

Technologies, Methods, and Values: Changes in Empirical Research at CSCW 1990 – 2015

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CCS Concepts: • **Human-centered computing** → **HCI theory, concepts and models**;

Additional Key Words and Phrases: systematic review; empirical research;

ACM Reference format:

James R. Wallace, Saba Oji, and Craig Anslow. 2017. Technologies, Methods, and Values: Changes in Empirical Research at CSCW 1990 – 2015. *Proc. ACM Hum.-Comput. Interact.* 1, 2, Article 106 (November 2017), 18 pages. <https://doi.org/10.1145/3134741>

1 INTRODUCTION

Since its inception in the 1980s, the field of Computer-Supported Cooperative Work has sought to understand the broad, diverse, and challenging research questions faced by those seeking to develop, deploy, or use collaborative technologies. Effective support for multiple users, groups, or organizations requires a deep understanding of interactions between technology and complex social, political, and motivational dynamics [27, 28, 31]; complexities that have been described as being “almost insurmountable to meaningful, generalizable analysis and evaluation of groupware” [13, p.97]. In response to these diverse challenges, the field of CSCW has brought together researchers from Computer Science, Psychology, the Social Sciences, and many other disciplines to develop a multi-faceted literature surrounding the use of computer systems across a variety of collaborative settings.

However, over time technological and social aspects of computing have changed dramatically. Lee and Paine [20] note that while early CSCW research was initially defined as focusing on small groups, it now encompasses a spectrum of coordinated activity. Where early literature reviews were concerned with questions such as “How do we evaluate?” [26], often in domains with a focus on co-located collaboration around PCs, it now spans small groups, teams, and organizations distributed globally, interacting through novel, “Post-PC” technologies such as smartphones, tablets, and wearables. As these new technologies have emerged, been adopted, and influenced the way that we collaborate, it is unclear how researchers tackle increasingly complex tasks and user domains, how results are synthesized and extended within the CSCW community, or even whether the types of research contributions valued by the community have changed over time.

To answer these questions, we conducted a systematic review of the ACM Conference on Computer Supported Cooperative Work (CSCW) proceedings spanning 1990 – 2015. Our methodology

This work was supported by the Natural Sciences and Engineering Research Council of Canada.

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2573-0142/2017/11-ART106

<https://doi.org/10.1145/3134741>

builds on two previous reviews [26, 30] to classify the type of research conducted, and the methodologies used by CSCW researchers. Given the introduction and rise of social networking and novel devices such as smartphones, tablets, and wearables, we also extended their analyses to understand how research has responded to these technological trends across the same period.

Our review shows that research methods at CSCW have changed with the emergence of social networking and Post-PC devices over the past decade, but that these changes have *followed*, rather than anticipated technological advances. In particular, CSCW now places most emphasis on research that describes collaborative work environments in practice, as opposed to work that develops novel systems in the laboratory or tests scientific hypotheses. We also note a lack of bibliographic work at the conference, despite continued challenges with fundamental questions, such as how systems should be developed to encourage adoption in practice. Finally, we find that research has predominantly focused on single-device studies, despite the rise of device ecologies at home and in the workplace. In reflecting on our results, we suggest challenges for CSCW research in understanding how to synthesize results across disparate usage contexts, which research contributions are most valued by the field, and how research must adapt in the face of technological change.

2 RESEARCH AT CSCW

Research published at the CSCW conference has often explored complex social and cultural barriers to use of technologies [13] and developed guidance for their development and deployment into the workplace [9]. However as the field has matured, the scope of investigation has expanded from small groups to large, social systems. Similarly, over time underlying technologies have changed, evolving from traditional desktop PCs to mobile, portable, and wearable devices. In characterizing how CSCW has responded to these changes, we leverage two previous reviews of the literature:

2.1 Pinelle and Gutwin (1990 – 1998)

A review of early CSCW conference proceedings spanning 1990 – 1998 conducted by Pinelle and Gutwin [26] primarily focused on how researchers evaluate groupware systems. A theme that pervades the literature review is “How do we evaluate?”, and in particular how to ensure that research systems developed in the lab can be successfully deployed in practice [13]. To understand how the community addressed this question, the review classified the type of evaluation, characteristics of evaluation, data collection techniques, placement of evaluation in the software lifecycle, and evaluation focus of each contribution.

In summarizing their results, Pinelle and Gutwin report an overall need to “focus on conducting these longitudinal studies in a way that is time and cost efficient” (p. 90), citing that nearly 75% of reported evaluations were qualitative in nature, and that only 25% considered the software’s organizational and work impact. This need to refine evaluation methodologies and consider how research prototypes will ultimately influence practice are questions that underlie much of the early CSCW literature. One finding of our review is that the community has responded to these needs, and has moved to perform more field studies, and to more often adopt mixed-methods designs when evaluating technologies.

2.2 Wainer and Barsottini (1998 – 2004)

In 2004, Wainer and Barsottini [30] extended Pinelle and Gutwin’s analysis to include publications from an additional three CSCW conferences. In conducting their review, they refined the classification of evaluation methods and pursued a more quantitative evaluation of CSCW research. This quantitative approach enabled objective comparisons between types of research conducted at CSCW across different years; revealing trends in published research at the conference. Wainer and

Barsottini conclude that in the 1998 – 2004 period CSCW moved to more consistently report on empirical evaluations. They also report a steady growth in the acceptance of Explanatory research that tests scientific hypotheses, and suggest that this trend may indicate a maturing of CSCW as a field. Our review shows a reversal of this trend, and that recent CSCW conferences have been dominated by research that describes work environments or settings where collaboration is important, or the introduction of new tools into such environments.

2.3 The “Post-PC Era” (2006 – 2015)

Since Wainer and Barsottini’s 2004 review, devices such as smartphones and tablets have emerged and encompass a large and growing portion of daily activity, reflected in workplace practices such as Bring-Your-Own-Device. Further, these devices are rapidly approaching the unit sales numbers of traditional desktop and laptop devices [6], and may ultimately replace traditional computing devices in supporting many collaborative activities. Despite these rapid and profound changes in collaborative technologies, few researchers have considered the impact of these changes on published research. For example, Keegan et al. [17] performed a network analysis of CSCW publications and researchers, but did not take into account methodological or technical trends in their analysis. Fitzpatrick and Ellingsen [11] review healthcare research in CSCW, and identified contributions, challenges, and future agendas for the field. However, this research focused on applications to healthcare and does not consider more general trends. Blomberg and Karasti [2] provide an overview of the application of ethnographic methods in the field over the same time period.

Our systematic review provides the first comprehensive review of empirical research at CSCW in more than a decade, and investigates how research at the conference has adapted to the rapidly changing, ‘Post-PC’ landscape. Notably, since the 2004 review two technological trends have been particularly influential for collaborative computing. First, the emergence of cloud computing and social networks means that, increasingly, work performed on a daily basis is done on infrastructure that is inaccessible to end users and researchers alike. Moving this computation to the cloud means that researchers often have limited capability to design new systems, collect data, and test hypotheses than they did in the past. In lay terms, research is often subject to the will of ‘data barons’ [29]. Second, computing hardware has shifted towards vertical integration, and modern ‘smart’ devices often limit the degree to which researchers can experiment with computing systems in favour of improved power management (i.e., battery life), security, and simplicity.

Our review integrates existing methods established by Pinelle and Gutwin [26] and Wainer and Barsottini [30] with more recently published frameworks. In particular, Lee and Paine [20] propose a Model of Coordinated Action (MoCA), which summarizes many of these research trends and suggest a comprehensive set of dimensions upon which research can be classified. While they suggest novel dimensions such as nascence, planned permanence, number of communities of practice, turnover, and number of users, their review is directed at the classification of individual contributions instead of understanding trends within the field over time. Further, we had difficulty operationalizing metrics such as number of users, rated on a scale of 1 ... n , as objective components of our review when considering applications such as Twitter and Facebook. However, we incorporate *nascence* through our investigation of studied devices, a dimension that has not previously been explored in reviews of the CSCW literature, but which is particularly relevant given the recent shift towards ‘Post-PC’ computing.

3 APPROACH

We included the core pool of 1209 papers and notes published in the CSCW conference proceedings from 1990 – 2015. Our review differed from previous reviews in two ways. First, where notes

had previously been excluded from literature reviews, we chose to include them. This decision was made to account for CSCW's shift to variable length submissions, notes' similarity to full papers in format and visibility, and to take into account the growing stature of notes as a means of communicating new findings. Second, we chose to *exclude* the Extended Abstracts publications introduced in 2014 to maintain consistency between literature reviews, and to ensure that our review included only archival publications.

We followed a systematic review methodology [18]. Papers were tabulated in a shared spreadsheet, capturing data such as publication year, type of empirical research, type of empirical evaluations used, and the systems/technologies involved¹. To allow for comparisons between pre- and post-2004 publications, we used the classification schemes developed by Wainer and Barsottini for Research Type and Evaluation Type [30]. In addition to those classifications, also classified publications according to Johansen's Synchronicity / Distribution quadrants and the types of devices studied [7, 15]. We defined each of these categories as follows.

3.1 Synchronicity and Distribution

We first classified publications across Johansen's Synchronicity and Distribution dimensions [7, 15]. Publications were classified as being Synchronous or Asynchronous (i.e., Time) and Collocated or Distributed (i.e., Place). While the utility of these dimensions has been criticized in the past (e.g., Mogenson and Robinson [23]), these dimensions are often used to scope research, in literature reviews, and inform models of collaboration [10, 20, 26]. We therefore included Synchronicity and Distribution for consistency and continuity with other reviews, and to provide a high-level perspective of research over time. During our initial classification we found that publications were increasingly addressing more than one quadrant, and so we allowed individual publications to be classified under multiple quadrants.

3.2 Research Type

In their review, Wainer and Barsottini [30] classified publications as belonging to one of five research types:

Design and Evaluation papers describe the development of a system in detail, typically followed by a brief evaluation of its affordances for supporting collaboration.

Descriptive research usually describes a work environment/setting where collaboration is important, or the introduction of a new tool into such an environment.

Explanatory papers describe scientific experiments designed to test one or more hypotheses and explain underlying phenomenon.

Bibliographic papers systematically collect and analyse a set of scientific publications.

Not Empirical research typically presents a new tool, framework, or toolkit to support collaboration, or a model for classifying or evaluating groupware without an empirical validation. This work is often colloquially referred to as 'Systems' research.

These categories were derived from those used by Pinelle and Gutwin [26], and enable the comparison of contributions across a range of publications. Our classification differed from previous work in that publications fell into only one of the five categories, whereas Wainer and Barsottini classified 4/169 publications as falling into multiple categories. Given the low frequency of publications falling into more than one category, the use of mutually exclusive classifications simplified the review process.

¹Tabulated data available at <http://goo.gl/14r5sW>

3.3 Evaluation Type

For publications whose main contribution was categorized as Design and Evaluation, the Evaluation Type was also classified as belonging to one of three categories:

Field Experiments are performed in a non-artificial (or naturalistic) environment but with manipulation of some dependent variable.

Field and Case Studies are performed in a naturalistic environment but with minimal manipulation of dependent variables.

Laboratory Experiments are performed in a controlled environment with manipulation of the dependent variable.

These classifications are based on categories used by Pinelle and Gutwin and refined in Wainer and Barsottini's review. As with those reviews, in addition to the type of evaluation, we classified Evaluation Measures as being *qualitative*, *quantitative*, or *both*. That is, these classifications were *not* mutually exclusive. For example, Wainer and Barsottini report that as many as 38% of papers in 2004 involved both qualitative and quantitative measures.

While the qualitative/quantitative categorizations were used by both Pinelle and Gutwin and Wainer and Barsottini in their reviews, they were not formally defined. For our review, we typically considered research quantitative when it relied upon statistical comparisons of collected data, whereas qualitative research often sought to explain why or how findings occurred through observational data, interviews, or case studies.

3.4 Devices

Finally, to capture the impact of changes in technology over the past 25 years, we categorized the device hardware targeted by each publication. We classified the types of devices studied in each publication as: PC, wall, table, handheld, tablet, wearables, and other. Handheld devices a range of portable devices that include older technologies, such as Personal Digital Assistants (PDAs), as well as more recent devices such as smartphones. Our 'Other' category included devices such as cameras, phidgets, and other custom-designed hardware. This categorization provides a means of measuring the 'nascence' [20] of each contribution, enabled us to explore how quickly CSCW has published research relating to the use of novel technologies such as smartphones and tablets before and after their emergence as mainstream computing devices, and provided an opportunity to characterize how frequently CSCW research explores the use of novel or experimental technologies.

3.5 Raters

The review was performed by two raters. Rater 1 was an Undergraduate student with no previous CSCW experience. Rater 2 was an Assistant Professor with approximately 10 years experience in CSCW research, and who has published more than 10 papers at CSCW conferences and journals.

3.6 Data Collection and Analysis

To ensure consistency between previous reviews and our own, publications were classified for *Research Type*, *Synchronicity/Distribution*, and *Devices* in three stages. First, our two raters collaboratively discussed and classified 120 papers, in 3 sets of 10 followed by 3 sets of 30. Over the course of this exercise, our raters achieved a 'good' level of agreement ($\kappa = .473$), including initial disagreements. Second, our raters independently classified all 53 full papers from CSCW 2004, corresponding to Wainer and Barsottini's review, and inter-rater reliability scores were calculated for agreement (Cohen's $\kappa_{R1} = 0.581$, $\kappa_{R2} = 0.818$). Finally, the remaining 1035 papers were independently classified by the two raters. When difficulty arose in determining an appropriate

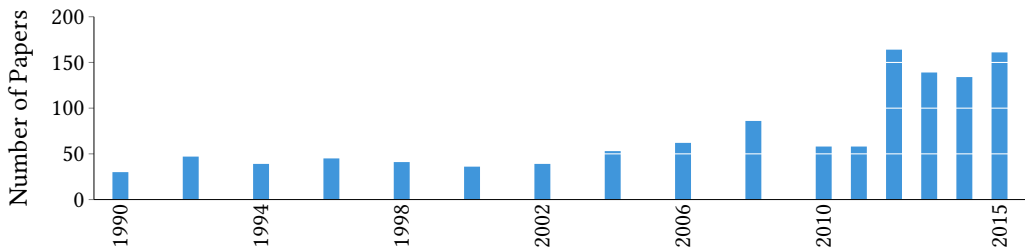


Fig. 1. Number of publications at the ACM Conference on Computer Supported Cooperative Work, 1990 – 2015.

empirical research type, papers were discussed. When agreement could not be reached, Rater 2’s classifications were reported.

A similar process was then followed for *Evaluation Type*. Rater 2 independently classified all 16 Design and Evaluation papers from CSCW 2004, achieving a very strong level of agreement with Wainer and Barsottini ($\kappa = .802$). After reviewing these classifications with Rater 1, and having achieved this high level of agreement, Rater 2 then classified all 200 Design and Evaluation papers from CSCW 2006 – 2015.

We analyzed papers across 4 time periods: 1990 – 1996, 1998 – 2004, 2006 – 2011, 2012 – 2015. The time periods were selected to account for the shift to annual meetings in 2010, with each period including 4 conferences. We compared the *ratio* of papers in each category. Comparing the ratio of papers as a percentage of all publications within the year enabled us to normalize data and account for an increased number of submissions over the past 5 conferences. For mutually exclusive categorizations (Research Type, Evaluation Type, and Evaluation Measures) comparisons were made using Pearson’s χ^2 test for independence and inspected adjusted residuals to identify changes across eras. For the non-mutually exclusive Synchronicity, Distribution, and Devices categories, comparisons were made using a Repeated Measures Analysis of Variance (RM-ANOVA). Due to the limited number of Bibliographic publications, this category was excluded from our analysis. An alpha-value of .05 was used for all statistical tests.

For all categories, we tested the null-hypothesis that no changes in publication rates had occurred over the 25-year period included in our review. In consideration of the growth of the conference, and drastic changes in computing over that time period, these hypotheses were unlikely to hold, but provide a reasonable starting point for further analysis.

4 RESULTS

Our analysis included a total of 1209 papers from CSCWs 1990 – 2015. Importantly, these trends are interpreted within the context of an overall increase in the number of published works at the conference over the 25-year period (Figure 1). We present results separately from each of our classification categories: Synchronicity and Distribution, Research and Evaluation Type, and Devices.

4.1 Synchronicity and Distribution

Our analysis revealed an increase in the amount of Distributed/Synchronous research ($F_{3,12} = 7.788, p = .004, \eta_p^2 = .661$) during the 2012 – 2015 conferences when compared to CSCWs 1990 – 1996 and 1998 – 2004 ($p = .013, .011$) (Figure 2). Between 1990 and 2015, the growth in Distributed/Synchronous research accounts for about a 6% increase in its share of research published

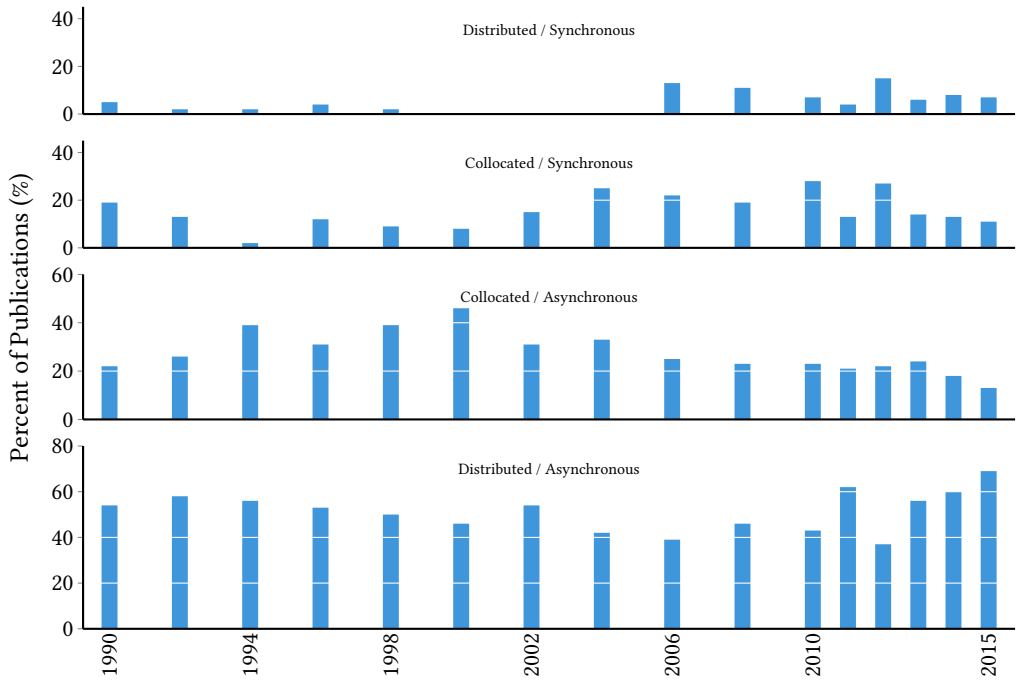


Fig. 2. Research at CSCW as categorized across Johansen’s Time/Place spectrum. Our results demonstrate increases in Distributed/Synchronous and decreases in Collocated/Asynchronous research in the most recent conference publications.

at CSCW. On the other hand, Collocated/Asynchronous research decreased ($F_{3,12} = 7.952, p = .003, \eta_p^2 = .665$) over the same periods ($p = .022, .004$) from a relative high in CSCWs 1998 – 2004 of 37% of CSCW publications to about 19% of publications between 2012 – 2015. We discuss these trends later, and argue that they are reflective of trends towards social networking and mobile computing.

No differences were found for Collocated/Synchronous ($F_{3,12} = 1.134, p = .374, \eta_p^2 = .221$) or Distributed/Asynchronous research ($F_{3,12} = .987, p = .431, \eta_p^2 = .198$), which accounted for an average of 15.7% and 51.5% of publications, respectively.

Finally, our categorizations were not mutually exclusive. In total, 1018 (84%) of publications were categorized as addressing a single quadrant, 99 (8%) as two quadrants, 29 (2%) as 4 quadrants, and 63 (5%) in no quadrants.

4.2 Research Type

Our analyses revealed notable trends in the rate of publication of Not Empirical, Explanatory, and Descriptive research published at CSCW ($\chi_9^2 = 189.509, p \approx .000, V = .230$). Inspection of adjusted residuals revealed changes in Descriptive, Explanatory, and Not Empirical research. In recent years, Descriptive research has increased, and now represents more than 55% of publications. We also noted a peak and decline in Explanatory research that tests hypotheses over the 2006 – 2011 and 2012 – 2015 periods, even as overall publication output at the conference has increased. Perhaps the most dramatic shift over the conference is in the decline of Not Empirical (i.e., ‘Systems’)

research. Thus, as expected the null hypothesis was rejected, and we next explored trends within each category of research separately.

Descriptive research accounted for an all-time high percentage of publications in the four-year period ending 2015 ($\bar{x} = 55.75\%$, $Res_{Adj} = 7.2$), higher than in the 1990 – 1996 ($\bar{x} = 31\%$, $Res_{Adj} = -3.5$) and 1998 – 2004 periods ($\bar{x} = 29\%$, $Res_{Adj} = -4.7$). This rise must also be considered in the context of 6-fold increase in the number of publications at CSCW; for example, an average of 12.5 papers were classified as Descriptive in the 1990 – 1998 period, compared to an average of 84.5 between 2012 – 2015.

On the other hand, our analysis suggests a recent peak and decline in Explanatory research published at CSCW. Explanatory research was more dominant in the four-year period ending 2011 ($\bar{x} = 22.75\%$, $Res_{Adj} = 5.4$), than during the periods ending 1996 ($\bar{x} = 3\%$, $Res_{Adj} = -3.9$) and 2004 ($\bar{x} = 9\%$, $Res_{Adj} = -1.4$) but no difference was found for the period ending in 2015 ($\bar{x} = 12\%$, $Res_{Adj} = -1.0$).

Further, our analysis shows a general downward trend in the amount of Not Empirical research published at CSCW. Not Empirical research decreased in 2015 ($\bar{x} = 7\%$, $Res_{Adj} = -9.8$) from highs in 1996 ($\bar{x} = 41\%$, $Res_{Adj} = 9.2$) and 2004 ($\bar{x} = 32\%$, $Res_{Adj} = 4.6$). In absolute terms, an average of 16.75 Not Empirical papers were published on average between 1990 and 1998, compared to an average of 12.4 at conferences between 2012 – 2015.

No differences were found for Design and Evaluation or Bibliographic research (Figure 3).

4.3 Evaluation Type

Our review also provides an opportunity to revisit analyses of Design and Evaluation research by Pinelle and Gutwin [26]. In particular, they noted that nearly 75% of prototype evaluations were classified as Laboratory Experiments. Our data suggests that CSCW has responded to this imbalance, with Field Experiments (21%) and Field % Case Studies (45%) representing a significantly larger portion of evaluations in 2015.

Our statistical analysis of the evaluations reported during Design and Evaluation research revealed no changes in Evaluation Type across the four time periods ($\chi_6^2 = 11.646$, $p = .070$, $V = .144$). Across all included CSCW conferences, Field Experiments accounted for approximately 22% of evaluations, Laboratory Experiments 47%, and Field and Case Studies 31% (Figure 4). This lack of statistical significance suggests that the need for Field research was rapidly addressed by the CSCW community, and a visual inspection of Figure 4 supports this notion.

Similarly, researchers have moved to adopt both qualitative and quantitative measures in their evaluations – 46% of evaluations utilized a mixed-methods approach in the 2015 conference. Our analyses revealed an increase in the use of both qualitative and quantitative measures ($\chi_6^2 = 17.543$, $p = .007$, $V = .178$), where nearly half of publications in the most recent 4-year period employed both types of measures (49%, $Res_{Adj} = 3.1$), compared to publications between 1990 – 1996 ($\bar{x} = 17\%$, $Res_{Adj} = -2.4$) and 1998 – 2004 ($\bar{x} = 23\%$, $Res_{Adj} = -2.6$). Our analyses revealed no differences in the use of quantitative or qualitative measures independently (Figure 5).

Finally, it is important to note that while we rejected the null hypothesis for changes in Evaluation Type over time, our results can be considered borderline significant ($p = .07$). That is, there may be an emerging trend that suggests a decrease in lab experiments published at CSCW, and a corresponding increase in field work. As additional data becomes available, this trend may cross over to statistical significance, and support our findings surrounding the decline of Explanatory research. We suggest that future reviews should revisit this analysis as more data becomes available.

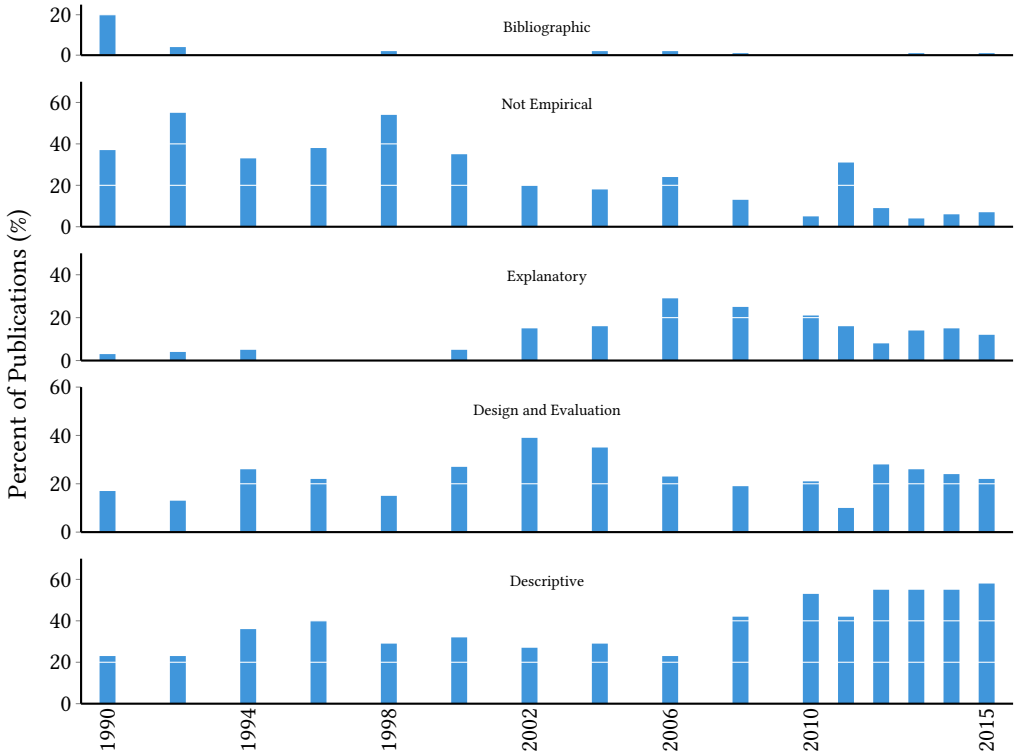


Fig. 3. Publication rates by Research Type. Our review identified an increase in Descriptive research published at CSCW, as well as decreases in Explanatory and Not Empirical research.

4.4 Devices

Our analyses also revealed overall changes in the devices targeted by CSCW research. As expected, there was an increase in the number of publications that studied Tablets ($F_{3,12} = 13.505, p \approx .000, \eta_p^2 = .771$) and Handhelds ($F_{3,12} = 37.325, p \approx .000, \eta_p^2 = .903$), commensurate with the widespread adoption of smartphones and tablets in the late 2000s. In the most recent four conferences, research involving Tablets accounted for 12% of publications, and Handhelds 21%.

Over the same time period, we found the number of publications addressing use of PCs ($F_{3,12} = 15.620, p \approx .000, \eta_p^2 = .796$), Wall displays ($F_{3,12} = 3.727, p = .042, \eta_p^2 = .482$), Wearables ($F_{3,12} = 11.014, p = .001, \eta_p^2 = .734$), and Other devices ($F_{3,12} = 4.214, p = .030, \eta_p^2 = .513$) decreased. While research involving these devices has trended downwards, research involving PCs still accounts for more than half of published research in the four-year period ending 2015 (55%). Research involving wall displays and devices classified as ‘other’ represent a niche within CSCW, accounting for 2.4% and 5% of publications, respectively. Research involving Wearables represented a lower portion of research in the period ending 2011 (0%), than in the period ending 2004 (3.6%, $p = .001$).

Our analysis revealed no overall changes in the number of publications studying Tabletops ($F_{3,12} = 2.363, p = .122, \eta_p^2 = .371$). Finally, our classification scheme allowed for individual contributions to investigate the use of multiple devices. We found that 8.84% of papers (127)

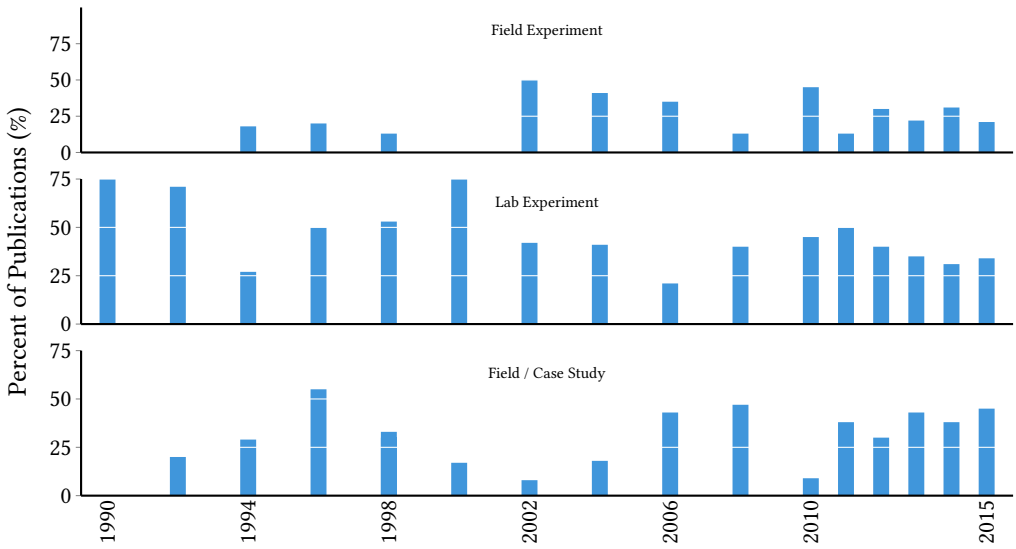


Fig. 4. Publication rates by Evaluation Type, for all papers classified as Design and Evaluation. Where early meta-reviews of the CSCW literature suggested an emphasis on laboratory experiments, our review suggests a relative balance between lab work and field work in recent research.

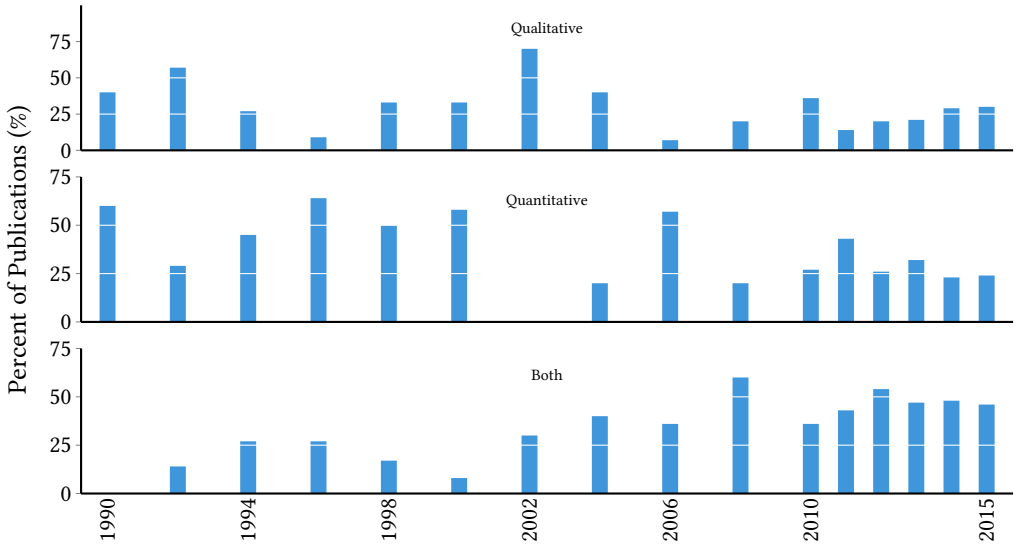


Fig. 5. Publication rates by Experimental Measures. Where early research often utilized exclusively qualitative or quantitative measures, more recent research frequently uses a mixed-methods approach.

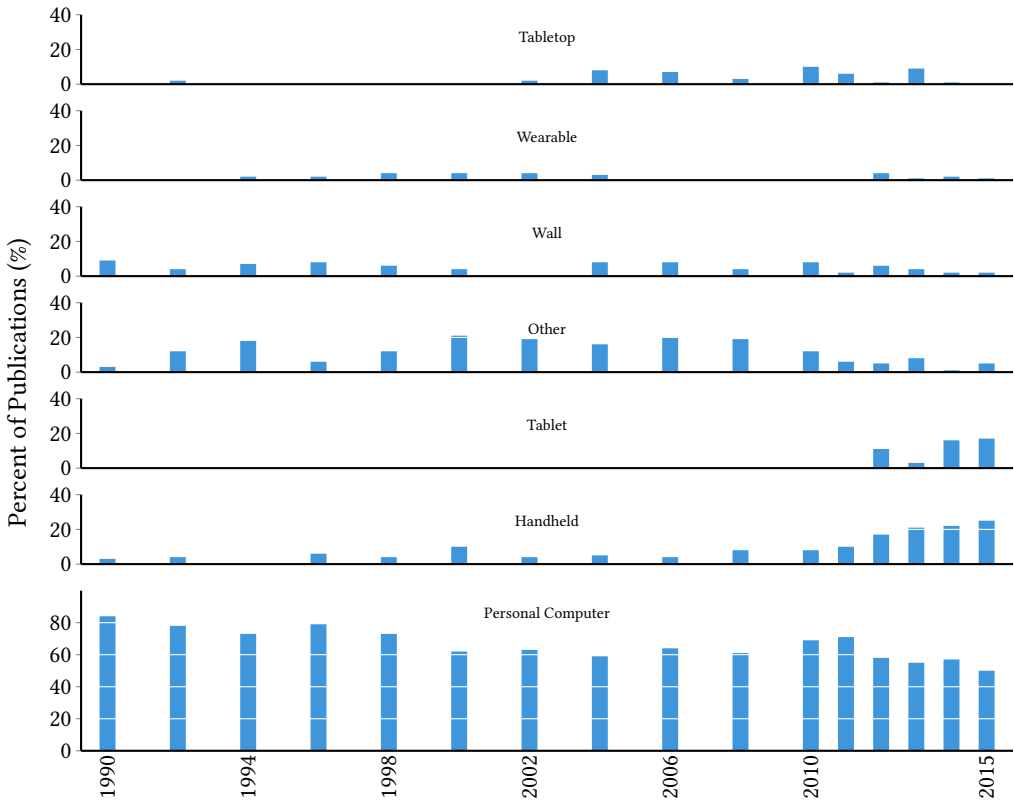


Fig. 6. Papers addressing specific devices, including: Tabletop, Wearable, Wall Display, ‘Other’, Tablet, Handheld, and PCs. Ordered from least to most dominant, as of CSCW 2015.

investigated the use of two device types, 8.4% of papers (121) involve 3 types of devices, and 1 paper studied the use of 4 devices concurrently (Figure 6).

Our results demonstrate the relatively slow decline in PC-based research, despite the rapidly growing influence of Post-PC devices. For example, we found no evidence of tablet research until 2012, 2 years following the introduction of the first tablet devices, and little research on wearables. A more careful examination of research by Device Type (Table 1) reveals a divergence in the types of research conducted on PC vs. Post-PC devices. In terms of raw output, the amount of Design & Evaluation and Explanatory research performed on PCs far outpaces that performed on Post-PC devices, but is approximately consistent when considered as a portion of overall research output. More tellingly, the amount of Not Empirical research performed on PCs corresponds to about 5× of that on all other devices types.

Comparison of research across Device Type and Synchronicity and Distribution categories (Table 2) is also revealing. For example, PC-based research heavily favours Distributed applications by a factor of about 5-to-1. Similarly, research on Handheld and Tablet devices, the largest and most rapidly growing categories of Post-PC devices, is predominantly conducted in Distributed settings. In step with these trends, we found a decrease in the amount of research on Tabletop, Wall, and ‘Other’ devices. Tabletop and Wall displays in particular are often associated with supporting

Device Type	Research Type				
	Design & Evaluation	Descriptive	Explanatory	Bibliographic	Not Empirical
PC	145	374	114	6	101
Tabletop	13	18	4	0	1
Wall	20	13	6	0	4
Tablet	19	60	19	0	2
Handheld	45	123	27	1	6
Wearable	12	2	4	0	0
Other	38	38	8	1	9

Table 1. A breakdown of research by Device and Research Types reveals that Post-PC devices are often a focus of Descriptive research, but are less often used in Not Empirical or Explanatory research.

Device Type	Time and Place			
	Collocated / Synchronous	Collocated / Asynchronous	Distributed / Synchronous	Distributed / Asynchronous
PC	101	58	239	601
Tabletop	24	2	5	16
Wall	35	8	18	5
Tablet	9	7	12	80
Handheld	30	18	58	146
Wearable	9	2	14	2
Other	49	15	59	30

Table 2. A breakdown of research by Device and Time/Place reveals that Post-PC devices are often a focus of Distributed/Asynchronous research, but are rarely used in Collocated research.

Collocated/Synchronous applications, as opposed to Post-PC devices such as tablets and handhelds which are used more for Distributed/Asynchronous applications.

5 IMPLICATIONS FOR CSCW

The past 25 years have marked significant changes in the structure and attendance of the CSCW conference, including the welcoming of practitioners from myriad fields, the acceptance of new research methodologies, and a shift towards annual conferences; culminating in a 6-fold increase in research published annually. Our review suggests that the types of research conducted and published within the CSCW community have fundamentally shifted to account for technological advancements, but also points to types of research that are underrepresented at the conference. Given the lack of bibliographic research across this period, our analyses provide a unique perspective on CSCW research, and an opportunity to reflect on challenges and opportunities for the field in light of these advances:

5.1 How do we synthesize results?

While our findings suggest that CSCW evaluations now draw from a more diverse set of Evaluation Types and Measures, researchers continue to struggle with open questions that require broad

perspective and replication to answer. For example, Pinelle and Gutwin's 1998 questions regarding "How do we evaluate" resonate with advocates for "adoption-centred design" [4] that can aid in translating HCI research to commercial products. Similarly, the field continues to struggle with foundational aspects of CSCW, such as Grudin's Eight Challenges for Groupware [13], and their application to new technologies such as public wall displays [5] and social computing [3].

These challenges point to a need to synthesize results, and continued struggle with open research questions, however our review illustrates a dearth of bibliographic work at CSCW; bibliographic publications account for less than 1% of those presented at recent conferences. Historically, this rate translates to an average of about 1 bibliographic publication every other conference. The need for bibliographic research is particularly salient following the growth of the conference, its shift to a yearly schedule and expansion in scope, and the emergence and success of related conferences such as ECSCW and GROUP. There is more CSCW research published now than at any point in the past 30 years, yet few publications synthesize knowledge.

This gap provides an opportunity for targeted reviews that address specific topics such as 'How do we evaluate?' [26], as well as more general reflection on 'What do we research?', as presented in this review. These more general reviews are particularly important as CSCW moves towards a journal publication model, and there is an opportunity to reflect on the types of research valued (and ultimately published) by the CSCW community.

5.2 What research contributions do we value?

The growth of social networking and Post-PC computing has meant that research must often study applications in contexts and at a scale that cannot be developed or contained in the laboratory. Our review suggests that the field has responded to these changes by conducting more Descriptive research. During our literature review, we noted that much of this research was categorized as exploring Distributed/Asynchronous applications (121/548 publications) and hypothesize that the shift may be driven by difficulties in performing Not Empirical, Explanatory, and Design and Evaluation and research with complex, in-place, and vertically integrated commercial systems. This approach is well justified, and appropriate given the need and ethical complexities of understanding these rapidly evolving, socio-cultural systems in the wild [19]. However, coinciding with this increase in Descriptive research, we also found less work addressing the design of novel computing systems, hypothesis testing, and knowledge synthesis – tenets of traditional CSCW research [20].

Contributions across the Explanatory (i.e., hypothesis testing) and Not Empirical (i.e., novel, untested systems) categories have decreased during the most recent CSCW conferences. Explanatory research peaked in 2008, contrasting pre-2006 trends noted by Wainer and Barsottini [30], who optimistically noted an increase in Explanatory research and that "Creativity, in [the] natural sciences, comes in the proposal of new theories and hypothesis [sic], and progress comes from systematically testing the theories and hypothesis with well planned, precise, and rigorous experiments." That is, Explanatory contributions mark the maturity of CSCW as a field. Similarly, we found a decline in Not Empirical research – or 'Systems' research that proposes novel frameworks, interaction techniques, or algorithms – which accounted for an all-time low of 7.5% of publications at CSCW 2015, a noteworthy decline from the nearly 1/3 of publications at CSCWs 1990 – 1998 [26]. Not Empirical research is particularly important because it seeds new ideas and initiates conversation within the community [12], often as a precursor to larger research trends. When taken into consideration with the lack of bibliographic research in the field altogether, CSCW research is arguably less diverse today than it has been at any time in the past.

These trends away from theoretical and systems research give pause, and beg the question as to what types of contributions are valued at CSCW. Our review shows that Design & Evaluation (22%) and Descriptive (58%) research account for the vast majority of publications at CSCW, but does not

explain *why* these trends are happening. For example, one might suggest that the current scientific funding model emphasizes Descriptive publications that require less investment in expensive technologies (but more researcher time). Likewise, one might suggest that the emphasis on ‘novelty’ [12] in CSCW’s peer review model favours work that involves Design & Evaluation over Explanatory research. Grudin [14] also notes that lower acceptance rates have historically influenced the kinds of research published within the SIGCHI community, and discouraged participation by industry. These trends, and others, deserve an open discussion within the research community.

The discussion surrounding how to strike an appropriate balance between contribution types is ongoing and spans related conferences such as CHI and UIST [16, 21, 24, 32] – the latter which often encourages Not Empirical contributions without requiring a user study. However, contributions to the discussion to date have been based on opinion, and have not drawn upon objective measures such as those presented in this review – likely due to the lack of bibliographic work at the conference. For example, the lack of ‘systems’ research is often noted at CSCW following the shift to Social Computing, but no objective measures have been available to help ground this observation. The data collected during this systematic review provides a unique perspective on the CSCW conference, confirms opinions such as those surrounding Not Empirical research, and helps to identify other trends that have not been discussed by the community, even informally, such as the decrease in Explanatory research or shift towards Descriptive research. We hope that this information will play a role in grounding future discussions within the community, in quantitatively characterizing trends in research publications, and in fostering discussions about how different types of research can be encouraged at the conference.

5.3 How do we support exploratory research?

As CSCW systems continue to develop, they have become increasingly complex, embedded, and distributed across devices such as PCs, smartphones, and tablets and to social networking platforms and ‘the cloud’. However, our results suggest that research at CSCW has largely trailed mainstream adoption of technology such as smartphones and tablets, and remained focused on single-device interactions. For example, the observed expansion in tablet and handheld research mirrors the release schedule and adoption rates of iOS and Android devices (e.g., smartphones in 2007 and tablets in 2010). Similarly, the decline in PC-based research mirrors a decline in unit sales of PCs over the past decade.

This distribution of research amongst popular, mainstream devices may come at the expense of the more experimental and forward-looking research historically featured at CSCW (i.e., Not Empirical or systems research). Given these shortcomings, One might question whether the CSCW community is able to anticipate and provide leadership in use of novel technologies for collaboration. For example, the Internet of Things (IoT) is likely to be an influential development for both small groups and organizations, but is not currently well-represented by research at the conference. These trends carry over to the more complex computing environments experienced in today’s home and BYOD workplace; our review identified only 51/281 (18%) Design and Evaluation publications involving the use of multiple devices.

Moreover, the growing ‘device ecology’ brings into question the validity of past CSCW findings, and suggests an opportunity to re-evaluate and replicate past Explanatory work. For example, Work Rhythms [1] identified typical usage patterns over a 3-week period of office work with noted implications on our ability to identify when individuals are available for communication. Contemporary work [22] has investigated similar trends within the workplace, but has not looked at this work within the broader device ecology. There are opportunities to explore how work rhythms have changed in a world where professionals sleep with their smartphone charging next to them and where a typical meeting may include opportunities to interact, communicate, and

collaborate via tens of devices. The implications of the growing device ecology are likely to have a far reach, and impact foundational CSCW research in areas such as awareness and communication [8] and the adoption of new tools [13, 25].

6 LIMITATIONS

We conducted a systematic analysis of publications at CSCW conferences between 1990 and 2015. This work builds on two previous reviews [26, 30] that each addressed a 4-year subset of these publications. We expand on these reviews to include a more diverse set of papers and paper types, including works over a 25-year period of research. However, while we expanded the scope of the review in regards to the number of papers surveyed and the addition of the Devices and Synchronicity and Distribution dimensions, there are other aspects of the review that could still be expanded upon.

First, we focused on publications solely from the ACM Conference on Computer Supported Cooperative Work (CSCW). This choice necessarily limited the scope of our review. For example, publications could have been included from the Journal of Collaborative Computing and Work Practices (JCSCW), the European Conference on Computer Supported Cooperative Work (ECSCW), and the ACM Conference on Supporting Group Work (GROUP). We also omitted works from the more general Human-Computer Interaction community, such as the ACM Conference on Human-Factors in Computing Systems (CHI), the ACM Conference on User Interface Software and Technology (UIST), the ACM Conference on Interactive Surfaces and Spaces (ISS), and the ACM International Symposium on Pervasive Displays amongst many others. While including these papers may have provided a more complete perspective on the evolution of CSCW research, they also would have substantially increased the size and complexity of our review. It is also not clear that comparisons between, for example, UIST and CSCW publications in general would be fair to make. Thus, we leave such reviews to future work.

Second, our classification of papers was limited to a finite set of categories, and may not have addressed every possible dimension of interest to CSCW researchers. We classified papers using a priori categories derived from previous reviews [26, 30], and extended these categories using more recent models of CSCW research (e.g., Lee and Paine [20]). While Lee and Paine [20] in particular identify additional dimensions that may be useful in classifying CSCW research, we had difficulty with objectively incorporating them into our review. Similarly, Pinelle and Gutwin [26] categorized Design and Evaluation contributions along subcategories that we felt were not objective such as whether the application was academic vs real world, or the placement of evaluation in the product lifecycle; thus they were omitted. We felt that these decisions were supported by those made by others in conducting previous reviews of the literature [30].

Third, given the large number of Descriptive publications, it may be worthwhile to further sub-divide and categorize these publications. During our review, we noticed that many publications categorized as Descriptive contributed a mathematical model of user behaviour, and led towards use of machine learning techniques to support collaboration – these contributions in particular may justify a new category of empirical research that was not well described by existing categories. We also note that Wainer and Barsottini suggested a similar need in their review for Design and Evaluation publications, and that the goal of classifying publications at a fine-grained level may be a moving target. Future reviews of the literature may more closely define types of Descriptive research, or may simply find that research methods have shifted to favour a different category of research that in-turn begs for more refined analysis. Our approach of replicating Wainer and Barsottini's categories strikes a middle-ground of coarsely categorizing research across the conference, and allowing for comparisons with their review.

To help address these limitations, we have made the results of our work available to the CSCW community, in hope that this work can be revisited, extended, and enhanced. All of our data have been shared on a publicly accessible spreadsheet, which can be inspected and used freely. All of our categorizations are documented here, and build upon previously established classifications. We hope that any shortcomings of this research can thus be addressed through future iterations that build on this review, that compare and contrast our results to findings from related conferences, and that document the continuing evolution of CSCW research. In consideration of the dearth of bibliographic research presented at the conference, we feel that sharing the results of our comprehensive review provides an opportunity to more thoroughly investigate and understand CSCW's research practices on an ongoing basis.

7 CONCLUSION

To understand how CSCW research practice has changed over the past decades, we systematically reviewed all publications at the ACM Conference on Computer Supported Cooperative Work (CSCW) from 1990 – 2015, and analyzed publications across Synchronicity/Distribution, Research Type, Evaluation Type, and Technology dimensions. Our results demonstrate trends in the types of research published at the conference: an increase in Descriptive research that studies existing users or tasks, a decrease in Explanatory and Not Empirical research that develops theories or propose novel systems, and a lack of bibliographic research that synthesizes findings. We also show a fundamental shift in research at CSCW, and a focus in recent conferences on Distributed and Asynchronous collaboration.

Finally, it is worth considering that the SIGCHI community is adopting a journal-based publication model, and that starting this year the ACM CSCW proceedings will be published through the new *Proceedings of the ACM*. It is therefore an opportune time to reflect on how CSCW publications have changed over the past 30 years, to determine as a community the types of research we most value, and to consider how this new publication model can encourage this research. Our results provide a perspective on changes in CSCW as a research field, the opportunity to objectively investigate how the community has adopted new methods, and for the community to reflect on how work practices have been impacted by changes in technology over this time period.

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Received April 2017; revised July 2017