IEEE Transactions on Visualization and Computer Graphics* 18, 12 (2012), 2859–2868.

[35] Christopher A Le Dantec and Carl DiSalvo. 2013. Infrastructuring and the formation of publics in participatory design. *Social Studies of Science* 43, 2 (2013), 241–264.

[36] Anna De Liddo and Rosa Strube. 2021. Understanding Failures and Potentials of Argumentation Tools for Public Deliberation. In *C&T'21: Proceedings of the 10th International Conference on Communities & Technologies-Wicked Problems in the Age of Tech*. unknown, unknown, 75–88.

[37] Prince William County Public School Planning Department. 2021. *Example of Planning Department Size*. unknown, https://www.pwcs.edu/departments/facilities_services.

[38] Jessa Dickinson, Mark Díaz, Christopher A Le Dantec, and Sheena Erete. 2019. " The cavalry ain't coming in to save us" Supporting Capacities and Relationships through Civic Tech. *Proceedings of the ACM on Human-Computer Interaction* 3, CSCW (2019), 1–21.

[39] Carl DiSalvo, Phoebe Sengers, and Hrönn Brynjarsdóttir. 2010. Mapping the landscape of sustainable HCI. In *Proceedings of the SIGCHI conference on human factors in computing systems*. unknown, unknown, 1975–1984.

[40] Andy Dow, Rob Comber, and John Vines. 2018. Between grassroots and the hierarchy: Lessons learned from the design of a public services directory. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. unknown, unknown, 1–13.

[41] Steven Draper. 2016. [Online]. Computer Supported Cooperative lecture notes: Research Protocols. URL: https://www.psy.gla.ac.uk/~steve/HCI/cscln/trail1/Lecture5.html.

[42] S. M. Easterbrook, E. E. Beck, J. S. Goodlet, L. Plowman, M. Sharples, and C. C. Wood. 1993. *A Survey of Empirical Studies of Conflict*. Springer London, London, 1–68. https://doi.org/10.1007/978-1-4471-1981-4_1

[43] Richard F Elmore. 1993. The role of local school districts in instructional improvement. *Designing coherent education policy: Improving the system* 0, 0 (1993), 96–124.

[44] Sheena Erete and Jennifer O Burrell. 2017. Empowered participation: How citizens use technology in local governance. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. unknown, unknown, 2307–2319.

[45] Jennifer Evans-Cowley and Justin Hollander. 2010. The New Generation of Public Participation: Internet-based Participation Tools. *Planning Practice & Research* 25, 3 (2010), 397–408. https://doi.org/10.1080/02697459.2010.503432 arXiv:https://doi.org/10.1080/02697459.2010.503432

[46] Jennifer S. Evans-Cowley. 2010. Planning in the age of Facebook: the role of social networking in planning processes. *GeoJournal* 75, 5 (2010), 407–420. https://doi.org/10.1007/s10708-010-9388-0

[47] Marcus Foth and Margot Brereton. 2004. Enabling local interaction and personalised networking in residential communities through action research and participatory design. In *OZCHI 2004 Conference Proceedings. Supporting Community Interaction: Possibilities and Challenges*. Computer-Human Interaction Special Interest Group (CHISIG), ACM, not released, 1–5.

[48] Eric Gordon and Jessica Baldwin-Philippi. 2014. Playful civic learning: Enabling lateral trust and reflection in game-based public participation. *International Journal of Communication* 8 (2014), 28.

[49] Mike Harding, Bran Knowles, Nigel Davies, and Mark Rouncefield. 2015. HCI, civic engagement & trust. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. unknown, unknown, 2833–2842.

[50] Naja Holten Møller, Irina Shklovski, and Thomas T Hildebrandt. 2020. Shifting concepts of value: Designing algorithmic decision-support systems for public services. In *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society*. unknown, unknown, 1–12.

[51] John A Hughes, Wolfgang Prinz, Tom Rodden, Kjeld Schmidt, Liam Bannon, and Susanne Bødker. 1997. Constructing common information spaces. In *Proceedings of the Fifth European Conference on Computer Supported Cooperative Work*. Springer, Eusset, -, 81–96.

[52] Patch Mayor Hussein Hachem. 2019. Overcrowding in Schools: Why is it a Huge Issue? *Online* unknown (2019), unknown. https://patch.com/michigan/dearborn/overcrowding-schools-why-it-huge-issue

[53] Mahmood Jasim, Enamul Hoque, Ali Sarvghad, and Narges Mahyar. 2021. CommunityPulse: Facilitating community input analysis by surfacing hidden insights, reflections, and priorities. In *Designing Interactive Systems Conference 2021*. unknown, unknown, 846–863.

[54] Ian G Johnson, Aare Puussaar, Jennifer Manuel, and Peter Wright. 2018. Neighbourhood data: Exploring the role of open data in locally devolved policymaking processes. *Proceedings of the ACM on Human-Computer Interaction* 2, CSCW (2018), 1–20.

[55] Ian G. Johnson, John Vines, Nick Taylor, Edward Jenkins, and Justin Marshall. 2016. Reflections on Deploying Distributed Consultation Technologies with Community Organisations. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '16)*. Association for Computing Machinery,

New York, NY, USA, 2945–2957. https://doi.org/10.1145/2858036.2858098

[56] Travis Kriplean, Jonathan Morgan, Deen Freelon, Alan Borning, and Lance Bennett. 2012. Supporting reflective public thought with considerit. In *Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work*. unknown, unknown, 265–274.

[57] Travis Kriplean, Michael Toomim, JT Morgan, Alan Borning, and AJ Ko. 2011. REFLECT: Supporting active listening and grounding on the Web through restatement. In *Proceedings of the Conference on Computer Supported Cooperative Work, Hangzhou, China*. -, -, –.

[58] Eun-Ju Lee. 2002. Factors that enhance consumer trust in human-computer interaction: An examination of interface factors and moderating influences. *unknown* unknown (2002), unknown.

[59] Josh A Lerner. 2014. *Making democracy fun: How game design can empower citizens and transform politics*. MIT Press, -.

[60] Ann Light and Anna Seravalli. 2019. The breakdown of the municipality as caring platform: lessons for co-design and co-learning in the age of platform capitalism. *CoDesign* 15, 3 (2019), 192–211.

[61] Narges Mahyar, Michael R. James, Michelle M. Ng, Reginald A. Wu, and Steven P. Dow. 2018. CommunityCrit: Inviting the Public to Improve and Evaluate Urban Design Ideas through Micro-Activities. In *ACM Human Factors in Computing Systems (CHI 2018)*. unknown Press, Montréal, Québec, Canada, 10.

[62] Narges Mahyar, Weichen Liu, Sijia Xiao, Jacob Browne, Ming Yang, and Steven P Dow. 2017. ConsesnsUs: Visualizing points of disagreement for multi-criteria collaborative decision making. In *Companion of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing*. ACM, CSCW, 17–20.

[63] Carman Neustaedter and Phoebe Sengers. 2012. Autobiographical design in HCI research: designing and learning through use-it-yourself. In *Proceedings of the Designing Interactive Systems Conference*. unknown, unknown, 514–523.

[64] U.S. Department of Education. 2014. *Protecting Student Privacy*. A Service of the Privacy Technical Asistanc Center and the Student Privacy Policy Office.

[65] Rosemary A Olender, Jacquelyn Elias, and Rosemary D Mastroleo. 2010. *The school-home connection: Forging positive relationships with parents*. Corwin Press, unknown.

[66] Sharon Oviatt. 2006. Human-centered design meets cognitive load theory: designing interfaces that help people think. In *Proceedings of the 14th ACM international conference on Multimedia*. unknown, unknown, 871–880.

[67] Caitlynn Peetz. 2019. *'This is Just People Screaming': Tension Boils Over at School Boundaries Meeting*. https://files.eric.ed.gov/fulltext/ED521600.pdf.

[68] Washington Post. 2019. *Lines that divide*. https://www.washingtonpost.com/education/2019/12/16/lines-that-divide-school-district-boundaries-often-stymie-integration/?arc404=true.

[69] Washington Post. 2019. [Online]. Marches, letters, and emotions: School redistricting plan rolls a suburban Maryland county. URL: https://www.washingtonpost.com/local/education/marches-letters-emotions-school-redistricting-roils-a-suburban-maryland-county/2019/11/14/a63a3f36-db1a-11e9-a688-303693fb4b0b_story.html.

[70] Dave Randall. 2016. What Is Common in Accounts of Common Ground? *Computer Supported Cooperative Work (CSCW)* 25, 4 (2016), 409–423.

[71] Meredith P Richards. 2014. The gerrymandering of school attendance zones and the segregation of public schools: A geospatial analysis. *American Educational Research Journal* 51, 6 (2014), 1119–1157.

[72] Meredith P Richards, Kori J Stroub, Julian Vasquez Heilig, and Michael R Volonnino. 2012. Achieving diversity in the Parents Involved era: Evidence for geographic integration plans in metropolitan school districts. *Berkeley J. Afr.-Am. L. & Pol'y* 14 (2012), 67.

[73] Johnny Saldaña. 2015. *The Coding Manual for Qualitative Researchers*. SAGE Publications, unknown.

[74] Jorge Saldivar, Cristhian Parra, Marcelo Alcaraz, Rebeca Arteta, and Luca Cernuzzi. 2019. Civic Technology for Social Innovation. *Computer Supported Cooperative Work (CSCW)* 28, 1 (2019), 169–207. https://doi.org/10.1007/s10606-018-9311-7

[75] Devansh Saxena and Shion Guha. 2020. Conducting participatory design to improve algorithms in public services: Lessons and challenges. In *Conference Companion Publication of the 2020 on Computer Supported Cooperative Work and Social Computing*. unknown, unknown, 383–388.

[76] Andreea Sistrunk. 2022. Public School Boundaries and Society. In *ECSCW'22*. EUSSET, Europe.

[77] Andreea Sistrunk, Subhodip Biswas, Nathan Self, Kurt Luther, and Naren Ramakrishnan. 2022. Redistricting Practices in Public Schools: Social Progress or Necessity? In *Proceedings of 20th European Conference on Computer-Supported Cooperative Work*. European Society for Socially Embedded Technologies (EUSSET), Europe. https://doi.org/10.48340/ecscw2022_p05

[78] Andreea Sistrunk, Nathan Self, Subhodip Biswas, Kurt Luther, Nervo Verdezoto, and Naren Ramakrishnan. 2023. Redistrict: designing a self-serve interactive boundary optimization system. In *Companion Publication of the 2023 ACM Designing Interactive Systems Conference*. ACM, Pensylvania, U.S., 284–287.

[79] Andreea Sistrunk, Nathan Self, Biswas Subhodip, James Egenrieder, William Glenn, Kurt Luther, and Naren Ramakrishnan. 2023. Redrawing Public School Boundaries: An Intersection of Geography, Education Policy, and Computer

Science. In *Proceedings of 21st European Conference on Computer-Supported Cooperative Work*. European Society for Socially Embedded Technologies (EUSSET), Europe. https://doi.org/10.48340/ecscw2023_ep05
[80] Jeffrey S Sutton. 2008. San Antonio Independent School District v. Rodriguez and Its Aftermath. *Virginia Law Review* unknown, unknown (2008), 1963–1986.
[81] Javier Tibau, Michael Stewart, Steve Harrison, and Deborah Tatar. 2019. FamilySong: Designing to Enable Music for Connection and Culture in Internationally Distributed Families. In *Proceedings of the 2019 on Designing Interactive Systems Conference* (San Diego, CA, USA) *(DIS '19)*. Association for Computing Machinery, New York, NY, USA, 785–798. https://doi.org/10.1145/3322276.3322279
[82] Karen Tracy. 2011. *Challenges of ordinary democracy: A case study in deliberation and dissent*. Vol. 1. Penn State Press, -.
[83] travis@consider.it. 2004. *cdc*. https://www.cdc.gov/niosh/topics/workschedules/default.htm, unknown.
[84] Randall H Trigg and Susanne Bødker. 1994. From implementation to design: Tailoring and the emergence of systematization in CSCW. In *Proceedings of the 1994 ACM conference on Computer supported cooperative work*. unknown, unknown, 45–54.
[85] Alarith Uhde, Nadine Schlicker, Dieter P Wallach, and Marc Hassenzahl. 2020. Fairness and decision-making in collaborative shift scheduling systems. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. unknown, unknown, 1–13.
[86] Vasillis Vlachokyriakos, Clara Crivellaro, Christopher A. Le Dantec, Eric Gordon, Pete Wright, and Patrick Olivier. 2016. Digital Civics: Citizen Empowerment With and Through Technology. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI EA '16)*. Association for Computing Machinery, New York, NY, USA, 1096–1099. https://doi.org/10.1145/2851581.2886436
[87] Hao-Chuan Wang, Susan R Fussell, and Dan Cosley. 2011. From diversity to creativity: Stimulating group brainstorming with cultural differences and conversationally-retrieved pictures. In *Proceedings of the ACM 2011 conference on Computer supported cooperative work*. unknown, unknown, 265–274.
[88] Charles WJ Withers. 2018. Trust–in geography. *Progress in Human Geography* 42, 4 (2018), 489–508.
[89] Lu Xiao, Weiyu Zhang, Anna Przybylska, Anna De Liddo, Gregorio Convertino, Todd Davies, and Mark Klein. 2015. Design for online deliberative processes and technologies: Towards a multidisciplinary research agenda. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems*. unknown, unknown, 865–868.
[90] Ee-Seul Yoon, Kalervo Gulson, and Christopher Lubienski. 2018. A Brief History of the Geography of Education Policy: Ongoing Conversations and Generative Tensions. *AERA Open* 4, 4 (2018), 2332858418820940. https://doi.org/10.1177/2332858418820940

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