Author Reflections on Creating Accessible Academic Papers

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Author Reflections on Creating Accessible Academic Papers

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Academic papers demonstrate inaccessibility despite accessible writing resources made available by SIGACCESS and others. The move from accessibility guidance to accessibility implementation is challenging for authors. Our work focuses on understanding what challenges authors of academic papers face in creating content elements (e.g., tables, charts, images) to better understand how to improve accessibility. We classified 3866 content elements from 330 papers covering a 10-year sample of academic work from ASSETS to understand the variety used. We also reflected on the design choices that make the content elements inaccessible. We then conducted interviews with 13 academic authors from PhD student through to Professor Emeritus that publish within top-tier accessibility and HCI venues to understand the challenges faced in creating accessible content. We found critical issues in how academics understand and implement accessibility while also balancing the visual design of the paper. We provide recommendations for improving accessibility in the academic paper writing process and focus on steps that can be taken by authors, publishers, researchers, and universities.

CCS Concepts: • **Human-centered computing → Accessibility**.

Additional Key Words and Phrases: Accessibility, Content Elements, Charts, Tables, Images

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1 INTRODUCTION

Academic publications are a key part of knowledge dissemination. However, the papers are often not accessible [7], meaning that people with disabilities are going to face barriers when trying to access the information. Recently, a large-scale analysis of 11,397 PDFs sourced from different research areas (e.g., Biology, Computer Science, Physics, Sociology) found that 97.6% had accessibility issues [80]. Prior work found similar PDF issues for HCI papers (e.g., only 23.3% of the 459 CHI 2014 Papers and Notes used heading tags) making them inaccessible to screen reader users [9], even though CHI 2014 promoted the importance of creating accessible PDFs [38]. However, those studies are mostly focused on screen reader and magnifier accessibility, and we need to consider PDF accessibility broadly for many types of impairments. Addressing paper accessibility is one important step toward meeting the goal of making computing more inclusive [38].

In recent years, there has been advocation for accessibility becoming integral to creating academic content [13]. SIGCHI has already committed to making sure the academic papers from its many conferences are accessible. The CHI conference strongly encourages authors to make their papers accessible and provides guidance (sigchi.org/conferences/author-resources/accessibility-guide), which has built upon the work of the SIGACCESS community [2, 3, 28, 76]. Furthermore, there has been a recent call to action for the HCI community to create

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inclusive data visualisations for people with disabilities [44]. Data visualisations found in research papers can range from simple bar charts to more complex and custom images.

Although prior research has investigated this issue from the reader's experience with inaccessible content, we want to focus on understanding what challenges authors of academic papers[1] face that is contributing to inaccessible papers.

Academic work often consists of many different content elements, such as tables, charts, images, and other labelled content, which are chosen with the intent to best facilitate the reader in understanding the written work and arguments being put forth [6, 36, 51, 54, 59]. However, authors need to be cognisant of the varying abilities of the readers, and strive to ensure all readers have an equitable experience in accessing the information—especially because academic work is often funded by public money [64].

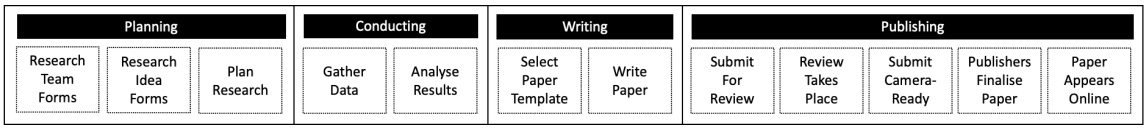

Fig. 1. Timeline showing four parts of the research process toward publication: 1) Planning; 2) Conducting, 3) Writing; and 4) Publishing.

Although accessible writing resources are available, the evidence of inaccessible papers from prior research suggest that the move from *guidance* to *implementation* is challenging for authors.

We conducted a study that examined the frequency of specific content elements appearing in 330 ASSETS PDF papers published between 2011-2020. We focused on ASSETS because ASSETS has a long history for requesting accessible papers, and we can also review full proceedings across multiple years. Conducting this review helped us to plan for our interviews discussing content element creation and to understand the variability in content elements over time. We identified a total of 3866 content elements and classified them into 21 separate element types (e.g., Annotated Screenshot). We also reflected on the design choices that make the content elements inaccessible.

Next, we interviewed 13 academic authors from PhD student through to Professor Emeritus who have published academic work within top-tier HCI and accessibility venues.

Our interviewees discussed their experience with the writing and content element creation process (including wider research team contributions), the motivation behind including content elements within their papers, how the accessibility of content elements is considered, and what challenges may affect the process.

We found that authors carry out a balancing act between their preferred design of content elements and ensuring the information is accessible. Creating accessible content elements is a multi-faceted issue that involves consideration of all accessibility domains, but authors often do not have this specific expertise. Implementing accessible content elements requires specific knowledge and skills, with guidance required on many granular levels.

We discuss the implications of our findings across the dimensions of content creator expertise, conferences/publisher guidance, opportunities for researchers/industry to design new academic publishing tools that support the creation of accessible content elements, and the role university/funders can play in supporting positive change.

Paper Contributions: We make the following contributions: **1)** We contribute quantitative data summarising the frequency of use of content elements (e.g., tables, charts, images) over 10 years of paper proceedings, which

[1]We will use the term authors for simplicity in our paper. However, we want to acknowledge that other people in a research team may help to create content appearing in published work but who do not get authorship recognition.

helps inform trends within accessibility and HCI research, as well as where to focus efforts when designing new academic publishing tools that support the creation of accessible content elements; **2)** We provide a thematic analysis of 13 interviews with academic authors who describe how they consider accessibility when writing accessible academic papers and the challenge they face achieving this; **3)** We contribute recommendations on how to improve the academic publishing process to support authors in making accessible content elements.

2 RELATED WORK

A CHI 2021 paper surveying accessibility papers published in CHI and ASSETS found that from 1994 to 2019 focus on accessibility research had considerably increased [43], indicating a growing interest from the wider HCI community toward accessibility research—albeit one that disproportionately focuses on specific types of disabilities. Studies that reflect on HCI's progress are essential for us to continue making positive change, and we were inspired to inspect how the HCI publication process mediates the accessibility of papers.

2.1 Publication Process

Academic publication is complex and varied, with many different venues and formats used to share academic outcomes. For example, an academic publication may include a PDF document, an HTML version of the paper, a video, a talk, and supplementary materials such as data sets or code libraries. The primary publication is the paper, which is typically presented as a PDF document. For many publishers, an HTML version of the paper may also be available. The other 'parts' of a publication are expected to provide an introduction to the material (e.g. a teaser video at CHI), a summary of the material (e.g. a conference talk), or to provide further detail (e.g. a data set that can be downloaded and inspected). However, it is common that the additional elements will refer users back to the paper in either PDF or HTML format. Furthermore, PDFs still remain the most convenient method for sharing the detailed insights outside of an academic community. For instance, although the HTML versions of papers are very accessible, they are behind a paywall and currently authors do not have an author-accepted HTML manuscript that they can share. In this paper, we are focusing on the development of the written presentation of academic publications as a PDF document, since this format is included at multiple stages of the publication process, i.e. during peer review and as a final publication.

The publication of academic work comprises many stages, from the conception of a research idea to a publication. An example timeline is shown in Figure 1 and can be summarised as (1) Planning; (2) Conducting, (3) Writing and (4) Publishing. Our timeline is not to be taken as definitive, we acknowledge that at each stage we can expect some variation based on preferences and requirements of both authors and publishers, but we are highlighting a typical standard process. In some cases, research is conducted by an individual and in some cases by a team which can lead to variations such as allocation of tasks. The writing process also varies depending on preferred tools and writing styles, as well as conference requirements. The submission of research papers is particularly varied across different conferences. For example, ASSETS has a rebuttal phase[2], CHI has moved to a revise and resubmit model for full papers[3], and NordiCHI has an accept or decline model[4].

Considering the many variations that are possible within the publication timeline, we expect this is going to affect the extent that authors can make a paper accessible. Furthermore, each author's abilities and experience will factor into this process. For example, academic authors with vision impairments face many challenges working with sighted collaborators and particular collaborative writing tools [15]. Next we focus on prior work that details the content presented within academic papers.

[2]https://assets21.sigaccess.org/call_for_papers.html
[3]https://chi2022.acm.org/for-authors/presenting/papers/
[4]https://www.nordichi.eu/2020/research-papers.html#/

2.2 Types of Content Elements

An academic paper presented as a PDF document contains many content elements. In this paper, we focus on visual content elements such as tables, charts, and images that can be used in academic papers to convey complex ideas in a small amount of space [49] and considered an abstract entity with semantics that subsequently convey meaning [24]. It is the development of this *meaning* that assists in creating structure between content elements and the academic work as a whole [71]. Visual data allows readers to consider the information collected and encourages the comparison of multiple pieces of data [78], can assist in making arguments more persuasive [62] and provide a rich way to assist in the storytelling aspect of a narrative [27].

Content elements should be accessible for all readers to interpret [39]. The process of achieving accessibility first requires that content elements are semantically correct, which is not always the case. Pareddy et al [55] conducted an analysis of images in HCI conferences and CS ArXiV. Reviewing papers across one year, they identified content being misrepresented as an image, e.g. a screenshot of a table being included in a paper. In addition, achieving accessibility involves making sure that elements are visually accessible (e.g., using patterns instead of colours in charts) and also that an additional text-based alternative is present for usage when content is not consumed visually (e.g., image alt text for screen readers). This process includes making sure that elements can be perceived and understood, while also allowing creativity to occur with *forgiveness*, where misunderstands in data presentation will still lead readers to the correct final outcomes [40].

One method of presenting data in a paper is to use tables that enables the reader to view precise numbers whilst also referring to summary values [46]. Tables are generally structured into rows that represent variables and columns that represent records [33]. Within a table, creators should consider the clarity of data being presented, consistency in design, the use of abbreviations, and logical order of row and column data [52]. Authors also need to consider the available space (sometimes limited by paper format) when constructing tabular data [70].

Second, data can be presented visually in charts [25] to create a graphical representation of categorical (i.e. nominal and ordinal) [26] and numerical (i.e. interval and ratio) data [33]. Using charts can support readers in understanding data that might not translate well in summary information alone. Such visualisations can reveal information that is '*hidden by computed statistics*' [53] and is seen as a method to discover and reason through data.

Third, images can be used to help the reader to understand specific points being made and also to illustrate ideas that the author may have [12]. They are traditionally used as a graphical representation of an object or a scene that can be used to show the reader contextual information about a specific moment in time or to provide a broader overview of an event [45]. Photographs, in particular, provide the opportunity to place a lens through which readers can view different lifestyles and cultures that may be important to understand for a given research topic [58]. However, care must be taken when including images within work as they can be received as filler content that is seen as a way to increase paper length [47].

When images are used within academic work, the overall composition should increase reader focus on the highlighted aspects [41]. If possible, a clear white background should be used to reduce image clutter and increase image attention [74]. Images of scenes should be captured in good lighting and with sufficient detail [32].

2.3 Understanding Accessibility and Why Accessible Content Elements Are Important

Creating accessible content is important but requires an understanding of the process. We have seen that formal education rarely prepares people with the expertise needed to avoid creating accessibility barriers (e.g., software engineers [56]), and this is likely due to accessibility topics being less developed than other Computer Science topics [4]. The result is a general lack of understanding of how a person with a disability uses technology, and impedes the way that developers create digital resources [14].

Inaccessible visual information can impact the ability of people to understand content. Accessibility can be categorised into the general areas of visual, cognitive, physical, communication, emotional, and intersectional areas [14]; content elements can impact all of these areas. For example, poorly made charts can cause cognitive accessibility challenges if the information is difficult to understand [34], but the inclusion of items such as flow charts to explain procedures can increase overall accessibility by providing information in a different manner[5]. Additionally, content elements that are too small (e.g. condensed legends in charts, or highly detailed images) can pose visual challenges that can be solved by zooming in digital formats, however, this also increases dexterity demands which may isolate other readers [77].

Visual data should be presented to increase the accessibility for all readers [21, 31]. As part of this, the selection of colour within visualisations is an important aspect to consider. Colours should be easily understood by people with impaired colour vision [11], print well in grey-scale, and also remain pleasant to look at [8]. As a requirement, the level of detail between colour levels (luminance contrast) should be as high as possible to allow adequate differences to be present [81]. In addition, the presentation of supplemental information to assist in understanding charts (e.g. legends, labels) should be of sufficient size for the reader to easily see [5].

Visual data can be remapped to provide an alternative accessible format. The challenge here is to present the data in both a visual and non-visual manner. This dual presentation of information presentation is not new; when visual content was becoming commonplace within academic work the Royal Society asked for it to additionally be reduced to writing so that a deeper understanding of the data can be obtained [29]. It is now common to expect *'alt-text'* to be presented for every piece of visual content within a piece of work[6] as a method of providing accessible content to all readers. Alt text is important for screen reader accessibility, but people do not often create well defined alt text. For example, Sharif et al [65] identified that alt text is frequently lacking for screen reader users or does not contain effective descriptions such as overall trends for charts, which renders data visualizations inaccessible for screen reader users. They showed that screen reader users extract information 61.48% less accurately and spend 210.96% more time interacting with online data visualizations compared to people who do not use screen readers. In addressing this challenge, Mack et al. has created an alt text authoring and feedback tool [42].

Once we understand where HCI authors are struggling in the paper writing process, it will provide us with insights on where new accessibility tools for content elements should be developed.

Despite the large body of prior work that has focused on understanding what the accessible format of data may look like, very little has focused on the processes that authors and designers must go through in order to reach this level. Accessibility does not constrain visual design [57], yet a mixture of creative forgiveness [40] and complex accessibility requirements makes it very difficult to produce a method to easily assess and implement accessibility associated with content elements within academic work. It has been discussed that less than 25% of author-supplied alternative text is sufficient enough to understand visual data contents [7].

2.3.1 Accessible Content Guidance. When discussing the accessibility of online content, it is common for the W3C Web Content Accessibility Guidelines (WCAG) [35] to be one of the primary resources that is used. The main purpose of WCAG is to improve the accessibility web content by providing guidance that assists in making material perceivable, operable, understandable, and robust. These four guiding principles are used to categorize guidelines that can then be met via a number of success criteria.

Of interest for this work is success criteria that relate to non-visual text[7] and PDF documents[8]. Yet, a challenge arises in creating accessible scientific documents due to the complexity of images used, the form factor of the

[5]https://www.w3.org/TR/coga-user-research/
[6]https://authors.acm.org/journals/how-to-write-alt-text-and-why
[7]https://www.w3.org/TR/UNDERSTANDING-WCAG20/text-equiv-all.html
[8]https://www.w3.org/TR/WCAG20-TECHS/pdf.html#pdf_notes

documents themselves (i.e. PDF), and a lack of technical guidance on how to create suitable alternatives. The W3C Web Accessibility Initiative provides tutorials on providing alternative text for complex images[9], but success criteria linked to this are either based on general implementation or technical implementation for HTML. Prior work has also mentioned data visualization practitioners fo not have sufficient evidence-based guidelines and tools to support them in creating accessible content [44].

An alternative to WCAG when focusing on the accessibility of digital documents is ISO 14289:1[10], commonly referred to as PDF/UA (Universal Accessibility). This international standard focuses on the technical implementation of accessibility inside of PDF documents with a focus on correct methods of tagging content inside of a document itself. Similar to WCAG, PDF/UA provides general guidance on how individual elements can be made accessible and the subsequent technical implementation of these methods within the PDF file format. The challenge in both cases is in the overall granularity of the information that is provided, and how authors use these sources (and others) in the development of accessible scientific papers.

2.4 Summary and Research Question

The previous work we report outlines variations in the publication process, types of content elements used in papers, understanding accessibility, and why accessible content elements are important. However, since academic papers are often inaccessible, it seems there is still a challenge with creating accessible content for academic paper and suggests that the move from *guidance* to *implementation* is challenging for authors. To address this we need to better understand the challenges that authors face in making their papers accessible—not only for screen readers, but to accommodate many different impairments. Our work is therefore motivated by our **RQ**: *What challenges exist when implementing accessible content within academic writing?*

3 QUANTIFYING CONTENT ELEMENTS

Inaccessible papers are a known issue within the research community [7, 9]. However, the focus of our research is on understanding what challenges authors face that is contributing to inaccessible content elements. The primary focus of our work is qualitative research with academic authors who publish academic work within top-tier HCI and accessibility venues, but in order to prepare for our interviews (see sections 4 and 5) we first want to understand the extent and variability of content elements added to research papers in our field, and how trends might have changed in recent years. In addition, our quantification of content elements can be used to prioritise the development for future tools to support content creation (see section 6.4).

3.1 Method

We base our content elements quantification method on prior work from ACM ITiCSE [69]. We quantified all content elements within full papers from the ASSETS conference over a ten year period (2011-2020).

We chose ten years of ASSETS papers for several reasons. First, ASSETS is an accessibility based conference, with a community that has close ties to larger conferences such as CHI, and it has a long history of encouraging authors to make their work accessible (i.e., we expect ASSETS papers to demonstrate best practices). Second, ASSETS 2011 follows a year after the conference first promoted the importance of creating accessible PDFs, so organisers had time to refine anything after the its introduction if authors needed more guidance[11]. Our examination of a ten year sample allowed us to include papers that have gone through five format changes of varying page lengths and reference limit. Third, conferences (including CHI) regularly signpost to ASSETS

[9] https://www.w3.org/WAI/tutorials/images/complex/
[10] https://www.iso.org/standard/64599.html
[11] http://assets10.sigaccess.org/accessible_pdfs.html

materials for creating accessible papers and publications from ASSETS is reflected in this guidance, meaning that the HCI community recognizes ASSETS as the top-tier conferences for leading accessibility efforts.

Our code book contains 21 codes within four broad categories: Table, Chart, Images, Other. The full code book can be found in Appendix A, with this being created after pilot work examining papers from ASSETS 2018. We applied the code book to the ten years of papers, such that two authors were assigned to each year. Each author coded papers individually and then discussed disagreements. The purpose of this initial study was not specifically to identify accessibility challenges in the papers as this is considered in previous work (e.g., [1, 7, 9, 80]). The primary purpose was to identify the types and frequency of content elements in order to better inform the design of future tools and applications to support their development and inclusion in academic work.

However, we did reflect on the accessibility of each element based on our own previous experience (a combined 33 years in accessibility research). Each author kept notes during this process on any good practice that was identified and any accessibility challenges encountered. These notes form the basis of insights presented in section 3.3. Initial agreement over all conference years was 75.9%, with the remaining author consulting when a consensus could not be reached.

We did not make decisions based on the appropriateness of figures used, but on the content of the figure. For example, where charts were used inappropriately, we coded the intention of the author, e.g. a line chart that incorrectly uses categorical data will be coded as a line chart (even though the more appropriate chart to present the data would have been a bar chart).

For single figures with multiple component parts, e.g. two charts that are labelled or defined in the figure caption as parts (a) and (b) were coded as individual instances. Where a figure consisted of multiple parts that were not labelled or defined these were split whenever each part contains specific different information components.

In some cases we encountered content that was not captioned as a figure or equivalent. When data was presented, e.g. as a table, without a caption it was coded, but for equations presented within a block of text, these were not coded because they were not called out as a distinct content element for readers.

3.2 Results

We reviewed 330 papers, and these contained 3866 content elements (tables and figures). Table 1 summarises the total count of each broad-category content element type per year. The average number of elements in each paper was 12 (min=0; max=88). Six papers had no content elements.

3.2.1 Tables. 76% of all papers contained at least one table of any type. The average number per paper was 2 (min=0, median=2.5, max=10). Of the tables presented, 94% were basic presentations of data using text and numbers, with varied template compliance.

Some papers (n=41) contained more complex tables that used colour or images as part of the data. We also found examples of tables being used to appear visually as charts. In one paper we even noted a table that contained animations embedded into the PDF file itself—but the animations would only work if viewed in Adobe Acrobat.

3.2.2 Charts. The average number of charts per paper was 2.4 (min=0, median=1, max=16) and 54% of papers contained at least one chart. The types of charts presented most frequently were bar charts (35% of all charts), "other" charts (28%) and line charts (21%). "Other" charts included complex presentations of data, e.g. with multiple axes or stacked bar charts. Pie charts, histograms and scatter plots were considerably less popular (see Table 1).

3.2.3 Images. The average number of images per paper was 6.7 (min=0, median=5, max=69) and 86% of papers contained at least one image. We recreated an example of each type of image (see Figure 2). The images presented most frequently were screenshots (24% of all images), diagrams (19%) and photo scenes (18%).

Screenshots comprised high-fidelity screen mock-ups as well as capturing applications on a range of different devices, such as smartwatches, mobile phones, tablets, desktop computers, Augmented Reality (AR) headsets and

Table 1. Frequency of each broad-category of visual element identified by proceedings (number of papers each year). Additional data tables for specific content element frequency are in Appendix B (see Section 7 for a reflection on the different table and chart designs we tried before settling on a simple table).

Papers	Year	Tables	Charts	Images	"Other"	Total
27	2011	56	73	172	15	316
24	2012	37	64	186	37	324
29	2013	65	80	171	19	335
29	2014	62	70	203	1	336
31	2015	61	41	184	9	295
28	2016	43	81	205	11	340
36	2017	82	75	249	12	418
31	2018	65	84	176	11	336
45	2019	91	101	332	14	538
50	2020	100	126	347	55	628
–	**Total**	662	795	2225	184	3866

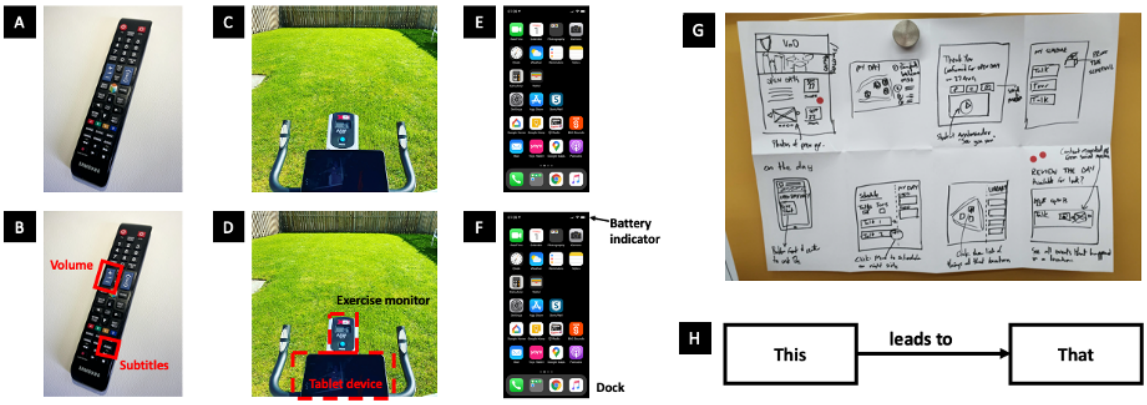

Fig. 2. Our recreation (to preserve anonymity) of (a) a photo object, (b) an annotated photo object, (c) a photo scene, (d) an annotated photo scene, (e) a screenshot, (f) an annotated screenshot, (g) a drawing, (h) a diagram.

Virtual Reality (VR) headsets. Annotated screenshots typically included labelling different parts of the screenshot to aid in further discussion within the paper, but were much less common, being only 4% of all images.

Diagrams typically included flowcharts to explain experimental or algorithmic processes, room setups for experiments and representations of different interface interactions.

Photo scenes presented assistive technology being used in context or a research session in progress. Annotated photo scenes, e.g. to label different aspects of the scene, represented 7% of all images.

3.2.4 Other. The average number of "other" content elements per paper was 0.6 (min=0, max=18) and 14% of papers contained at least one "other" visual element. These are listed in order of percentage of papers that contain at least one of these: equation (7%), text (5%), pseudocode (1.5%) and code (1.5%). Text as a figure was found in 16

papers. Examples included presenting audio transcripts or screen reader output alongside screenshots, as well as highlighting design prompts used in focus groups, such as method cards.

3.2.5 Comparison to other selected work. We compared our results with those from Simon et al. [69], on which our methodology was based. We found that content elements were more prevalent in ASSETS papers compared to computing education papers at ITiCSE: 76% of the papers contained tables compared to 61%, 54% of the papers contained charts compared to 49%, and 86% of the papers contained images compared to 69%.

In addition, other work from within HCI, e.g. [55] has identified a number of issues that relate to the creation of different content elements. Analysis of images in HCI conferences and CS ArXiV from 2018 were reviewed to determine the content elements within a sub-set of these papers.

Images were the most popular content elements across both ASSETS and iTICSE conferences, but the types of images differed: in the accessibility papers, photos were more popular with a particular emphasis on annotated photo objects. This is consistent with the prevalence of ASSETS papers that investigate new assistive technologies since many images detailed the construction and use of assistive technologies, and is also common for papers published within the accessibility sub-committee at CHI. Of interest, Pareddy et al [55] confirmed that the variety of content elements seen in ASSETS proceedings are also found across other HCI conferences. Hybrid images (figures containing more than one image) were less common in ASSETS than other conferences.

Despite variations in the prevalence of different content elements, it is clear that the different categories exist across at least two different subject areas and that the order of popularity is consistent: images are the most popular, followed by tables and then charts. Therefore, it is likely that content elements can result in challenges in multiple research areas. With this in mind, it is clear that if we are to prioritise the development of accessibility design tools to support implementing accessibility in academic writing, then tools for making accessible images is a priority across the accessibility/HCI and educational computing domains, followed by table creation, and then chart creation. However, to inform the development of such tools, we still need to understand how and why authors create the content elements they do and where there are issues in the writing process.

3.3 Accessibility Challenges Encountered

During our audit of papers, we identified inaccessible content elements that were present in the papers. Insights recognised during the audit were discussed by the authors on completion of the audit, and are outlined here. Prior work discusses the need to consider cognitive, motor, and visual impairments when creating inclusive data visualisations for people with disabilities [44], although for our work we want to have a broader outlook by considering all aspects of paper content, as well as situational impairment when reading. The purpose of sharing these details is to emphasise that even with guidance for authors to follow, papers are being published with various inaccessible content elements. Reflecting on these observations also helped us with planning for our interviews to find out why inaccessible content occurs.

3.3.1 Complexity of Information. We found evidence of rather complex tables being used within the papers. Examples of this include: headings with subheadings, merged table cells resulting in headings spanning multiple columns, multiple values contained in a single cell, the inclusion of images and animations within cells (see Figure 3.b), as well as other information "baked" into the visual design of the values (e.g., bold or underline styles to indicate statistical significance, table cell background colours with assigned meaning, and symbols). It is no longer a simple task to read from the top heading down or left column across. Sometimes tables include a new top-level heading or commentary midway down the table and it often seems like those decisions are a result of trying to save space rather opting to present multiple tables, which would simplify the table design. As a result, the reading flow is easily interrupted.

A

1. I found the system easy to understand.

	SD	D	N	A	SA
System 1			2.5		
System 2				3.0	
System 3			2.5		

2. I would recommend this system to others.

	SD	D	N	A	SA
System 1			2.5		
System 2					3.0
System 3		2.0			

B

Chess piece	Image	Possible moves
Rook		moves any number of vacant squares forwards, backwards, left, or right in a straight line
Knight		moves on an extended diagonal from one corner of any 2×3 rectangle of squares to the furthest opposite corner
Bishop		moves any number of vacant squares diagonally in a straight line

Fig. 3. Our recreation of challenges with presentation of tables: (a) a table being used to create a chart, (b) a tables containing images.

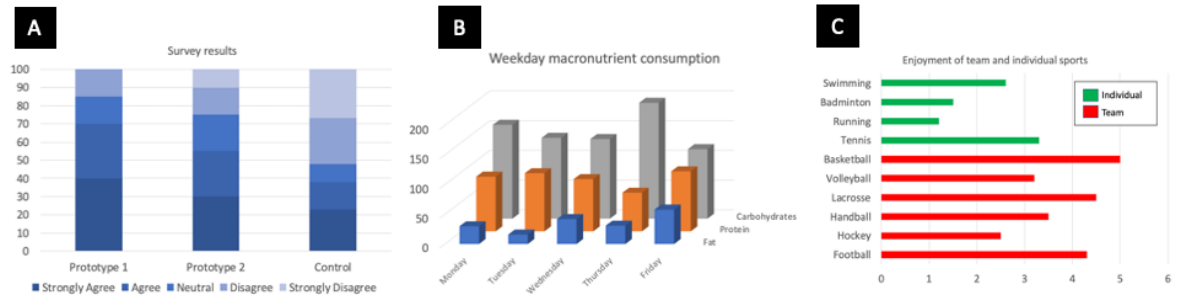

Fig. 4. Challenges with presentation of charts: (a) a stacked bar chart, (b) a 3D bar chart, (c) a bar chart using only colour to determine categories.

We found examples of many different charts, and, while one type of chart may be used, the data sometimes could have been presented in another format with the added benefit of being more accessible. For example, two types of problematic charts we want to highlight are the stacked bar charts and 3D charts (see Figure 4.a and Figure 4.b). Prior work has warned about the difficulty of interpreting those styles of chart. Specifically, stacked bar charts can be difficult to compare adjacent bars in a stack [73], while the use of 3D effects can negatively impact readability by affecting a person's ability to judge bar height accurately and in the context of surrounding bars [83]. Using a standard, flat bar chart design with patterns to distinguish between bars would likely improve readability. Furthermore, the use of colour and symbols in charts will also add to their visual complexity (see Section 3.3.2 for a discussion on colour accessibility).

Finally, the various figures included in an academic paper can range from a simple photo of a device to a complicated diagram made up of screenshots, arrows, labels, and icons with different meanings. Images can include multiple layers of meaning that require specific scientific or cultural knowledge and these should be appropriately explained.

3.3.2 Use of Colour and Symbols. Colour often plays a role within society and in different cultures to signify information [18, 19]. For many people, colour seems like a natural way in which to represent or highlight

information. Yet, using colour as the sole means of representing information is problematic [11] and the approach is discouraged by the Web Content Accessibility Guidelines (WCAG) [35].

We are often advised to consider colour blind people who have reduced colour differentiation abilities compared to people with typical colour vision, however, this view is restrictive. It is more appropriate to discuss the idea of impaired colour vision (ICV) and when doing so, it is clear how important the consideration of colour is on a large-scale. ICV can result from three non-mutually exclusive factors: congenital ICV (e.g., affected X-chromosome [50]), acquired ICV (e.g., solvent abuse [17], brain damage [84], aging [16]) and situational ICV (e.g., printing papers in greyscale, ICV caused by room lighting or tinted lenses [23, 75]).

We often found colour was used to represent information without any other visual indicator. Sometimes the chosen colours lacked sufficient distinction and at other times were easy to distinguish but only when not experiencing any form of ICV. Red, orange, yellow, and green were common colours found within various charts (see Figure 4.c) and figures, and although their chromatic difference may be distinguishable for some, these colour are difficult to distinguish for the most common type of congenital ICV [66]. Sometimes the brightness of the colour is varied, which should help since contrast detection is often not a problem, but this relies on the authors applying a sufficient level of contrast between the colours. One example of insufficient contrast being applied was to a stacked bar chart using a single hue and seven shades of a single colour. The difference between the darkest and lightest shades was a contrast ratio of 5.1:1, but the difference between the darkest colour and next shade lighter was only 1.26:1 difference, and even the data point two shades lighter still failed to meet WCAG's minimum recommendation of 3:1 [35].

In one case, we found a table with two background colours that only had a contrast ratio of 1.12:1. Colour was also used to emphasise the difference in the size of numbers, and although this approach is fine when the number itself is present to represent the data in another form, an issue arises when the background colour and text colour converge so that they become indistinguishable. When measuring an example of this, we found a contrast ratio of 2.02:1 for the darkest background shade with black font.

This is not to say we found no evidence of good practice for using colour with visual element. Some papers utilised patterns, shape, size, and labels to represent information in another way so that if the colour was used, it was not the only method for displaying important information. However, it is easy to make errors, and even within papers that demonstrated good practice, this was not always consistently applied.

In some cases, patterns or symbols were used in place of colour. Sometimes the difference between dashed lines or symbols was not distinct enough and could result in confusion. For charts, there may be some expectation the reader will match the order of the chart key to the order of the bars in the chart, but the reader has to make an assumption here, and we know that mistakes can make it through to publication (see Section 3.3.4 for discussion).

3.3.3 Image Quality. Image quality is an important part of visual elements within research papers. Papers can include example figures that are not meant to provide specific information beyond a high-level overview. For example, one paper provided an example of different chart graphics and clearly stated as such with the caption.

Usually, these examples are not given much space in a paper and so the finer details are lost. This should be acceptable if the reader is explicitly made aware that the figures purpose is not to give detailed information, otherwise, an argument could be made that unnecessary information should be removed for simplicity (see Section 3.3.1).

Ideally, authors should seek to include text and equations as an embedded part of the document and not part of images, but we found this not always to be the case. For example, we found an image of an equation—it was slightly squished and stretched, which made for an odd reading experience. Furthermore, if the reader needs to adjust the font for improved readability, such as to accommodate dyslexia [60], then this important element will not have the reader's preferences applied to it.

3.3.4 Misleading Information and Unconventional Formatting. We found evidence of mislabelling that can create confusion for readers, such as with the numbering of tables and figures. For example, 'Table 2' listed in a paper without any existing 'Table 1' or two tables both labelled 'Table 1'. The organisation layout for a paper is also important to consider and we found the numbering of visual elements could sometimes fall out of the typical reading order (e.g., 'Table 3' appearing before 'Table 1' and 'Table 2'). We also found an example of no in-text reference to a figure, but the figure did include a detailed caption. However, the question is at what point is the reader supposed to focus on the figure or can it be ignored entirely, and if so, is there a need to include the figure?

Captions help to explain the content shown in tables and figures but they can be a source of confusion. Challenges we found included mentioning something in the caption that is not included in an image[12], captions lacking in sufficient detail, and omitting captions entirely. In the case of vague or no captions, these instance will causing the reader to switch their attention between the relevant body text and the visual element position, which may not always be in close proximity. Captions are also an opportunity to highlight when charts may be using a particular type of scale such as a logarithmic scale. In doing so, authors can use captions as an opportunity to emphasise this to the reader who may otherwise misinterpret the chart by assuming something else like the use of a linear scale.

We previously discussed the challenge presented by complex formatting of visual elements, such as tables with many headings, sub-headings, merged cells, images or animations (see Section 3.3.1), yet another aspect worth discussing is opting for a visual element that may be unconventional or unnecessary. For example, the use of a table to list information rather than using a bullet point list or using a different design for each table in a paper, thus lacking consistency. Further, we often saw tables listed as figures, and even a chart styled to appear as a chart in a similar way that one could inappropriately use a table for layout purposes in HTML (see Figure 3.a).

Finally, found visual elements with parts missing, either during the writing process or when the publishers format the final document. We found an example of this in a paper using radar plots. The radar plots were missing the axis, grid, and lines connecting the data points, but the authors had also included the same data in a table and so readers are still able to access accurate results information.

3.4 Summary

Overall, we coded 3866 content elements within 330 papers. The most common type of visual element used was images. Tables were also a common way to visually display information. The use of charts was varied, with bar charts being the most popular. Only six papers (2% of the total) did not contain any content elements. We therefore ran interviews to further understand the content element creation process.

We also found many different types of issues related to content elements in the research papers, reinforcing suggestions from prior research that the move from *guidance* to *implementation* of accessible content is challenging for authors. Our discussion of the problems we identified primarily isolated the issues so that we could discuss the implications of each with more clarity. However, we want to stress that these issues can appear in conjunction with other issues in the same visual element (e.g., a low-resolution image that relies on colour-coded annotations and abbreviations), as well as a single paper having multiple visual elements with problems.

It is clear that authors value the inclusion of content elements to assist in demonstrating aspects of their work that cannot be easily explained by text alone—this finding likely generalises across HCI when we consider the popularity of system building and evaluating at conferences such as ACM CHI and UIST. However, the challenges faced by authors when making content accessible to the wider scientific community remains present. Implementing accessibility can be a challenging task with a large number of areas that have to be considered. In order to investigate this further, we carried out semi-structured interviews with academics from the HCI

[12]The object was likely removed during the writing process and the caption was not updated.

community to focus on the implementation of accessibility within academic work, and to identify what solutions can address this problem in the future.

4 INTERVIEW METHOD

Our review of 330 academic papers provided us with insights into the frequent use of a variety of content elements over time, as well as the presence of accessibility issues, and the wide variety of ways HCI authors present information in papers. In order to understand how, and why, these content elements were created, and to see if authors can reflect on why accessibility challenges are occurring, we conducted interviews with authors to answer our **RQ**: *What challenges exist when implementing accessible content within academic writing?*

4.1 Procedure

After obtaining ethical approval from our IRB, we conducted semi-structured one-to-one interviews using video conferencing tools. The first and second authors conducted all interviews using a shared interview guide. Both independently conducted a pilot interview and compared approaches to ensure consistency, and to review the interview structure and questions. Our participants were recruited via social media and the ACM *access-announcements* mailing list. The mean interview time was 54 minutes (range: 35-66 minutes).

4.2 Participants

We present only minimal professional experience details and omit personal data such as age and gender in order to preserve author anonymity, especially to reduce risk of our disabled authors being identified from within the relatively small academic accessibility community; a practice followed by other authors in the area of accessibility [67, 68].

We interviewed 13 participants who have published academic work both within top-tier HCI (e.g., ACM CHI, CSCW, DIS, IDC, ISS, TOCHI, UIST) and accessibility (e.g., ACM ASSETS, TACCESS) venues. We did not target authors from within any particular conference, but instead focused on authors with experience of publishing papers related to accessibility topics. Published papers had coverage of seven contribution types within HCI [82]: empirical, artefact, methodological, theoretical, dataset, survey and opinion.

Our participant sample represented diversity with regards to the current stage they are at in their careers: from PhD student through to Professor Emeritus. Our participants had varying levels of publishing experience, which was reflective of how long they had each worked within academia. Publication output was as low as three to over 250 published works (median=44). When we focus specifically on their experience with publishing accessibility research, the median self-reported number of years was five (min=1; max=23) and median self-reported number of published accessibility papers number was nine (min=1; max=200).

Participants were not asked to disclose if they had a disability during the interview. However, some disclosures were made to give context to the participant's answers: Three participants disclosed that they were blind or had a significant visual impairment, and one participant disclosed that they had a movement disorder.

4.3 Analysis

We analysed our interview transcripts using thematic analysis [10] with all interviews being transcribed by the third author. Codes were generated by the first author using a data-driven approach then collated and collapsed. All authors then reviewed the final coding and identified similarities to allow thematic grouping by creating an initial thematic map. We did not conduct inter-rater reliability because it is not part of Braun and Clarke's checklist for good thematic analysis [10].

5 INTERVIEW RESULTS

Our thematic analysis identified four themes: 1) Inclusion of content elements is based on visual design and presentation, 2) Motivation for accessible content elements is grounded in awareness of others and self, 3) Implementation of accessible content elements is heterogeneous, and 4) There is a balance between accessibility and visual presentation of content elements.

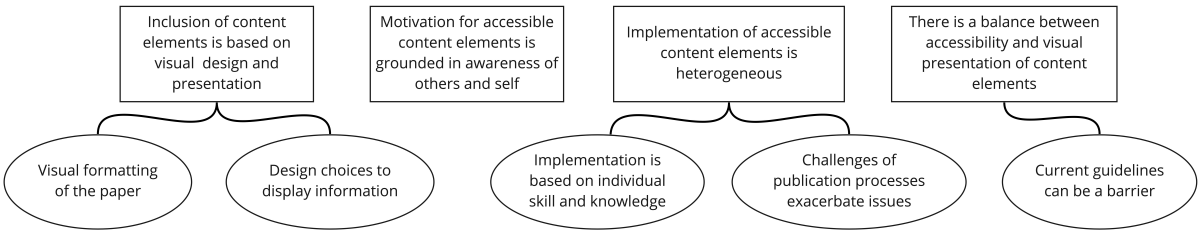

Fig. 5. Final thematic map of four main themes and their sub-themes: 1) Inclusion of content elements is based on visual design and presentation, 2) Motivation for accessible content elements is grounded in awareness of others and self, 3) Implementation of accessible content elements is heterogeneous, and 4) There is a balance between accessibility and visual presentation of content elements.

Unsurprisingly, participants approached paper writing in a variety of ways which reflects the different writing styles within academia. For example, participants made use of their preferred templates at different stages of their writing process, and reported a range of writing strategies, e.g. starting with headings and bullet points or writing linearly from beginning to end of the paper.

5.1 Inclusion of content elements is based on visual design and presentation

The inclusion of content elements within the paper is primarily based on visual design and presentation. The visual aesthetic of papers was important to participants, with some noting the impact of images on the reader and the importance of the visual presentation within the paper. For example, a teaser image was considered to be a key element of the visual presentation of the paper:

P1: *"If you don't have a [teaser] image, they won't read past the abstract and I always thought this was very sad, but it is kind of true."*

However, the emphasis of visual formatting was a concern, due to the additional impact on accessibility:

P6: *"If you distinguish content from presentation, we indulge ourselves in a world that is presentation oriented, and then we have to do all this work to repair the deficiencies of that particular presentation."*

Information was presented in content elements in a variety of ways, e.g. tables for demographics or raw data, figures to show a user journey or to showcase a prototype interface. Overall, there were many positive reasons for including these, such as enhancing the understanding of the paper, particularly for different audiences:

P9: *"We use that visual representation to help non-technical people understand how the data worked in the...algorithms."*

Enhancing this understanding was achieved through adding context in several different ways. For example, our participants discussed how visuals in the form of charts, diagrams, figures, images, and tables. Images can be useful to "*to demonstrate members of the community engaging with technology*" (P12), whereas tables can provide a "*concise and visual way [...] to provide contextualised information on the participants*" (P4), and diagrams to place the work within the context of the author's wider research contributions. This matches our observations when we reflect on our first study evaluating ASSETS proceedings over 10 years. We saw how authors meticulously

annotated photos and screenshots—sometime with intricate detail—while breaking what might be viewed as classic convention to creatively share information albeit at the cost of accessibility (e.g., rather than tables being reserved for reporting basic text and numerical info, we saw complex tables with nested information, colour coding, and even animations that only work if viewed with Adobe Acrobat). Some of this provision of context was considered to be required by "*convention*" (P2) and was "*standard practice*" (P7), which suggests that there are tensions surrounding expected author practice in how to effectively disseminate research in an accessible way and sharing information in creative and immersive ways.

Content elements were considered to be of value to the reader, not only for the content that they provide. For example, P11 commented that they make use of images for *"mixing up the medium a little bit, giving people a break from the text"*.

Despite the ways that the content elements added value, participants agreed that they are supplementary to the textual content and tended to favour sighted readers in particular:

P8: *"Someone with a visual impairment who is using a screen reader would still have access to the data, but, for sighted people, it just adds that little extra bit."*

5.2 Motivations for accessible content elements is grounded in awareness of others and self

Participants have a range of motivations for creating accessible content elements in their papers based on their knowledge and awareness of abilities and disabilities of authors, reviewers and readers. P4 stated that they *"want to reach more people"*, while P10 indicates that accessible papers have wider career benefits:

P10: *"It's also a bit selfish because it increases your citations."*

Initially, participants focus on making their papers accessible for reviewers in order to aid their acceptance for publication.

P7: *"I always like to submit accessible versions for review because I assume that my reviewer is going to be a screen reader user."*

However, this was not always the case for participants at an earlier stage in their careers, with participants becoming more aware of reviewers with disabilities later on:

P4: *"I think it's a huge hindsight of mine that I didn't think about reviewers who might have certain kinds of impairment."*

5.2.1 Reviewers can influence paper content. One prominent discussion around the role of the reviewer was requests from the reviewer for changes to the paper. In one case, a participant was asked to remove external links from their paper, due to concerns about readers not having access to appropriate libraries to access accessible charts online, leading to a conflict between providing alternative formats and readers having access to those alternative formats:

P5: *"I think the reviewer said: [he] would probably remove [links to accessible charts] because, unless you have various packages installed, it doesn't really work, and it could lead to frustration in querying the data and querying the work".*

In contrast, reviewers have also asked for additional content elements to be provided, such as adding tables to show data. Given the anonymity of the review process, there is no way for a reviewer to know whether the submitting author(s) have disabilities, which can lead to tension when these requests are made:

P11: *"Being that I'm blind, I have gotten more than one review saying that maybe I should have more visuals in my papers... which I'm just kind of always annoyed about!"*

Many of our participants were also reviewers for HCI and accessibility conferences and reported a lack of requirements to consider accessibility as a reviewer:

P10: *"There weren't any guidelines to check accessibility, so, I didn't really do it, I was more focused on the content at that point."*

5.2.2 Awareness of the reader can be limited. When considering the abilities of the reader, participants focus mainly on screen reader users, with some consideration of low vision users. There was a consensus that accessibility requirements for screen reader users were relatively simple to achieve. However, participants typically had no method for verifying the accuracy or usefulness of their alt text, even though it may have been developed iteratively over time as the figure was developed:

P9: *"I literally can't remember any discussion about what we would want in the alt text."*

Beyond accessibility for blind and low vision users, this leaves a gap with little consideration of the wider disabled academic community or indeed beyond the academic community.

P6: *"When people say accessibility, they mean accessible to blind readers, and, I'll mention, the main thing that leaves out is a constituency and area that I write for sometimes, and that's people with cognitive limitations."*

P12: *"I think that we often focus on visual disabilities, which I think is really good. I'm also like kind of interested to see how you would make like all of our papers more accessible to a much wider audience beyond the academic community, and also in our end communities, but, also people with disabilities in the academic community."*

5.2.3 People have abilities and disabilities. People with disabilities within the academic community face additional challenges when writing papers and creating accessible content elements (see [15, 30, 68] for a wider reflection on academic challenges). For example, inaccessible tools can delay or stop progress and remove independence for authors. In one case, a blind participant was able to create a diagram using an accessible tool, but was unable to verify the output:

P5: *"The output [from a javascript diagram library] is not accessible, it's an image. But to create them, that's a game changer for me."*

This lived experience was prominent in our participants who self-disclosed a disability, with this affecting how they approached the generation of visual content:

P11: *"My questions about the design tend to be like utilitarian in terms of does it fit the design of the paper, and does it communicate the message that we're hoping to communicate, but as far as like the lower-level intricacies of font and spacing and style, I probably don't know. No clue."*

In addition to being aware of this varied approach in light of their own disability, P11 also noted the need to foster an awareness of the wider needs of co-authors or readers, and considering what accessibility might mean for them.

P11: *"Now I'm thinking a little bit more about like, how do I work with difference? Instead of just saying this is what I need, like, how do I think about, like, what do other people need as well?"*

This awareness of others was reported more generally when participants reflected on working with authors with disabilities and the benefits that interactions brings to them when creating accessible content.

P8: *"As I started being around more researchers within accessibility, it really kind of helped establish empathy and understanding why it's important, and I think that's a big motivator for doing it now."*

5.2.4 Senior academics have responsibility for creating an accessibility ethos. Reflections of the participants show a clear desire for an accessible ethos within research to drive change. We found that more established researchers were confident to speak out about issues related to accessibility, even if they do not have much local support or resources. This contrasts with the experience of early career researchers who lack confidence to lead on matters of accessibility and look to more senior colleagues to address systemic issues.

P10: *"I don't think I've got the confidence to do that ... I think that would be more for senior academics to raise [a lack of accessibility review requirements] ... I wouldn't stand up at a conference and say that you should consider accessibility."*

More broadly, participants reflected on who had responsibility for accessibility and the role of universities in this infrastructure. This reflects various levels of support and education for authors.

P4: *I would really love for the supervisor, for the Department, and even for the University as a whole, to put accessibility education in the curriculum.*

5.3 The implementation of accessible content elements is heterogeneous

5.3.1 Implementation is based on individual skill and knowledge. We found that authors considered accessibility at different stages of the writing process. Participant discussions around this topic highlighted focusing on accessibility early: *"Accessibility is front and centre from the beginning"* (P7) and this could be motivated by the desire to avoid challenges of implementation later on:

P5: "*It doesn't matter whether it's a document or website to retrofit. Accessibility is actually harder than baking it into being.*"

In other cases, our participants took a more iterative approach to including accessibility in the writing process (i.e., accessibility is going to be revisited throughout):

P12: "*We normally write the paper in LaTeX, so what we normally do is we—as we add an image into the paper—we write an alt text caption for it, which kind of gets iterated as part of the process [...] but normally it's done kind of as we iterate the paper, so, if we change, perhaps the caption of the figure, we will update the alt text. Or, if we change some wording, or whatever it is, we'll keep the alt text kind of in the loop.*"

However, accessibility is part of the "*last step*" (P4) in the process, and this could be "*because it's just complicated*" (P1) to do it any earlier than when making the final PDF. Consideration of the type of content to include in a paper would be prioritised.

Our participants explained how they would collate accessibility resources to supplement their writing process with additional support. For example, bookmarking resources for future use (P4) and backing up of conference writing guides such as SIGACCESS in the event the website becomes unavailable (P10), although the saved resources may end up being infrequently used (P2).

We also found that the participants had different opinions on who is responsible for accessibility. One perspective was that the lead author was responsible:

P13: "*Usually, we make a rule that I think 2 hours or 3 hours before that deadline we make a final accessibility check so that we could make it everything fine, so that responsibility goes to the main author of the paper, so [the person] who is leading the writing process.*"

However, there are many factors making this a more complicated situation. Others on the project have a responsibility to check, but after the author responsible for including that content in the paper (P8). A research team may need to share responsibility, but this is not necessarily evenly distributed on account of authors having varied skills and abilities. For example:

P9: "*In my team its normally [name], he knows more about the technical aspects of accessibility.*"

There was also additional pressure put on disabled authors in maintaining their integrity with advocating for and producing accessible papers:

P11 "*It's not something I always do as well as I want, and that is, that's really upsetting to me, particularly on the collaborations when I'm not the leader and then I see something go out into the world and I'm like 'that wasn't accessible like now that has my name on it you need to fix that right now.'*"

With deeper reflections on who is responsible, some participants raised the question of whether responsibility falls outside of the research team and onto universities or even the publisher. For example:

P6: "*I left the consideration of things like alt text... I'm embarrassed to say that I haven't checked to see how inclusive or accessible the finished book is. I kind of left that to the publisher and figured that they would have some sort of process for that, and I now think that maybe they didn't.*"

P07: "*I would say first the author themselves, and 2nd, do you wanna extend the University who is sponsoring this author? Because the University, you know it's the prestige of the University. So, the University, it's on the, on their best interests for the works to be accessible. I wonder the publishers. Ah, I would say yes. They are also responsible, and as I was telling you earlier, it's very disappointing to me to see that even if I send them an accessible PDF, they butcher my accessibility features in the, in the final published version. So I'd say the three of them are are responsible, to different degree of course.*"

There needs to be more support built into the whole publication process so that paper accessibility is also taken on by the publisher and does not end with the authors.

5.3.2 Challenges of publication processes exacerbate issues. The publication pipeline can be a factor that introduces challenges such as the requirements for the final format of the paper. Since proprietary software (Adobe Acrobat) is required to create accessible PDF documents, this can lead to inaccessibility and inequality, e.g. participants noted that "*the PDF editor from Adobe is expensive*" (P3). Indeed, some participants were forced to share licenses or download repeated free trials to access it, which can add stress to the final stages of the publication process:

P10: "*Our university doesn't have a licence for Adobe... Every time that I've needed it, I've downloaded free trials essentially on different laptops, which is a bit of a pain because I'm running out of laptops to download free trials on... Even my supervisor got a discounted licence for it, he's only got 2 licences and he's got a group of 7 or 8 PhD students. We have to switch the licence between us all, so, sometimes we don't have access to that software.*"

The PDF format itself was viewed as problematic, with repeated efforts needed ensure the accessibility of content elements:

P7: "*I am disheartened to see that we still rely on PDFs. And to see that even if I craft an accessible PDF, a lot of the times when it goes to copy editing the alt-text or the images is not, is not there once the final version makes it to the to the ACM Digital Library. I'm happier now that there's a bigger push for HTML versions.*"

Although, P7's comment positively viewed the publisher's openness for alternative formats, there is still an issue whereby the steps in the process from the publisher side is undoing authors' accessibility work. This had led to a lack in trust that the publishers will honour the accessibility efforts of the authors or even identify issues (e.g., P1: "*I think the last version didn't have alt-text because I had sent it before and just forgot about it.*").

Many tools are used to support the paper writing process, but, unfortunately, those tools can result in inaccessibility:

P5: "*The facility to actually navigate charts again in raw Excel, you can get some information from a chart, but to actually embed that in a Word document is not something I've had much success with. I've tried.*"

In addition to issues within tools an author may chose to use themselves, part of the publication process can dictate what tools need to be used when writing a paper:

P4: "*It is much easier to create accessible document from HTML based document than from word because you don't know what's happening in the automated process, but, with overleaf, it's easier to control the process.*"

5.4 There is a balance between accessibility and visual presentation of content elements

A key consideration shared by participants was the balance between including images to aid in comprehension and how they are also avoided due to accessibility constraints. Participants described that for *"empirical research*

I tend not to use that many pictures because it is... such an accessibility nightmare" (P1), and the recognition that *"textual presentation of ideas is more inclusive"* (P6). Participants also noted situations where they would *"keep the images to the minimum because of issues with screen readers"* (P7) and that there are times where they *"can't see how to do proper captions"* (P1) with the result being the removal of content elements, despite their inherent value.

One of the main constraints of this process is related to *"the hours it takes to actually check through [element accessibility]"* (P9). Participants also discussed the time constraints present in learning how to make use of tools and techniques that would assist in making accessible content elements:

P11: *"It takes a long time to develop knowledge that's beyond checklists."*

As an example, learning to effectively use screen reader software was discussed by participants to be a key skill in ensuring accessibility, however some participants noted that *"I just have never had the time to learn it"* (P12).

A further consideration on the inclusion of content elements within academic work is related to space constraints, which is something we observed when reviewing the collection of ASSETS papers. When publications have a strict page limit this impacts on the number of visuals that authors can include. Participants discussed this aspect and while they may have *"wanted to include more"* (P2), this may not be possible as content elements may take up *"too much space and conveys too few, too little information"* (P4), for example:

P12: *"In the old days of the old templates where they had to be a finite size, I found myself kind of squishing stuff onto a page to simply meet the page limit."*

Conversely, non-textual elements can also be used to save space within a paper where *"sharing that through text form like through a paragraph or something is really verbose"* (P8). Our participants mentioned that aspects such as participant background tables are *"the most concise and visual way to put together [participant data]"* (P4).

Our participants commented that images inside of academic work *"takes up a lot of space"* (P9) and that there is often a compromise required when there is a page limit. This was particularly true for qualitative work, meaning that some contextual information presented in the content elements cannot be provided in the most appropriate or accessible way.

P10: *I had to severely reduce the image size just because I would have been over the page by a couple of lines.*

Participants commented that when including content elements in academic work it is important to create a direct link between the elements that are included and the main body of the text. It is important to ensure that there is a *"a relationship between the first mention of the image and the image itself"* (P7) and to also *"add explanatory text in the surrounding paragraphs"* (P5) in order to give context to images.

When designing the elements themselves, participants discussed multiple reasons for design choices, with factors such as colour schemes being used because they are *"the default for Excel"* (P8), elements being *"visible in grayscale"* (P7), and also in giving *"a nod"* (P1) to methodological roots within colour choice. Participants also discussed imaging editing techniques, such as *"removing backgrounds"* (P12), *"image scaling"* (P10), and making sure an *"image is grayscale"* (P7) all being used.

5.4.1 Current guidelines can be barriers. Many guidelines and processes exist that have the end goal of improving accessibility within the academic publication process. Our participants showed an awareness of these and discussed versions such as the *"ACM guidelines on how to write accessible papers"* (P7), WC3 Web Guidelines as *"the go to"* (P8) reference, and venue specific guidance for *"venues like CHI and ASSETS"* (P11). However, participants had varied opinions about their expectations of accessibility guidance. P2 commented that they *"have lots of questions [but]...no answers like how to do that"*, with this sentiment echoed by others:

P4: "*I can't really comment on the CHI guideline because I don't know what a perfectly accessible paper would look like at that time. So, if I, if there is a good example that maybe we could see the discrepancy, but then again [it] goes back to the general awareness and education.*"

P7: "*I feel like they could give practical tips with screenshots, and giving you step by step instructions on how to do this, instead of just giving you like guidelines.*"

Overall, *"more systematic best practice"* (P4) is required and *"video resources on how to actually do these things"* (P7), may be beneficial.

Our participants also commented that there are a variety of tools that assist in improving document accessibility that are available as part of the writing process with this ranging from the *"accessibility validation of Microsoft Office"* (P3), to *"Adobe Acrobat to make a PDF accessible"* (P7). However, participants voiced heavy concerns about the tools themselves as *"tagging a PDF is actually an inaccessible process as a blind person"* (P5). When accessibility features are stripped out of a PDF as part of the publication pipeline, participants discussed that they *"can't go and remedy that because the tools are not accessible"* (P11). Participants also commented that the use of tools themselves requires skill and that sometimes it can be challenging to determine if a process has been successful:

P12: *"When I upload a paper, it's kind of made accessible by me or by my colleagues, but I'm never convinced that a person with a screen reader can access it because I've been shown in Adobe in a really visual way, with all the little blue boxes, and all the reading order stuff, but I'm not fully convinced that when it ends up on somebody's screen reader they're actually going to be reading it the way I want them to."*

6 DISCUSSION

***RQ:* What challenges exist when implementing accessible content within academic writing?**

Creating accessible publications is central in enabling access to scientific work for all people. However, the complexity required to illustrate certain aspects of our work creates challenging accessibility problems that authors must understand. Our interviews highlighted that authors carry out a balancing act between presenting information visually and making sure that this information is accessible. We also highlighted that creating accessible content elements is a multi-faceted issue that involves considering all accessibility domains. Finally, our participants discussed the challenges they have faced in implementing accessible figures, describing the specific skills and guidance required on many granular levels. We discuss these points below.

6.1 Balancing Accessibility and Visual Design

Authors consider the inclusion of graphical content as a core part of the academic paper writing process. Our initial quantification of content elements coded 3866 content elements within 330 papers. Images were the most common type of element that was used. Implementing accessibility within paper writing does not necessarily mean that no graphical content is included, and our interviews were designed to understand the process that authors go through when creating papers and making content accessible.

Our participants described that content elements are used within their work in order to provide a broader understanding of their work, but that they can also face challenges in presenting this in an accessible way, which supports the observations we made of the many different inaccessible content elements. Contemporary guidance on creating charts suggest that they should tell a specific story and assist in leading the reader to an intended understanding [78]. As a contrast, alternative text for charts remove this step of reader-led understanding and presents raw data in a form that is challenging to draw conclusions from [31]. In short, the visual representation of figures is often different from its accessible description.

A further challenge exists in interpreting the formatting guidelines that are attached to presenting work at academic venues. It is still common to see fixed page limits for conference venues, and for paper style guides to be viewed as compulsory (example style guides packaged as templates can be accessed at www.acm.org/publications/proceedings-template). Style guides can create friction between creating a final paper that is visually pleasant and functionally accessible, with a preference directed towards the former.

Participants described that content elements are mostly used as supplemental content in their work and can be used to present existing information in an alternative format. The decisions made by participants in how to include content elements within their paper are varied, and are seen elsewhere in the literature [55], e.g. personal preferences and time pressures played a key role. Ensuring that the PDF is accessible is generally thought of as a last step in the paper writing process and is considered very close to paper submission. This approach is very similar to that of waterfall software development life cycle [63], with accessibility seen as a final process that must be implemented without altering the visual presentation of the work. We suggest that an iterative and incremental approach [37] to accessibility throughout the paper writing process would be beneficial and is something that should be embraced and more readily facilitated.

6.2 Accessibility is Multi-Faceted

Accessibility is often viewed as a niche research domain [61], but it is one that contains a complex mix of areas that can intersect with each other. The resultant complexity makes it challenging to develop broad expertise in how to create fully accessible artefacts. Common techniques that are used to develop an awareness of accessibility challenges involve education, empathising with others, and personal experience [14]. These methods, whilst beneficial, individually require experience in order for them to be of value.

Our participants commented that having general accessibility knowledge when creating academic papers is important for all members of the research team. They added that it is also important for team members to have more specific areas of expertise with this being related to either individual accessibility areas or individual aspects of papers. Our participants gave examples of team members splitting up responsibility for the implementation of accessibility for different parts of their publications based on team member experience, expertise in a given area, and also as a method to provide training to new members.

In carrying out this work, we acknowledge that the challenges that our participants highlighted when creating accessible academic documents is very similar in nature to the challenges that are faced by the software development community as a whole [14]. While it is unsurprising that this may be the case, it highlights a systemic issue in accessibility training within the very broad computing domain.

6.3 Creating Accessible Content

It is not enough for academics to understand the specific accessibility challenges that can arise when creating publishable material. There is also a need to understand how these challenges can be overcome and what techniques and skills are required in order to achieve this. Common methods that are used include altering (e.g. colour palette changes), and adding content (e.g. alt-text, descriptive labels).

Our participants commented on the technical challenges that are associated with creating accessible elements within academic work. They discussed that available guidance for creating accessible elements can be challenging as advice is often offered at a very high level. Our participants' overall opinions on implementing this guidance was mixed. Participants commented that implementing screen reader accessibility can be simple to achieve, but the simplicity of this process is directly linked to the overall complexity of the paper that is being created.

We want to reiterate that our current work is focusing more broadly on the visual accessibility of content elements that appear in a paper and the overall paper pipeline from initial project idea to publication, rather than on PDF accessibility for screen readers, which prior work has demonstrated is a significant issue [7, 9, 80]. However, it is worth reflecting on the tools that are used to write academic papers and the effects this can have on the final PDF accessibility, since there are parallels with our findings for the challenges of creating accessible content for paper in terms of resources available. It is generally accepted that using Microsoft Word is a better starting point than using LaTeX if the intended outcome is to produce an accessible PDF. Microsoft Word and LaTeX both support necessary features for screen reader users such as a defined heading structures, but Microsoft

Word seems to succeed more at producing PDFs that preserve accessibility without the need to make refinements with additional software like Adobe Acrobat Pro. Furthermore, Microsoft Word is likely to be more readily available to authors than Adobe Acrobat Pro, even though both require a licence[13], and Microsoft Word requires less digital literacy than using the tagging features offered by Adobe Acrobat Pro, which is temperamental and can be used incorrectly if the user is not knowledgeable about best practice for tagging PDFs.

However, screen reader accessibility is only one part of the process that is required in making an accessible paper, and our participants discussed challenges in making content accessible outside of this. Participants described that advice may be more beneficial if it was offered at a more granular level, which would be better suited to the unique nature of individual figures within a paper. Our participants also commented that the challenges in creating accessible elements is compounded due to accessibility being seen as the *last step* in the paper development process. Placing accessibility as the final element in creating an academic publication creates similar challenges as those faced within the waterfall approach of software development, and any issues that are found are likely only going to be remedied by small alterations due to the larger cost involve for significant fixes.

6.4 Recommendations

Our participants have experience creating accessible HCI papers, yet still face challenges. These challenges can be even more difficult for those with less experience. We make recommendations across the publishing infrastructure to support accessible publications, which are mapped to an example publication timeline in Figure 6. These recommendations serve as a call to action to individuals within the accessibility community and beyond. We have not prioritised these actions since they are intricately linked to the skills and expertise from within the community. We envision that many of these actions can be completed concurrently. Further, the papers we reviewed were very varied in their inclusion of different categories of content elements, e.g. tables or images, and so action across the board is imperative to ensure that this complex issue is addressed efficiently in future research.

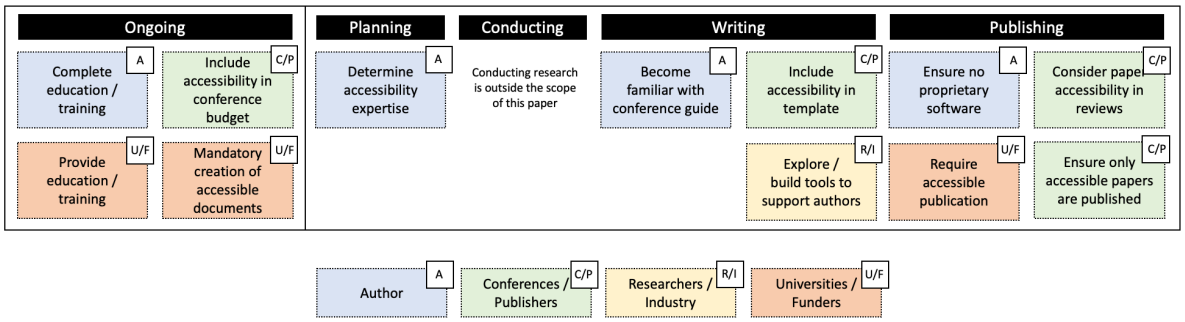

Fig. 6. Diagram showing the ongoing recommendations and those mapped to the four parts of the research process toward publication: 1) Planning; 2) Conducting; 3) Writing; and 4) Publishing.

6.4.1 Authors: Authors should identify expertise and knowledge gaps within the research team and then familiarise themselves with addressing access needs for different types of disabilities beyond their research area (e.g., cognitive, vision, etc). This is best achieved through education and familiarisation with conference guides[14].

[13] Adobe Acrobat's accessibility features are only available through purchasing a pro licence.

[14] For example the Accessibility guide for CHI 2021: https://chi2021.acm.org/for-authors/presenting/papers/guide-to-an-accessible-submission

Despite the availability of such guides for many conferences, there is a lack of accessibility in submitted papers, with authors having different knowledge and skills. For example, in our work, an awareness of screen reader users was prominent and correlates with a high instance of our papers being on vision impairment accessibility, but there was less reflection of wider accessibility considerations, such as for readers with cognitive disabilities. A reduced awareness of broader best practice was noted, with our participants tending to be knowledgeable within their own field of expertise and being more likely to have gaps in other areas. There was an expectation that authors within accessibility conferences should be leading in the creation of accessible papers, but, given the immaturity of creating accessible documents as a digital literacy skill, it may be the case that authors currently do not have sufficient skills and knowledge to do this.

The accessibility often discussed by our participants was the accessibility of the final PDF, with tagging often being seen as a required additional layer to create an accessible document. Less was discussed around ensuring that the content is accessible, e.g. by selecting appropriate colours and font size. This is concerning as it can perpetuate the myth that accessibility is for screen reader users only. Therefore, we recommend that authors engage with digital skills training to generate accessible content and presentation of visual Figures in their papers.

Finally, authors should ensure that their paper content does not require proprietary software, e.g. accessing animations using Adobe Acrobat only.

6.4.2 Conferences/Publishers: Conferences should ensure that only accessible papers are published by adding an additional layer of reviewer accountability. Reviewing relies heavily on community volunteering and, currently, although there is typically no requirement to consider the accessibility of submitted papers, some reviewers do consider this due to lived experience or personal expertise. However, we can reduce reliance on reviewers identifying issues by providing more support to authors so that they can address access needs before submission. Conferences should also ensure that any expenses relating to accessibility of the papers is included in budgets in order to engage relevant experts where required.

We recommend that the publishers enforce the exclusion of inaccessible content during the publication process. User-generated content elements are a common source of inaccessibility in research papers (e.g., inaccessible colours in charts), which would ideally be addressed by including accessibility in the review process. However, this depends on the reviewer having appropriate expertise to make recommendations and so a responsible publisher should make their own checks on content. With this in mind, there are remaining questions surrounding who will make decisions not to publish papers on the basis of inaccessibility, which may need to be addressed on a per-conference basis.

To support authors, publishers (and by extension conferences) should reflect on their guidelines to ensure they are comprehensive and easily discoverable with clear examples of good practice for different content elements and access needs (e.g., a set of exemplar accessible papers). This ensures that authors can address access needs for different types of disabilities and will reduce issues to be considered by reviewers and publishers. It is particularly important to ensure that such guidance is visible for new community members to encourage early adoption of best practice.

We commend the work currently being conducted to include accessibility in the ACM template and we advocate for continuing to ensure that accessibility is considered. Work on including the use of the Templates AND Publication Workflow[15] within the ACM is a positive move, as it is a step towards all user-generated content being available to users across as many platforms as possible in order to increase the likelihood of it being accessible.

6.4.3 Researchers/Industry: Researchers and industry organisations should take on the challenge to build new tools to best support authors (including authors with disabilities) during writing/publication processes to make

[15]https://www.acm.org/publications/taps/word-template-workflow

accessible content. Our suggestion is inline with a recent call to action to create inclusive data visualisations [44]. While there is no singular source of information on accessibility that is used by all [14], there is an appreciation of guidelines and tools that can support authors. However, there is often a gulf between these guides and the practical implementation. In addition, guidelines that are commonly cited as being important in developing accessibility (i.e. WCAG) can be challenging to implement [72] and this in turn can lead to reductions in accessibility.

Currently researchers use a variety of authoring tools such as MS Word and LaTeX to write papers, the selection of which is often based on the author's own preference, expertise and familiarity with the different tools. Specific tools that generate accessible content should be explored and used more widely within the researcher community, reducing the stress on authors working to an often tight deadline. For example, Morash et al. [48] and Mack et al. [42] have both developed tools to support making appropriate image descriptions for different types of content elements and Ferres et al. [22] developed a tool for improving accessibility of charts and graphs. We also want to highlight the very recent work by Elavsky et al. [20], which was published around the time our paper was accepted for publication. Elavsky et al. introduces Chartability—a set of heuristics to support the evaluation of a visualisation's accessibility. We are excited by the prospect of Chartability and it is a resource that would have helped us conduct an accessibility audit of the content elements we quantified since there was a lack of synthesised knowledge on how best to assess the accessibility of visualisations at the time we collected data (Section 3). We encourage authors to consult Chartability to support the inclusion of accessible visualisations in academic papers.

Care should also be taken in making sure any future tools are designed to be accessible. Our participants with disabilities highlighted the challenges using certain tools for creating content elements, which corroborates findings and recommendations from earlier work on writing practices [15, 79]. Elavsky et al. [20] also highlighted this concern from the perspective of auditors with disabilities—although we talk about authors creating content for papers, authors also take on the role of auditors when reviewing and editing their own papers for improved clarity and (hopefully) accessibility. The ethos of user-centered development is common within the accessibility community and should be utilised here, to ensure that the development of new tools is author-led. Our work provides a quantitative summary of the popularity of content elements used in ASSETS papers, which can inform where we should focus on creating new types of accessibility tools for academic publishing, as well as qualitative insights into the accessible paper writing experience.

6.4.4 Universities/Funders: Universities can and should do more to support and encourage authors to make work accessible. A positive culture of accessibility within universities is becoming more prominent and we encourage the continuation of such initiatives. We urge universities to implement mandatory training in accessibility for students and researchers, with a hope that this would encourage an increased understanding of accessibility issues and the challenges that they can create when developing academic papers.

We also recommend that accessible documents within these institutions should be mandatory (although this may be a legislative requirement, it is not typically enforced), e.g. for a student submitting a PhD thesis or for an academic policy document.

In the same way that funders stipulate or encourage open data repositories and open access publishing, we recommend similar requests for accessible publications. Although this does not solve the issue of implementing accessibility, funders may be able to provide additional resources for training and support to a wide range of researchers across many disciplines.

6.5 Limitations and Future Work

Each author we interviewed has experience of publishing papers on accessibility (and HCI), but has individual expertise within the field of accessibility (e.g. a focus on blind users, or quantitative methods). As a result, they

may inadvertently include accessibility barriers where they have less knowledge. This may also be the case for our paper, but with multiple authors the likelihood of this is reduced.

Our work has uncovered issues within the HCI academic publishing process that has resulted in accessibility barriers. While conducting this work, we had many discussions about the content elements that we would include in this paper (i.e., tables, charts, figures). These discussions on how best to create them were not straightforward, and we expect many—if not all—of the papers we analysed that include content elements involved similar in-depth discussions. However, those discussions and the final decision are ultimately never stated in the final outcome.

We did not gather demographics in order to protect the anonymity of our participants within the small accessibility community. Participants were not asked to disclose if they had a disability during the interview. However, some participants openly shared this information to give additional context to their experience in the paper writing process.

While our participants have focused on publishing at HCI and accessibility-related conferences, we expect that journal publications would result in similar challenges, e.g. the use of templates, the creation of accessible charts, requiring proprietary software), as well as other research topics not related to accessibility. We have already shown that there are similarities in the types of content elements presented between our paper and those in computing science education [69]. We propose exploring this further with authors who have less experience of creating accessible content in order to further examine the potential for education, new tools and processes to support the generation of accessible content more broadly. This will be applicable across ACM publications and beyond.

In our paper, we focused on the development of accessible PDF papers. PDFs remain the most convenient method for sharing the detailed insights outside of an academic community. For instance, although the HTML versions of papers are very accessible, they are behind a paywall and authors typically do not have an HTML manuscript that they can share. However, there are many other ways in which the HCI community can disseminate work, such as presentations. This can have implications for the detail conveyed (e.g. presentations are typically a summary of the key points made) as well as the accessibility aspects of presentations (e.g. ensuring that visual content elements are accessible, the onus on the presenter to ensure that all necessary visual information is conveyed). Future work could explore the accessibility of different types of dissemination.

We uncovered a number of instances where authors with disabilities have had to rely on others to complete tasks necessary for publication, such as creating diagrams, selecting figures and ensuring that the PDF submission is accessible. This should be explored further to identify key areas of support for authors with disabilities and to examine the independence of disabled authors.

7 AUTHOR REFLECTIONS ON THIS PAPER

We have had many interesting discussions on the topic of accessibility while completing this work and writing this paper. In this section, we reflect on some key discussions that we had as authors.

7.1 Author Expertise

Although we have experience in various accessibility research areas (e.g. autism, vision impairments, hearing impairments) we do not have lived experience of disabilities.

Our expertise is built on 33 combined years of conducting accessibility research, submitting papers to accessibility venues, reviewing work by other authors as a part of the publication process, taking on accessibility leadership positions within ACM Special Interest Groups, by attending accessible conferences, and working in institutions that have a research focus in accessibility.

We look at these experiences as assisting in helping us to develop an understanding of the accessibility challenges that appear within the creation of academic work. The requirements of submitting accessible papers

have greatly influenced the development of our skills more than we might have expected. For example, we would typically provide documents in Word format (or some other markup) to aid accessibility, but have learned new skills in PDF accessibility through the submission process of this and other papers. However, we continue to learn everyday and sometimes make accessibility mistakes in our papers that we do not realise until pointed out to us.

7.2 Presentation of Data

Many of our conversations have related to the presentation of data, with this likely due to the amount of time spent analysing data points in our review of ASSETS papers. We debated for a long time over whether to present the data in Table 1 as a table or as a series of charts. We created sample charts using tools such as Microsoft PowerPoint and Google Sheets to explore the data and review the different ways that we could present different sections of the data.

We settled on a table for two main reasons. First, the number of papers each year varies and so we determined that a data table allowed readers to explore the data in a more meaningful way with the number of papers available as a comparison. Second, we have recorded the total frequency of many categories. Even if we normalized this data against the number of papers each year, we would need to create a series of charts to display this information. We balanced—as our participants also reported—visual design and the space required for the presentation of visual elements. We decided that including many charts would be distracting for the reader and not be the best use of space within the paper.

However, readers may notice that even Table 1 is supplemented by additional tables placed in Appendix B. Our initial paper submission to TACCESS included a much more complex table (effectively a single table with all data that is currently represented across Tables 1, 3, 4, 5, and 6).

Our initial decision to include a more granular data table, as opposed to a series of figures, is indicative of the conflict that can exist between the visual ease that figures create and the accessibility of a paper. This is a critical instance where the complexity of the data presented demonstrates why a table is the preferred option. Yet, reviewer feedback pointed out the table was not screen reader accessible, and we realised that this occurred due to including a mixture of cells with vertical and horizontal text to fit the paper size (see section 7.3.2). Ultimately, we decided it was best to simplify the table for improved accessibility by representing a slightly higher-level overview of our findings, while giving readers the opportunity to access more specific detail at the end of the paper.

We did create some charts to support our discussion around the presentation of data. The chart in Figure 7 is an example of a simple chart, which shows the same summary data as Table 1. However, this did not show normalised data, since it does not take into account the increasing number of papers accepted to the conference each year. This contributed to our decision to include all data in a table, since we were then able to present both the year and the number of papers published in that year.

We also explored more granular data in the form of a chart, with Figure 8 showing the frequency of each type of chart within the papers. In the end, we decided that sharing all of the data in a series of charts would be also too complex: the volume of data points and number of categories in Figure 8 would make it challenging for the reader to identify any trends or data points with sufficient clarity. We spent a long time exploring different options to improve the accessibility of the more complex charts, such as Figure 8 which has seven categories of chart type within. We actively avoided using colour to distinguish between lines because that would be inaccessible for some readers, and instead focused on different line styles. However, the chart very quickly became complex, and Google Sheets only has six line styles when we have seven data lines. We could not easily add the labels in Google Sheets itself, and so we used additional software to annotate our chart. We added labels on both sides of the trend lines to assist the reader.

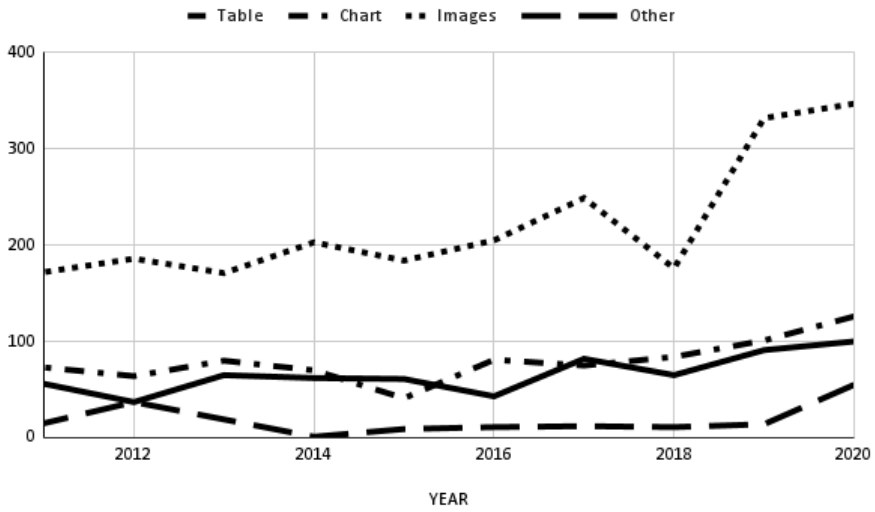

Fig. 7. Line chart showing the frequency of each broad-category of content element identified in proceedings from 2011 to 2020

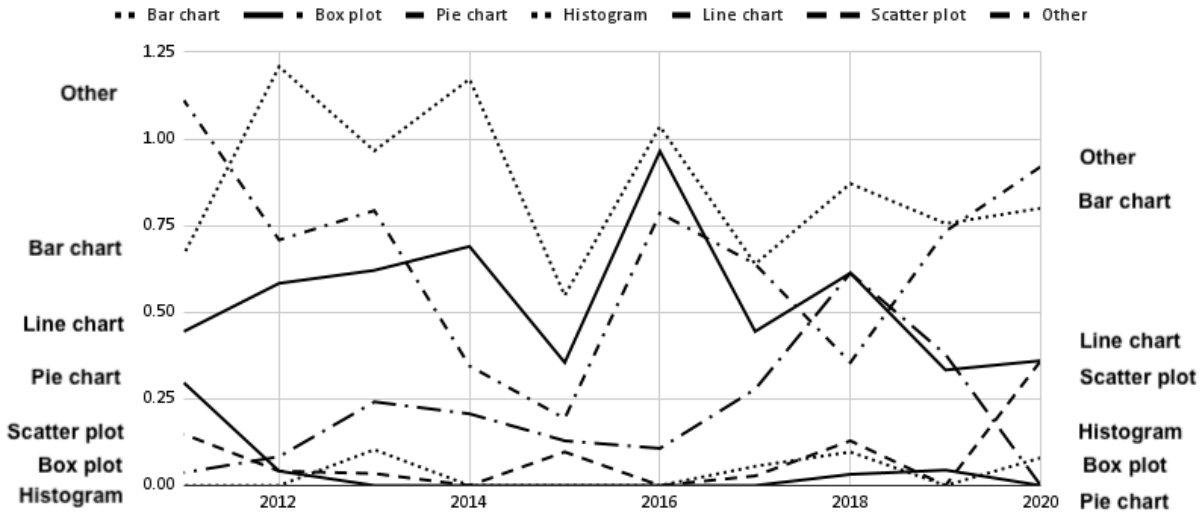

Fig. 8. Line chart showing the frequency of each chart category of visual element identified in proceedings from 2011 to 2020

7.3 PDF Accessibility

7.3.1 Displaying Data as a Table. Like many of our participants, we experienced a number of challenges when ensuring that our final submission was accessible. Although we ensured that we used appropriate markup within

LaTeX, the final step of tagging the PDF document was time-consuming. Some elements required additional research as we attempted to complete the tagging process and given the irregularity of the activity we had to refresh some knowledge by reviewing the materials available on the ACM website. To our frustration, we then identified some errors in our paper and had to re-complete the tagging process before we were able to submit the paper.

Despite submitting an accessible PDF, the addition of an extra rendering piece of software on submission, either to add on front matter or to add in additional venue information, can impact overall document accessibility. This can add additional pages to a publication that are untagged (e.g., the TACCESS submission portal adds an untagged summary page to the beginning of a submitted paper) or even remove all previously curated tags from a document. In our case, the previously curated tags were not removed, but reviewers did identify some inaccessible elements within our paper, despite our best efforts to ensure accessibility.

Table 1 was the source of much discussion between us during the writing process. Once we had agreed to display the data as a table, we uncovered a number of other challenges in our visual presentation. In our initial submission, we used thick lines in the table, which led to some gaps with white space around where these lines should cross. It seems that Adobe Acrobat did not tag the table, and this was picked up in the review process. We suspect that Adobe Acrobat uses shape recognition to identify the structure of a table, and the gaps in our table meant that the table structure could not be identified. Adobe Acrobat will sometimes display an error message when trying to tag the table. The message reads: "*Unknown table structure encountered. Please retag this table using the Reading Order Tool to possibly fix the problem*". Using the reading order tool still could not overcome the issue because the software could not recognise the basic elements of the table. We now use tables where each cell is enclosed in a complete border, and, after this change, we found that Adobe Acrobat no longer had issues in allowing us to tag the table correctly.

7.3.2 Page Size and Orientation. We were also challenged by the constraint of the page size. This meant that we would need to reduce the font size to accommodate a large table in portrait format if we were to avoid dividing the data across multiple tables or pages. For our initial submission, we tried heading cells with text displayed in a vertical arrangement to reduce table width. Again, this was a strategy employed to ensure that the table could fit in portrait width.

We considered displaying the table in landscape format, since this would have made it easier to accommodate all the cells within. However, we were unsure as to whether we could submit a paper where one page was in landscape and the rest portrait. Our alternative consideration was to keep the page portrait and instead rotated the table, but we were unsure whether this would be disruptive for readers who were relying on the visual representation of the table, as well as uncertainty on screen reader accessibility. We finally opted to include one overview table in the main body of the paper and additional tables as an appendix. We acknowledge this removes the data from the place where it is most useful (i.e., in close proximity to the related narrative), but we hope the inclusion of an overview table is enough and readers who wish to can still access more information.

7.3.3 Figures. Our reviewers suggested checking our figures' accessibility more closely. When we reviewed these figures, we identified that we had used PDF to insert these within our LaTeX document in an attempt to ensure better presentation and resolution for zooming. However, we have now learned that when tagging such images as a *Figure with Caption*, any text within the image confuses the system. Adobe Acrobat Pro expects a clear separation of an image and then text for the caption. we did encounter issues with tagging these figures which often resulted in the figure moving on the page or being positioned behind other text. We had inadvertently created some inaccessibility in our document by using PDF figures. All figures have been input as *.png* files in our final submission.

8 CONCLUSION

Content elements are commonly used to assist the reader in understanding different aspects of work reported in academic papers, but can often be inaccessible. Although prior research has investigated inaccessible papers and the implications for readers (e.g., screen reader users accessing PDFs), we focused on understanding the challenges authors experience when producing academic papers. In our analysis of 330 ASSETS papers published between 2011-2020, we identified an extensive range of content elements used by authors in their papers. We used this information to facilitate interviews with 13 academic authors to explore how these content elements are designed and implemented with the assumption they should be accessible. We found creating accessible content elements is a multi-faceted issue that involves consideration of all accessibility domains, but authors often do not have the specific expertise required. Implementing accessible content elements requires specific knowledge and skills, with guidance required on many granular levels. Our paper is a call to action for paper authors, conference organisers, publishers, researchers, industry partners, universities and funders. Future work should prioritise our recommendations and implement them in collaboration across the publishing pipeline.

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A CODING SCHEME

B ADDITIONAL DATA TABLES

Table 2. The coding scheme used during our analysis of the papers.

Category	Code	Description
Table	1. Basic Table	The display of numbers and text in rows and columns
Table	2. Other Table	The display of numbers and text in rows and columns including visual elements such as images and animations
Chart	1. Bar Chart	Using bars to present categorical data
Chart	2. Box Plot	Bars used to represent two dimensions of quantitative and categorical data
Chart	3. Pie Chart	A representation of proportional data
Chart	4. Histogram	Using bars to present continuous numerical data
Chart	5. Line Chart	Using a continuous line to represent change in one dimension, e.g. over time
Chart	6. Scatter Plot	Using points to represent two-dimensional data
Chart	7. Other	Any chart not listed above, e.g. radar plot, complex chart with additional dimension
Images	1. Photo of Scene	Representation of a scene taken by a camera
Images	2. Photo of Object	Representation of an object(s) taken by a camera
Images	3. Screenshot	A direct copy of an interface, e.g. screen grab
Images	4. Annotated Photo of Scene	Representation of a scene taken by a camera with additional components such as arrows or labels
Images	5. Annotated Photo of Object	Representation of a object taken by a camera with additional components such as arrows or labels
Images	6. Annotated Screenshot	Direct copy of an interface with additional components such as arrows or labels
Images	7. Drawing	A representation of something, e.g. a sample prototype interface, can be paper-based or digital.
Images	8. Diagram	A simple plan drawn to represent something, usually to explain how it works or how it is put together, e.g. screen flow, schematic, flowchart
Other	1. Pseudocode	Representation of programming language (e.g., for loops, variables) - using other means than displaying code, e.g. flowchart
Other	2. Code	Representation of programming language (e.g., for loops, variables) - actual code
Other	3. Text	Written words presented as a figure
Other	4. Equation	Representation of a mathematical equation presented as a figure

Table 3. Frequency of each category of tables identified by proceedings (number of papers each year).

Papers	Year	Basic Table	Other Table	Total
27	2011	54	2	56
24	2012	37	0	37
29	2013	60	5	65
29	2014	60	2	62
31	2015	58	3	61
28	2016	42	1	43
36	2017	81	1	82
31	2018	64	1	65
45	2019	84	7	91
50	2020	81	19	100
–	**Total**	621	41	662

Table 4. Frequency of each category of charts identified by proceedings (number of papers each year).

Papers	Year	Bar Chart	Box Plot	Pie Chart	Histogram	Line Chart	Scatter Plot	"Other" Chart	Total
27	2011	18	1	8	0	12	4	30	73
24	2012	29	2	1	0	14	1	17	64
29	2013	28	7	0	3	18	1	23	80
29	2014	34	6	0	0	20	0	10	70
31	2015	17	4	0	0	11	3	6	41
28	2016	29	3	0	0	27	0	22	81
36	2017	23	10	0	2	16	1	23	75
31	2018	27	19	1	3	19	4	11	84
45	2019	34	17	2	0	15	0	33	101
50	2020	40	0	0	4	18	18	46	126
–	**Total**	279	69	12	12	170	32	221	795

Table 5. Frequency of each category of images identified by proceedings (number of papers each year).

Papers	Year	Photo Scene	Photo Object	Annotated Photo Scene	Annotated Photo Object	Screenshot	Annotated Screenshot	Drawing	Diagram	Total
27	2011	30	10	15	1	66	3	26	21	172
24	2012	8	1	8	0	74	7	59	29	186
29	2013	24	5	16	2	39	16	21	48	171
29	2014	33	36	19	3	31	22	17	42	203
31	2015	25	28	15	1	55	3	31	26	184
28	2016	53	52	3	2	53	1	10	31	205
36	2017	44	39	18	7	46	8	19	68	249
31	2018	50	29	5	5	40	8	10	29	176
45	2019	86	56	46	14	46	3	10	71	332
50	2020	40	44	11	13	78	10	97	54	347
–	**Total**	393	300	156	48	528	81	300	419	2225

Table 6. Frequency of each category of "other" figures identified by proceedings (number of papers each year).

Papers	Year	Pseudocode	Code	Text	Equation	Total
27	2011	0	0	1	14	15
24	2012	3	13	2	19	37
29	2013	1	1	6	11	19
29	2014	0	0	0	1	1
31	2015	2	1	6	0	9
28	2016	3	0	1	7	11
36	2017	0	0	8	4	12
31	2018	0	0	4	7	11
45	2019	0	1	5	8	14
50	2020	1	1	27	26	55
–	**Total**	10	17	60	97	184