Web Science and Human-Computer Interaction: When Disciplines Collide

Clare J. Hooper
Culture Lab,
University of Newcastle, UK
clare.hooper@newcastle.ac.uk
+44 191 2464646

Alan Dix
Talis, Birmingham, UK
and
University of Birmingham, UK
alan@hcibook.com

ABSTRACT
Web Science and Human-Computer Interaction (HCI) are interdisciplinary arenas concerned with the intersection of people and technology. After introducing the two disciplines we discuss overlaps and notable differences between them, covering subject matter, scope and methodology. Given the longer history of HCI, we identify and discuss some potential lessons that the Web Science community may be able to take from this field. These concern: the division between interpretivist and positivist approaches; methods and methodology; evaluation; and design focus and methods. In summary, this paper clarifies the relationship between the communities, signposting complementary aspects and ways in which they might collaborate in future.

Author Keywords
HCI discipline; Web Science discipline; Methodology

ACM Classification Keywords
K.4.0. [**Computers and Society**]: General. H.5.4. [**Information Systems**]: Hypertext/Hypermedia – *user issues*. H5.m. Information interfaces and presentation.

General Terms
Design; Human Factors; Theory

INTRODUCTION
Web Science and Human-Computer Interaction (HCI) share certain similarities: both are interdisciplinary fields that concern the intersection of people and technology. This leads to the question, "How are these communities related?" and more pertinently, "What strengths do they share, and how might they benefit one another?"

Defining the precise boundaries of interdisciplinary arenas such as Web Science and HCI is an impossible task. The Web Science community is youthful, still consolidating its identity and often host to introspection and discussion about the definition of Web Science. Although HCI is by contrast an established field, like all other active research fields it is evolving: for instance, Shneiderman recently proposed a new direction and subfields within HCI [33].

We open this paper with a brief overview of Web Science and the disciplines subsumed within it, before providing a similar overview of HCI. We then discuss the confluence of the two fields, discussing their overall aims, scope and methodology. The final section of this paper presents some lessons for Web Science from HCI, drawing on relevant issues from the latter field. This 'lessons' section discusses: the division between interpretivist and positivist approaches; methods and methodology; evaluation; and design focus and methods.

WEB SCIENCE
Web Science was first formally proposed in 2006 [5, 6] and examines the web as an unfolding process. It has been defined in various ways, from "the science of decentralised information systems" [5] to "the study of social machines" [22]. Web Science studies the impact of the web upon society and vice versa, concerning web-enabled social practices.

Web Science is motivated by the complexity of the relationship between society and the web. The web is much more than the sum of its parts, and Web Science helps us understand the complex multiplicity of socio-technical interactions – both micro and macro – enabled by the web and the millions who contribute to that web. We need that understanding to make informed decisions, whether we're discussing government policy or infrastructures and standards, or trying to understand the ways in which online social networks fail to support the richness and dynamism of human relations.

We can gain some initial insight into the scope of Web Science by examining the categories offered by Web Science Trust [37]:

1. Computer Science
2. Artificial Intelligence
3. Web Engineering
4. Psychology
5. Economics
6. Law
7. Sociology

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8. Ecology
9. Socio-cultural
10. Media

We can also consider representation of disciplines and topics within the Web Science community. Figure 1 shows the 'Web Science butterfly', a diagram used to illustrated relevant disciplines when Web Science was first proposed [31]. Figure 2 is a 'heat map' of the butterfly [18]: this was created by analysing past Web Science papers (from the Web Science conferences 2009 – 2011) for topics which were clearly related to certain disciplines. As can be seen, AI, Computer Science, Mathematics and Sociology were strongly represented, while Biology, Economics and Law were not.

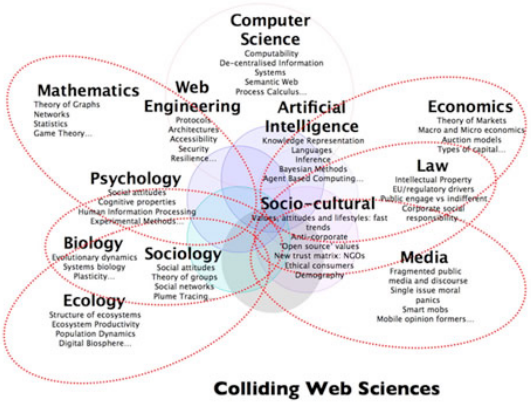

Figure 1: The original 'Web Science butterfly' [31]

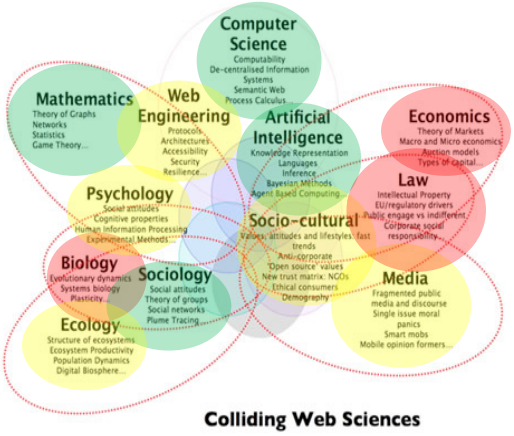

Figure 2: Web Science 'heat map', showing discipline presence [18]. Green denotes greater presence, yellow middling presence, red low presence

HUMAN-COMPUTER INTERACTION

Human–Computer Interaction (HCI) is the study of the issues that arise when people encounter computer-based technology, and the way this understanding can aid in the design of technology that is better (in various ways). Of course, increasingly 'computer-based technology' is all technology; indeed, the series title for the British Human–Computer Interaction conference series, which started in 1985, is simply "People and Technology". It is possible to trace the origins of HCI back more than 50 years, certainly to Brian Shackel's paper on "Ergonomics for a Computer" in 1959 [30] and Englebart's Augmentation Research Center at Stanford in the early 1960s [13]. However, the discipline really began in earnest with the rise of the PC in the early 1980s, with the first Interact, CHI and British HCI Conferences in 1984/5.

Like Web Science, HCI is radically interdisciplinary. One of the main HCI textbooks [10] describes the 'ideal' designer as having expertise including:

> "*Psychology and cognitive science to give her knowledge of the user's perceptual, cognitive and problem-solving skills; ergonomics for the user's physical capabilities; sociology to help her understand the wider context of the interaction; computer science and engineering to be able to build the necessary technology; business to be able to market it; graphic design to produce an effective interface presentation; technical writing to produce the manuals, ...*" [10]

The statement is somewhat tongue in cheek as the typical designer would be not expected to be quite such a polymath, and the text goes on to describe how this is achieved, at least partially, in practice. However, it gives some sense of the breadth of the discipline. Furthermore, this is just referring to the practicing designer, not necessarily the additional areas that contribute to the more theoretical / scientific aspects of HCI as a research discipline.

Many of the areas described above are also found in the Web Science butterfly, notably computer science and psychology, which have traditionally been at the heart of HCI. However, some are missing, so based on this list and the kinds of topics found in HCI conferences and journals, Figure 3 adds some areas to the Web Science butterfly. Some of these added areas are relatively minor within HCI, and so Figure 4 shows a heat map of the principle and secondary areas [1].

Note that one area added in Figure 3, philosophy, is arguably part of Web Science (e.g. see [15]) and merely happens to be absent from the Web Science butterfly. (For a deeper discussion on this point, see [18].) For a discussion on the relevance of Design to Web Science, see the 'lessons' section.

[1] The Web Science heat map in Figure 2 was the result of an empirical content analysis of published Web Science papers [18], while the HCI heat map in Figure 4 is a subjective assessment of the discipline by the second author.

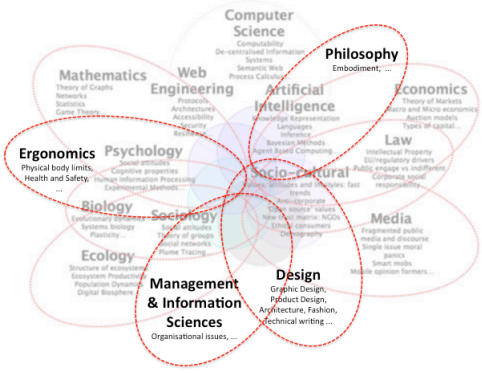

Figure 3: The 'HCI + Web Science butterfly'

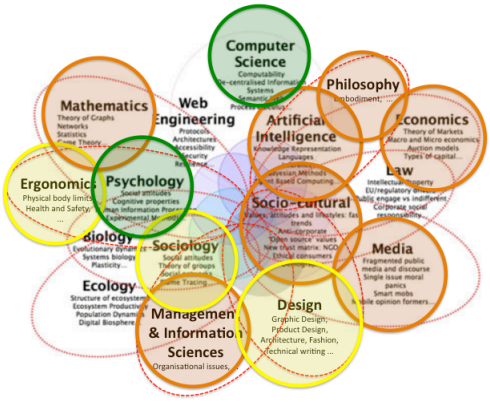

Figure 4: The HCI heat map

WHEN HCI AND WEB SCIENCE MEET

This section discusses the parallels between HCI and Web Science, in terms of subject matter, scope and methodology.

Subject Matter

HCI and Web Science clearly share similar application areas, and often ask similar questions. Shneiderman recently wrote:

> *HCI designs now influence commercial success, reform education, change family life, and affect the political stability of nations*." [33]

Arguably, Web Science studies this breadth of HCI's impact. Given this, Figure 5 shows a naïve view of how HCI and Web Science relate.

Of course, it is more complicated than this: Web Scientists do build and evaluate tools, while HCI researchers study the broader societal implications and interactions resulting from their systems. Indeed, these are perhaps the contexts in which collaboration between the fields would be most fruitful: tools from HCI can be useful to Web Scientists, and vice versa. For example:

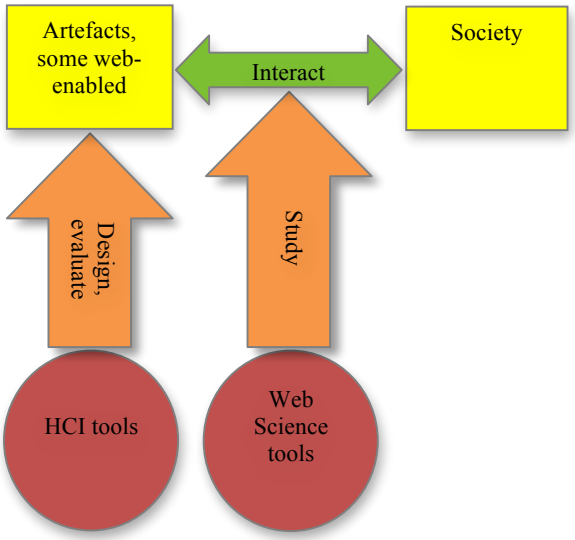

Figure 5: How HCI and Web Science relate (first impressions)

- Techniques from Web Science can help HCI practitioners understand the ways in which certain interactions propagate online
- Tools from HCI's arena of User Experience could help Web Scientists understand people's experiences of the mobile web

The two areas share broader parallels. Consider the cover story of a 2011 issue of ACM Interactions, entitled *Reimagining HCI: Toward a More Human-Centered Perspective* [2]. The author describes a refocusing within HCI from evaluation of interfaces through system design and into "general sense-making of our world." He remarks on the relevance of taking a sociotechnical perspective, adding:

> *This panoply of ideas, critiques, art, designs, and reflections at times sits uneasily with a more scientific research agenda. There is something about the kinds of questions being raised that makes us realize this mixing of scientific knowledge, on the one hand, and design expertise, on the other, can create uneasy bedfellows.* [2]

Both Web Science and HCI are domains where the concept of tension arising from multiple domains is not unfamiliar: indeed, we return to this topic in the 'lessons' section of this paper. Meanwhile, Bannon cites Winograd [38], who reportedly argues that the challenge for interaction design is combining:

- practical aspects from engineering
- human concerns that guide design
- social science perspectives on our world

Once again, we can see challenges which are applicable for both HCI and Web Science.

Finally, we should not forget that Web Science is about affecting as well as understanding that interaction between the web and society. This is another area in which HCI expertise could be relevant: socially-aware work in HCI has previously considered the use of technology to support emotional wellbeing [8], community engagement [34] and inclusion [16]. The methods, theory and results from such work could inform efforts in Web Science.

Scope

HCI is concerned with human interactions with all technology including traditional PCs, ubiquitous computation, tangibles, collaborative systems and hypertext. So, arguably, the web is just a particular example of a technology and hence Web Science a sub-discipline of HCI (see Figure 6). However, that would be a grossly simplistic view.

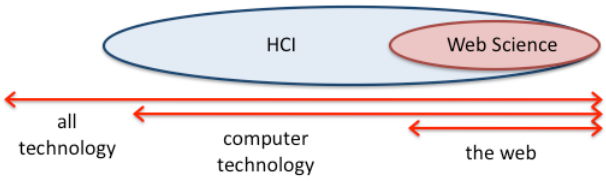

Figure 6: Scope of HCI and Web Science (first impressions)

On the other hand, it could be argued that just as nearly all technology is computer-based, nowadays nearly everything computer-based is becoming web-linked, and therefore over time HCI will be subsumed within Web Science.

In fact, while HCI and Web Science are clearly not unrelated, there are both overlaps and differences in emphasis between the two.

It is obvious that HCI includes areas that are not included in Web Science: basically anything to do with individual interfaces that are not web interfaces, from word processors to SatNavs. Indeed, many networked interfaces, collaborative and individual, are not really part of the wider web even if they often now use web protocols. HCI also deals with details of interactions, for example, the time it takes to hit a button on screen, which would seem out of place in a Web Science venue, even if the interface under consideration were on the web.

Similarly some areas of Web Science are outside or at the edge of the remit of HCI. For example, past Web Science papers have covered topics including (in the context of the web) politics [26], philosophy [15], law [21] and economics [36], while a significant portion of papers at the Web Science'11 conference drew on network science and network analysis techniques [20, 25, 40]. Web Science is often concerned with current affairs, for example censorship in China [39]; it is reasonable to expect that some material at WebSci'12 will deal with the recent SOPA blackouts[2].

There are, meanwhile, clear overlaps between the two fields. Recent examples of such work include Reinecke's contribution on culturally-adaptive interfaces [28], Bazan's evaluation of a web 2.0 learning system [3] and Karnstedt et al's analysis of the effect of user features on churn in social networks [19]. Looking back before Web Science, or even the web itself, Grudin's classic analysis of groupware "Why CSCW applications fail" [14] includes issues of critical mass and, what would now be called, 'network effects' [12, 23], which would not look out of place in a Web Science setting; indeed, it is not surprising that it was Gruden's work that was the inspiration for later analysis of the potential for CSCW applications on the web [9].

Shneiderman [33] recently discussed the role and range of modern-day HCI, proposing the dual concepts of *Macro-HCI* and *Micro-HCI*:

> *Micro-HCI researchers and developers design and build innovative interfaces and deliver validated guidelines for use across the range of desktop, Web, mobile, and ubiquitous devices. […] Micro-HCI researchers can take comfort in dealing with well-stated requirements, clear benchmark tasks, established measures of human performance, and effective predictive models, such as Fitts' Law.*
>
> *Macro-HCI researchers and developers design and build interfaces in expanding areas, such as affective experience, aesthetics, motivation, social participation, trust, empathy, responsibility, and privacy. […] Macro-HCI researchers have to face the challenge of more open tasks, unanticipated user goals, new measures of system efficacy, and even conflicts among users in large communities.* [33]

Shneiderman describes challenges for the two areas. For Micro-HCI he mentions accommodating the wide range of users (novice / expert, young / old, literate / illiterate, and abled / disabled), accounting for gender, personality, culture, ethnicity, and motivation. For Macro-HCI he touches on addressing the range of human experience: commerce, law, health / wellness, education, creative arts, community relationships, politics, policy negotiation, conflict resolution, international development, and peace studies.

We can immediately see that there are strong areas of overlap between HCI and Web Science, particularly when it comes to usability, cultural awareness, the evaluation of web-based systems, interfaces for web / mobile / ubiquitous computing, and Shneiderman's areas of Macro-HCI: affective experience, aesthetics, motivation, social participation, trust, empathy, responsibility, and privacy.

[2] For more, see: http://www.bbc.co.uk/news/technology-16604990

That said, parts of Micro-HCI clearly fall outside the remit of Web Science, although the design and evaluation of web and mobile devices do not. However, Macro-HCI sounds very close to Web Science: Web Scientists do at times design and build interfaces, and the application domains and challenges of Macro-HCI could appear in a description of Web Science.

This initially sounds as though the critical difference is the scale of human phenomena studied. If we expand the simplistic technological distinction of Figure 6 to include this, we can see Web Science and HCI occupying overlapping but distinct positions, where the overlap includes much (but not all) of Macro-HCI (see Figure 7).

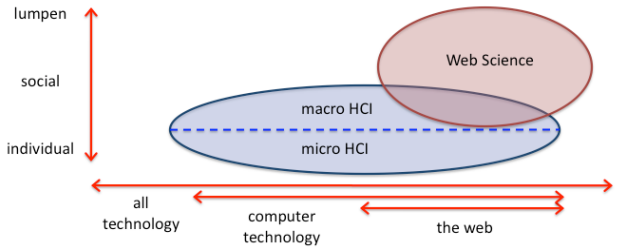

Figure 7: Scope of HCI and Web Science – scale of human phenomena vs. kind of technology

Note: the term 'lumpen' in the scale axis in Figure 7 (and Figure 8) reflects the way in which some parts of Web Science deal with people more in terms of their statistical qualities or aggregate behaviours. In HCI sometimes the individual can get lost behind *average* behaviours, but the focus tends to be more on the individual or social group. Again, there are counter examples. For example, Space Syntax [17], an analytic approach from architecture focusing on flows within buildings and urban environments, has been applied within HCI.

Figure 7 suggests that within HCI the distinction between Shneiderman's categories is purely scale. In fact, the differences are often more crucially methodological.

Methodology

Micro-HCI tends to favour more quantitative methods (measurements, log analysis, task timings, codified subjective ratings), whether these are laboratory experiments or studies 'in the wild'. In contrast, macro-HCI is more likely to adopt qualitative studies, with interpretative forms of analysis.

While the heat maps for both Web Science and HCI (Figure 2, Figure 4) include strong contributions from sociology, in the case of Web Science, this includes more quantitative and theoretical areas (such as social network analysis), whereas in HCI it is more observational techniques that have been adopted, notably ethnography with its roots in anthropology. Methodologically Web Science may have more in common with Micro-HCI than Macro-HCI (Figure 8); indeed the term "social machine" would be anathema to many on the more qualitative side of HCI. This is further emphasised by comparing the heatmaps in Figure 2 and Figure 4: in Web Science the more 'positivist' domains of mathematics and AI are prominent, whereas in HCI these are weaker, but found more in micro HCI.

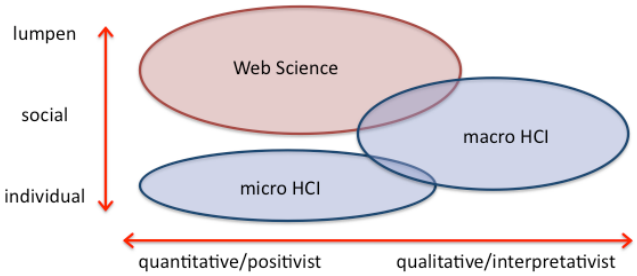

Figure 8: Scope of HCI and Web Science – human scale vs. methodological stance

Of course aggregate behaviour is the result of multiple individual choices, which suggests potential for complementary connections between the more methodologically similar micro HCI and quantitative Web Science. We can conceive a situation where Web Science makes sense of the overall impact of individual choices, and HCI addresses why these occur, and, if appropriate, how they may be influenced by suitable design.

LESSONS FOR WEB SCIENCE FROM HCI

Given the relative maturities of the areas and overlaps, it is interesting to see what lessons HCI might have for the emerging Web Science. This section discusses: the division between interpretivist and positivist approaches; methods and methodology; evaluation; and design focus and methods.

The Great Schism

While Shneiderman's micro/macro HCI article treats them as complementary, in practice there is often a sharp division from those who take a more wholistic / qualitative / interpretivist approach, and those taking a more reductionist / quantitative / positivist approach. While some of the strongest work in HCI is the result of holding on to both approaches (see discussion in [11]), still there are some researchers, sadly not inconsiderable, on either side of the divide who do not respect the complementary approaches.

Happily, so far in Web Science this does not seem to be a problem, and, perhaps because of the novelty of the area, those drawn into it embrace the richness of contrasting perspectives. As the field grows it is worth remembering that this mutual respect is powerful, precious and worth actively preserving. Neither is this difference one to be ignored: there are very different perspectives, and a truly interdisciplinary science needs to learn ways to encompass diverse and sometimes conflicting worldviews.

Research Methods and Methodology

The many disciplines and sub-disciplines that contribute to HCI have different methods that have been tuned to their own particular, albeit often unstated, assumptions. If these are imported without understanding the differing context of HCI this can lead to problems or methodological errors. Because of this [11] argues that HCI researchers have to be much more methodologically aware, understanding the assumptions underlying methods, in order to adapt and apply them appropriately.

This is equally true for Web Science. In some cases work is done that, while published under a Web Science banner, is still methodologically within one or other contributing discipline. However, where the interdisciplinary nature of Web Science is central, it too needs to face these methodological challenges.

There exist Web Science PhD students who are currently being supervised by academics from different disciplines: this is an exemplary approach towards encouraging interdisciplinary work. The community might benefit from feedback from these students and their supervisors about how the process has been panning out, and what stumbling blocks exist. Do they feel that a cross-disciplinary synthesis is forming in areas of intersection? Or do they simply feel torn two between academic cultures?

Evaluation

Evaluation has always been an important part of HCI, both in design practice as a way to assess and improve the utility of systems, and as part of empirical research. Traditionally measures have been focused on specific tasks, with both objective efficiency metrics, such as completion time and error rate, and subjective metrics, such as user satisfaction ratings.

These have proved powerful, but have struggled in a number of areas. In some cases tasks are not well defined, for example in exploratory search or visualisation. Indeed, the issue of evaluation in visualisation is sufficiently critical to have spawned its own workshop series [4]. In other cases, the phenomena are changing as we move from domains of work and productivity, to ones of leisure and experience. Shneiderman's micro/macro paper [33] suggests that we need new, more qualitative, metrics to help us understand mobile computing and the emergence of YouTube, Facebook and Twitter:

> "*Understanding this transformation would be facilitated by measures of "giga-hellos," "tera-contribs," and "peta-thankyous," and by newer metrics such as trust, empathy, responsibility, and privacy.*" [33]

Again, such metrics would be highly relevant to the Web Science community. Indeed, it is intriguing that Shneiderman did not explicitly relate his concept of Macro-HCI to Web Science. In his 2007 article [32] on how Web Science 'challenges' Computer Science, he included a table illustrating the differences between the two disciplines (Figure 9): here he chose quantitative/positivist metrics, as per Micro-HCI, yet topics relevant to both methodological stances (e.g. relationships, blogs and sharing).

Design Focus and Design Methods

HCI has always been a dual discipline, partly an academic study of people interacting with technology, partly a design discipline looking at ways to improve that interaction. These twin tracks are sometimes confluent, but also led to

Computer Science	Web Science
Metrics	
Moore's Law	Page views
Order (n) algorithm analysis	Unique visitors/month
Gigabytes	Number of songs or videos
Topics	
Computer networks	Social networks
Packet switching	Voice over IP, music sharing
Information	Relationships
Programming languages	Wikis, blogs, tagging
Databases, operating systems, compilers	E-commerce, e-learning, e-government, medical informatics, financial analysis
3D graphics, rendering algorithms, computational geometry, object modeling	Creating and sharing video, animation, music, photos, maps
Focus	
Technology	Applications
Computers	Users
Supercomputers	Mobile devices
Proficient programmers	Universal usability

Figure 9: Shneiderman's comparison of Computer Science and Web Science [32]

discussions in the early days as to whether it is craft, engineering or science [24]. This issue that has been revisited more recently in the John Long Festschrift issue of Interacting with Computers [7].

Web Science has eponymously settled this issue (!), but still would undoubtedly aspire to seek the practical implications of its science; to apply Web Science to the design of the web.

Within HCI the combination of science and experience has been crystallised in a number of ways to serve design. This ranges from more theoretically inspired formal models and frameworks, to principles, heuristics, style guides and design patterns. These vary in their level of domain and technology dependence, for example, style guides are often focused not just on a particular interaction genre, but also a particular platform (e.g. the classic Macintosh Human Interface Guidelines [1]).

However, it is the broad design methods, which have proved most long lasting as they transcend particular technologies, and even, to a large extent, styles of use. For example user-centred design [27, 35] and participatory design [29] were developed in the days of desktop interfaces, and early workplace automation, but have continued to prove useful in new technology areas, such as ubiquitous computation and Web2.0 interactions. New issues arise, such as user experience or understanding user values, but these have often fitted alongside or within these broad user-focused methods.

Of course both HCI and Web Science would expect to influence practice in other ways also, for example public policy. However, the design focus on HCI prompts the question of what a design focus within Web Science might be. Certainly not 'web design' in the standard sense of the term, but it would include understanding how to create systems that exploit the interactions between millions of people. How can, for example, Network Science and Design work together? Can we conceive of methods, patterns, or other ways in which the science of Web Science can serve design?

CONCLUSIONS

We have explored the parallels between HCI and Web Science, defining the two fields' relationship in terms of subject matter, scope and methodology. We have highlighted shared goals and challenges as well as areas that the communities do not have in common, and we have offered four lessons from the HCI community that may be helpful to Web Scientists in their emergent discipline.

The future of Web Science depends on maintaining our cohesive, balanced community in which no single discipline dominates. To this end, we would like more discussion about how disciplines collaborate: What are the stumbling blocks? Where do misunderstandings arise? What collaborations yielded stellar work, and why? Such questions are powerful, and relevant to both research and teaching (at this early stage, it is critical that we pay due heed to Web Science education). Similarly, we invite further discussion of what methods are key to Web Science, and – perhaps most important of all – the *ways* in which we can apply Web Science in the real world, whether in the context of legislation, business models, or design.

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