In the Flow: Evolving from Utility Based Social Medium to Community Peer

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1 Introduction

The word "media" evokes images of lively rooms packed with reporters frenetically covering events. Combined, the words "social media" today make one think of many people interacting online in a way that circumvents conventional media, but essentially accomplishes the same thing: making people rapidly aware of events, whether they are as global as an emerging international conflict or as local as the facial expression of one's cat on a given morning. Scholars on computer-mediated communication and human computer interaction regularly use the term social media in referring to a group of Internet-based technologies that allows users to easily create, edit, evaluate, and/or link to content or to other creators of content (c.f., Kaplan & Haenlein, 2010). In practice, one tends to think of Facebook and Twitter, where the nexus of interaction is a micro-expression of an event or idea. We may think less often of sites such as Wikipedia or LinkedIn, where the nexus of interaction is the more persistent longitudinal development of an article or professional profile, respectively.

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Regardless, the term "media" implies passive instruments that accept input from some people and allow reading of that input by other people. Input and output may undergo cycles of development as people "discuss" input. But when and where will we reach a point where "media" is no longer the right term and we are on the precipice of the medium becoming an active contributor to the body of knowledge that may be developed by it and its interactors? Perhaps "where" is in the online conduct of science and "when" is not so distant in the future.

The discussion in this chapter will use as an example nanoHUB.org, the world's largest online facility for the conduct of science related to nanotechnology. nanoHUB's "in the flow" development philosophy, its current status, its role as a platform in the nanotechnology and social science communities, and forward looking developments will be described in the context of it becoming a peer within its own community.

2 Design for Utility or Design for Social?

As it is the intent to discuss social media evolving into something different, the term "online interaction space" will be used here instead. The biggest upfront considerations when designing an online interaction space are utility margin and uniqueness. Utility margin conceptually is the difference between the benefit users gain from an online interaction space and the effort they must expend in using it. Note that the word "benefit" is important: to simply do something more efficiently is not sufficient if the user perceives little or no value in the outcome. Uniqueness is the degree to which no substitute exists that can satisfy the same needs by the same or different mechanisms. Too often interaction space creators are enamored with large successes and assume that providing the same or marginally more relevant capabilities to a more focused niche will ensure success, only to be disappointed when the intended audience does not adopt their creation. They misestimate their intended user's perception of utility margin (e.g. the benefit of an exclusive membership does not outweigh the work of having to log in to yet one more site) and uniqueness (e.g. a LinkedIn group will accomplish enough of what is needed to serve their community without a whole new site). In other cases, they seek to introduce a new behavior to their intended users without facilitating any of the current activities in which the intended users engage. As a result, the potential user has no frame of reference within which to judge marginal utility even though uniqueness may be high. Particularly when the design involves a new social mode of interaction that has no marginal utility unless a large community participates (the network effect), gaining users will be even more challenging. Designing to be social without designing for an achievable marginal utility is taking a shortcut that is highly likely to lead to failure.

Considering marginal utility and uniqueness, an interaction space must be designed in terms of its nexuses and modes of interaction to create an 'affordance' for everyday activities. The concept of an affordance refers to the action potential that can be taken given a technology to support a particular everyday task (Gibson, 1979; Majchrzak & Markus, 2013). The nexuses and modes can be chosen by looking at the assets and methods of working with those assets that the intended audience employs on a regular basis. In so doing, the interaction space is designed to facilitate some portion of the intended user's everyday workflow.

Without embedding one's creation into the flow of a user's normal activities and thus satisfying the selfish need to accelerate their individual efforts, gaining an appreciably sized audience of intended users is not likely and the network effect cannot be achieved. As pointed out by the psychologist Csikszentmihalyi, the interaction space may afford a flow state, a mental state, in which an individual user is fully immersed into a daily activity, and enjoys the process of the activity (Csikszentmihalyi, 1990).

One tends to attribute a sort of prescience of design to systems like Twitter and Facebook that, when viewed today, appear to have been successfully designed for social interaction without respect to utility. However, the first SMS transmission occurred in 1992 (Snowden, 2006) long before Twitter was conceived in 2006 (Miller, 2010), which simply created the ability to broadcast short messages to more than one follower simultaneously. Facebook also started by fulfilling the selfish need of people wanting to see pictures of other people on the same college campus, and only subsequently grew into the platform for social interaction. Both systems satisfied the selfish needs of the individual before gaining enough mass to realize the network effect. They were designed to be "in the flow" of the user, providing differentiation and beneficial marginal utility.

3 nanoHUB

Today nanoHUB hosts 342 simulation tools and 4,144 online resources in the form of courses, videos, animations, and downloadable documents (Fig. 1). nanoHUB currently serves over 325,000 users annually, over 13,000 of which run in excess of 500,000 simulations that consume more than 14,000 CPU days annually (Fig. 2). This may seem like success by design; however, like the much more successful and popular online interaction spaces discussed above, nanoHUB also achieved its audience by gradual evolution.

When created, nanoHUB was primarily focused on a goal of delivering access to simulation tools and computational resources over the web. The nexus of collaboration was the simulation tool. What previously had been individuals or small groups creating simulation tools for small user audiences changed with the introduction of nanoHUB: the audiences became much larger. As time progressed and audience size grew, additional modes of interaction were introduced, all based upon fitting into different elements of user workflows and in effect "purchasing the right" in the mindshare of the user to engage them in a successively broader social environment.

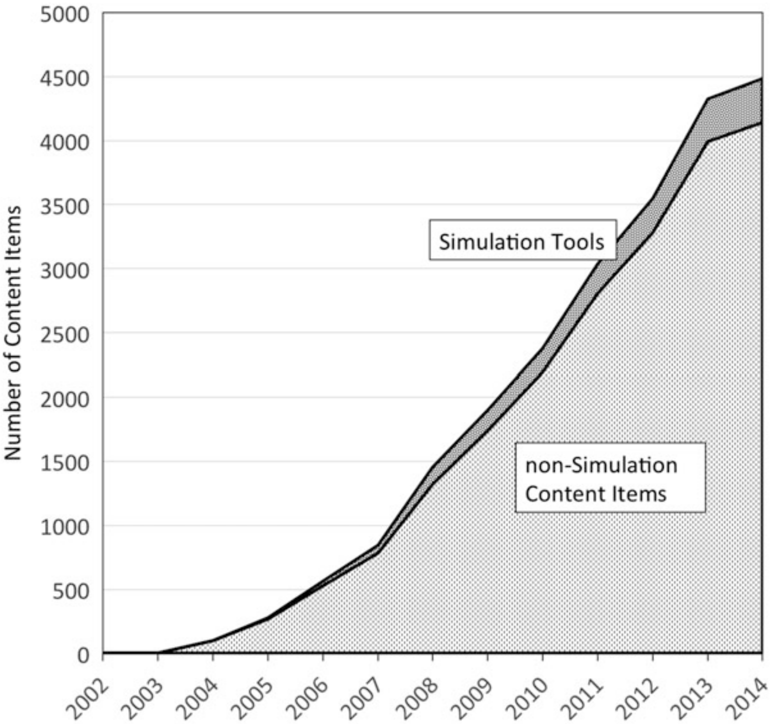

Fig. 1 This plot shows the growth in simulation tools and other resources over time on nanoHUB, culminating at 4,486 resources today. The change in slope in 2005 corresponds to the introduction of the Rappture simulation tool development kit. The corresponding increase in non-simulation content items suggests a relationship between tool creation and supporting technical materials

It is important to stress again that none of the design of nanoHUB has been from a speculative viewpoint of enabling a massive social network. Rather, each new development has been associated with increments of increased marginal utility and uniqueness.

4 Workflows Facilitated by nanoHUB

nanoHUB has been constructed on a gradual basis to fit into several workflows, all of which are centered around various aspects of the core nexus of interaction, simulation tools. Specifically, these include aspects of tool dissemination, interface construction, interface maintenance, sense-making, and publication of supporting augmentative information.

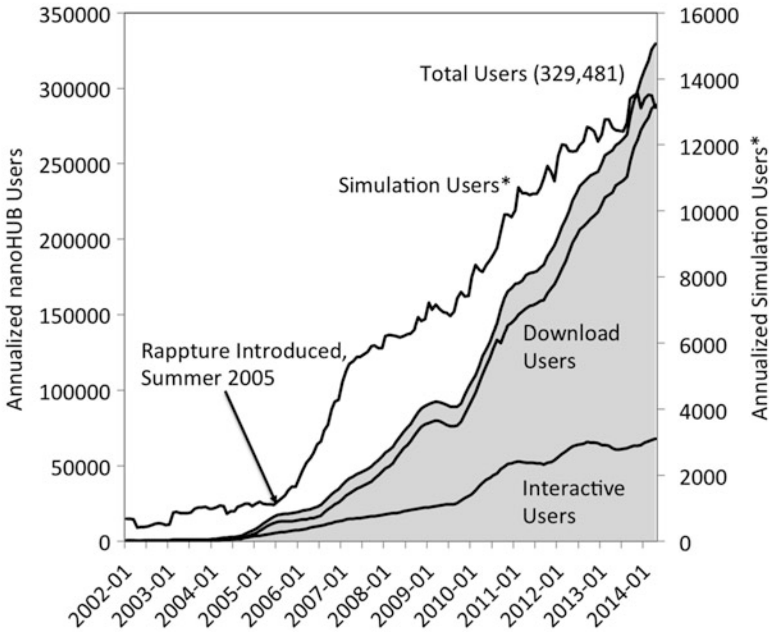

Fig. 2 Growth in total and simulation users over time. The introduction of the Rappture toolkit was instrumental in initiating the much more rapid growth rate, especially of simulation users

4.1 Tool Dissemination

Prior to nanoHUB's first publication of an online simulation tool, nanoscience researchers wishing to share their simulation tools were hindered by several difficulties. Consider this a two party relationship, where the supplying party is either an individual or a small group that has developed a simulation code and the consuming party is an individual, group, or institution that might wish to use that simulation code. The first barrier was awareness. The consumer might only become aware of the supplier's code through mention in the research literature. Such awareness has the time delay associated with publication of peer-reviewed articles, and the limitations on discoverability by common literature search methods at the time. At the same time, web search engines were becoming commonplace as a new mode of discovery. A second barrier was concerned with intellectual property. To distribute a simulation tool, the supplier would either need to distribute their source code, or create an installable binary version for the consumer. Until their research had advanced, suppliers were often uncomfortable with source code distribution and were reluctant to invest in the cost and time to create binary packages that could be easily installed on the wide variety of architectures, operating systems, and library versions owned by consumers. When a supplier was comfortable enough to distribute source code, a third barrier was the amount of effort required of the consumer to compile and install the tool locally. A fourth barrier was access to sufficient compute resources to run the tool once compiled. Not all consumers had access to enough compute power to effectively run the simulations. Finally, all of the barriers mentioned above were encountered again every time the original supplier revised the code, if the consumer desired access to the latest version. As a result, new releases reflecting the latest research results were not common.

nanoHUB interceded in this workflow by becoming a publicly available site that allowed suppliers to create and compile simulation tools, add web interfaces to them that could be accessed through a forms based web browser interface, and provide back-end compute resources (Kapadia, Fortes, & Lundstrom, 1997). As a result, suppliers could make their tools available on the web and accessible to search engines, even before publication in the research literature. They could avoid the intellectual property and installation package issues by retaining their source code and only building for one host environment. Consumers could access tools online without the significant effort of installing locally, and had access to back end compute resources that were otherwise unavailable to them. Updating to the most current version of the code became much easier. nanoHUB therefore added an active life-cycle management to the simulation tools.

4.2 Interface Construction, Interface Maintenance, and Sense-Making

With the initial workflow facilitated, a new need arose concerning the construction and maintenance of user interfaces. Nanoscience researchers are typically not web programmers, and therefore needed to engage such programmers to create interfaces for their tools. Often this meant that during the time a web interface was under construction, new research results would be incorporated into new versions of the simulation tool. By the time the web interface was finished and deployed, the underlying tool was no longer reflective of the most recent research. In addition, the interfaces were not significantly interactive, and therefore did not easily facilitate the user's examination and interpretation of results.

In response to these challenges, the Rappture (McLennan & Kennell, 2010) system was introduced. Rappture is a data and user interface management toolkit that allows a simulation tool programmer to easily construct a user interface on top of their core simulation code regardless of its language of implementation. Rappture also allows assembly and orchestration of parameters and data that feed the simulation. Further, Rappture's middleware layer allows for an interactive interface that can show tool run progress, that allows interactive inspection of results both textually and with powerful visualizations, and that enables side-by-side comparison of multiple simulation runs to help the user understand the cause and effect relationships as they investigate the simulation under various conditions. As a result, users

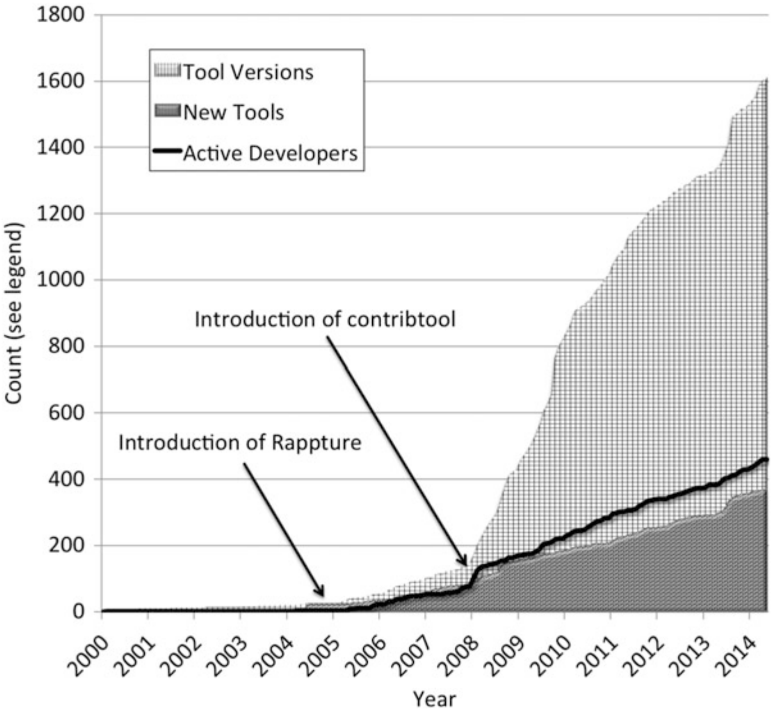

Fig. 3 This plot shows the relationship between the number of tool versions prior to and after the incorporation of Rappture and contribtool. The dramatic change in slope versus that of the rate of new tool creation indicates tool developers are much more often keeping their online simulations up to date with their most current results

were given a much richer experience. Also, tool developers no longer had long development cycles, and were able to keep their tools much more up to date as new versions were created, particularly with the introduction of a more automated update process called “contribtool” in late 2007 (Fig. 3).

4.3 Augmentative Information and Content Repurposing

From Fig. 2 there are clearly many more nanoHUB users than the subset that use simulation tools. This profile of the users evolved as a result of the community’s desire to understand on a wider basis what was being offered on nanoHUB. With Rappture introduced, nanoHUB made tools with rich interfaces available to a large community. This availability for each tool was originally expected to serve users in the same or similar research areas as the domain simulated by the tool. It became clear that additional support materials might be necessary in order to provide context for the simulation tools. This support took the form of user feedback mechanisms and a variety of categories of online resources in addition to the simulation tools. Indeed, Fig. 1 shows a slope change beginning near the time of the introduction of Rappture, indicating a rise in support materials accompanying the rise in simulation tools.

Modules were created for the nanoHUB content management system that allowed forum based discussions and question and answer capability around specific simulation tools. User feedback mechanisms were put in place for support ticket management and for a quality rating system. As a result, those who are contemplating the use of a simulation tool can see how well it is ranked by the independent community of users. They can often interact directly with the tool creators through the forums to gain a better understanding of the underlying principles of the simulation.

Many additional resource types were also created and opened for the public to make contributions, including animations, courses, downloads, learning modules, online presentations, presentation materials, publications, series, teaching materials, workshops, and most recently, databases and compact models. The initial intent of these resources was to supplement the simulations provided on nanoHUB by placing them in context. For example, such resources may contain technical information about the physical phenomena underlying the simulation, or about how the simulation may be positioned in classroom based learning contexts.

Another very popular nanoHUB feature has been the hosting of unique high quality video-based courses in nanotechnology that cannot be found anywhere else. These courses were originally standard courses over a whole semester consisting of about 45 lectures of 50 min each. Recently the course format has evolved into 5-week courses that are delivered in 20-min segments with active testing. This format is embodied in nanoHUB-U.

Supplemental information has likely assisted in the repurposing of tools, particularly with respect to classroom use. Based on a user similarity calculation and clustering algorithm (to be published separately), classroom behavior can be detected as groups of users utilize simulation tools in a time-coordinated manner (Fig. 4). The classroom use has grown significantly over time, to where over 20,000 students in over 1,100 classroom-like settings have been detected over the life of nanoHUB.

5 A Platform for Sociotechnical Research

Although the primary goal of nanoHUB has been to serve nanoscience researchers with simulation tools, the evolution of the capabilities offered on nanoHUB and the growing user audience has opened an entirely different research area. Every action over a period of more than 10 years has been recorded, including every resource accessed, every simulation run, and the parameterization of those simulation runs.

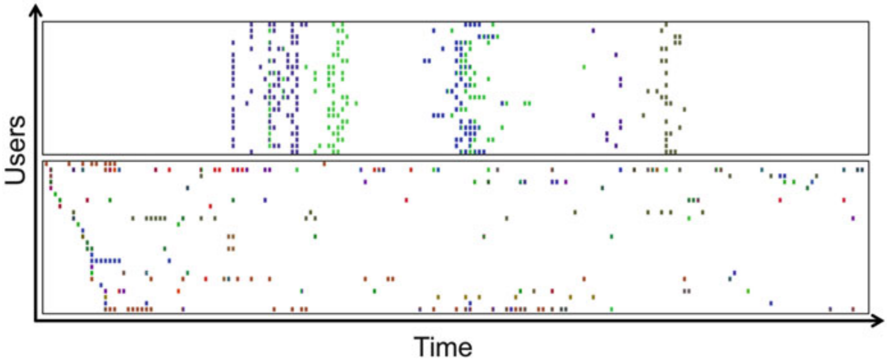

Fig. 4 This figure shows simulation activity over time. Each horizontal row corresponds to a single user. Each vertical column represents a given day. Each *dot* represents a user activating a simulation tool on a given day. Each unique shade corresponds to a different tool. The plot on *top* is an example of coordinated activity, corresponding to likely activity in a classroom scenario. The plot on *bottom* illustrates to non-coordinated activity

As such, nanoHUB has amassed a chronicle of a scientific community's online behavior over a meaningful timescale.

Figures 5 and 6 characterize the simulation data. Over the life of nanoHUB, 3.4 million simulations have been run in 697,725 sessions. The longitudinal assembly of sessions for a given user provides a trajectory of the direction, thoroughness, and pattern the user employed as they investigated the phenomena modeled by the simulation tools. Figure 6 illustrates an initial study of the novelty of the simulations during the period from early 2007 through mid 2011. One might expect simulations run in a classroom to be somewhat repetitive. Alternatively, one might expect simulations run for research to exhibit a high variety of differences. The concept of a simulation signature is used to identify the differences between simulation runs. Identical runs, such as those performed by students, will have a common signature. Different runs, like those run by researchers, will have different signatures. The growing variety of signatures indicates a collective user group that continues to innovate and explore new aspects of simulated phenomena.

For the resources that are not simulation tools, patterned use also emerges. A time and location based clustering method (to be published separately) has been developed to detect when groups of people from nearby locations exhibit time coordinated access of these resources as one might expect in a classroom setting. The analysis for the year of 2012 shows that 2,194 such coordinated clusters were found that utilized 1,319 resources, indicating that a significant number of these resources are being used as supporting information in the educational process. Figure 7 illustrates the breadth of use by such clustered users. There are 600 resources used by least 50 clustered users, and 200 resources with at least 200 clustered users. The lack of a steep decline in this relationship indicates that the classroom behaviors are served by a diverse set of resources, and not a small core.

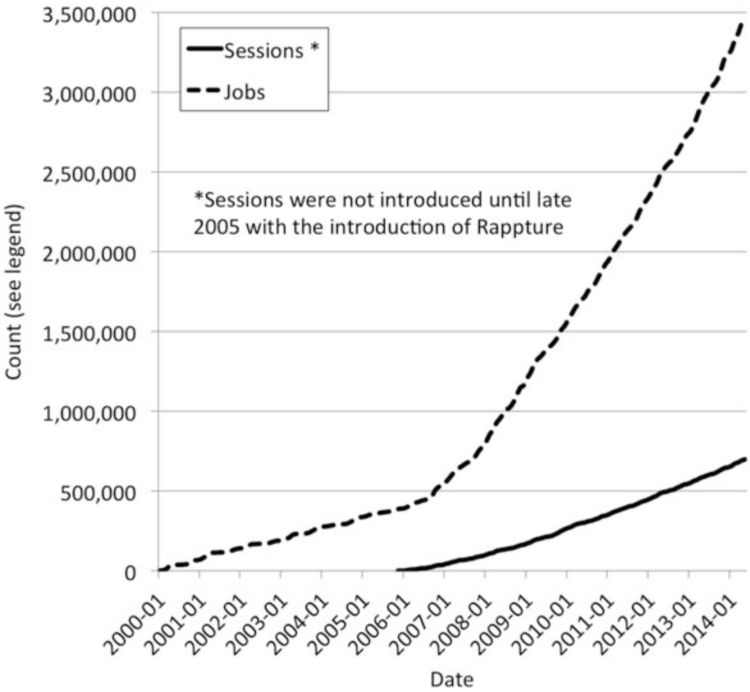

Fig. 5 This figure shows the number of simulation sessions and the number of simulation job runs over time. The significance of a session is that it represents an episode of one user's investigation, containing perhaps many individual simulation runs. The relationship between sessions and jobs indicates that simulation use is not casual: users undertake a significant amount of investigation at each sitting

These data suggest that nanoHUB has served as an enabling platform for the nanoscience community, where members can supply and consume resources, and thereby shape each other's experience. These data also suggest that nanoHUB has not played a passive role in shaping how the nanoscience community develops knowledge. To the contrary, each addition to nanoHUB to enable a new aspect of the users' workflows has changed the community's behavior while engaged in those workflows, and has also been repurposed by others for additional objectives. Simulation tool developers spontaneously increased the number of tool versions as Rappture enabled them to easily keep current. Users spontaneously began using simulation tools in classroom settings and migrated research results into the classroom with a median time of less than 6 months (Madhavan, Zentner, & Klimeck, 2013). Users spontaneously contributed supporting materials that were not simulation tools, and spontaneously began adopting those in classroom settings.

Aside from usage based metric evidence like that produced here, resource consumers have also documented their use of nanoHUB in the scientific literature by citation, as they would any other researcher. By this measure, the "persona of

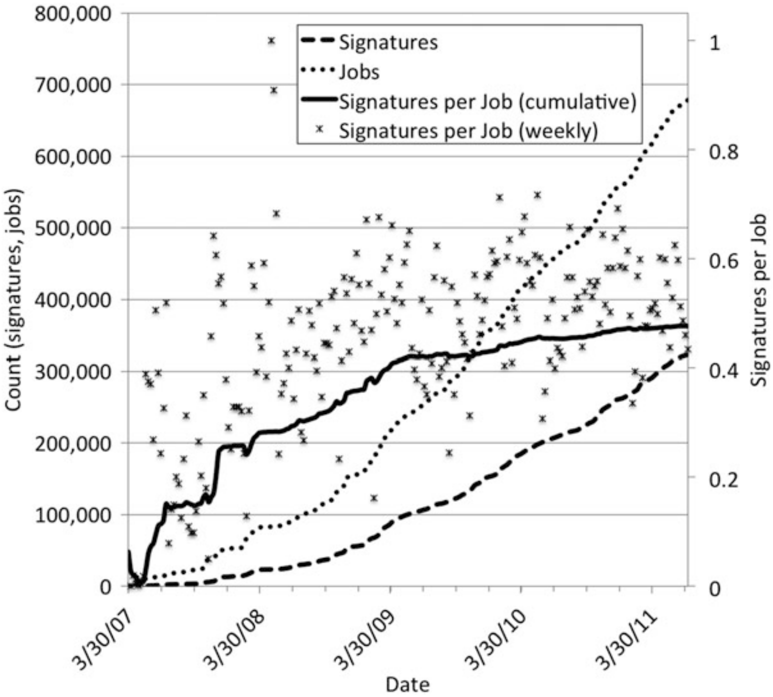

Fig. 6 This figure shows the growth in the number of signatures of tool runs from early 2007 to mid 2011. A signature is a collection of input parameters and their values. If two such collections are identical, they have the same signature. Nearly half of the jobs exhibit signature duplication (as one might expect for repetitive education use). Conversely, the other half are unique (as might be expected in a research environment). The growing number of unique signatures indicates that the community has not stagnated in its investigations, and continues to explore new regions of parameter space. This is a measure of the generative capacity of the nanoHUB user group

nanoHUB" has attained an h-index level in just over 10 years that is on par with that of career achievements of National Academy of Engineering members (Fig. 8).

Data like those described here are forming the basis of many new lines of investigation of the online behavior of this community and will be periodically released to the sociotechnical science research communities for additional studies of the online conduct of science. The purposes are for understanding the past, but more importantly for learning new ways in which the nanoHUB platform may serve and shape its community in the future. Technology changes how people interact as they engage in science (Orlikowski & Scott, 2008) and acts in shaping behavior (Bostrom, Gupta, & Thomas, 2009; Majchrzak & Markus, 2013; Orlikowski & Scott, 2008; Yoo, Boland, Lyytinen, & Majchrzak, 2012). With a large user community, nanoHUB is at the forefront of demonstrating these theories in the online conduct of science.

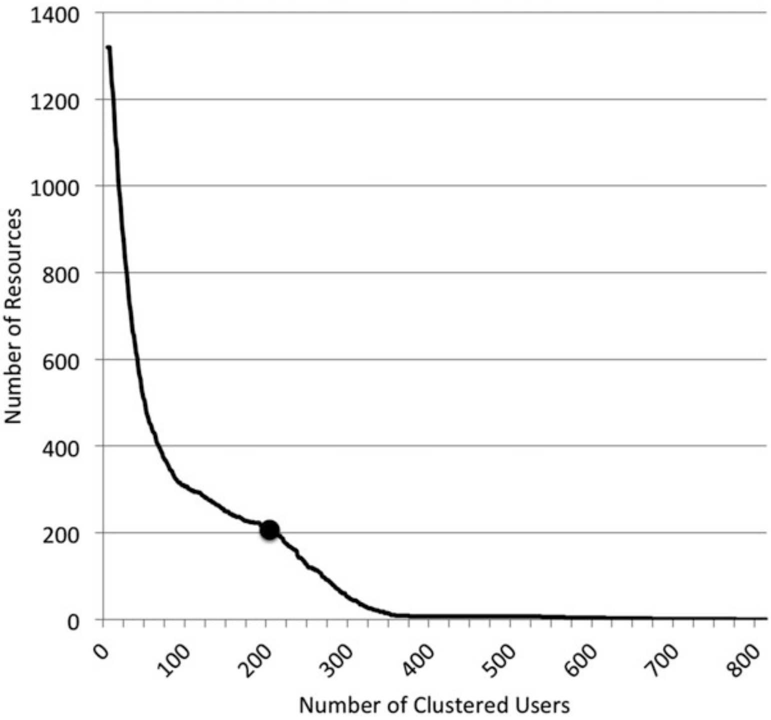

Fig. 7 This figure shows number of resources that have a set of users of at least a given size that exhibit clustered behavior. The labeled point for example indicates that slightly more than 200 resources have at least 200 distinct users exhibiting clustered behavior

6 Beyond Social Media Platforms: The Evolution of the Community Peer

In the introduction and in the previous section two provocative comments were made: (i) the medium of an online interaction environment becoming an active contributor to its own body of knowledge and (ii) that a platform like nanoHUB might have a persona. A key attribute of nanoHUB that makes it unique relative to other social media platforms resides in its nexus of interaction. Recall that for Twitter, Facebook, Wikipedia, and LinkedIn this nexus is a short text message, a status update, an article, and a personal profile, respectively. For nanoHUB, it is a simulation tool. Forums like Twitter, Facebook, and LinkedIn have passive nexuses: consuming information from them produces no new information other than that an individual consumed data. Simulation tools in nanoHUB, on the other hand, are active nexuses: consuming from them produces new information about a physical phenomenon under specified conditions. nanoHUB and science gateways like it that will emerge in the upcoming years are places for not just talking about science, but for conducting it.

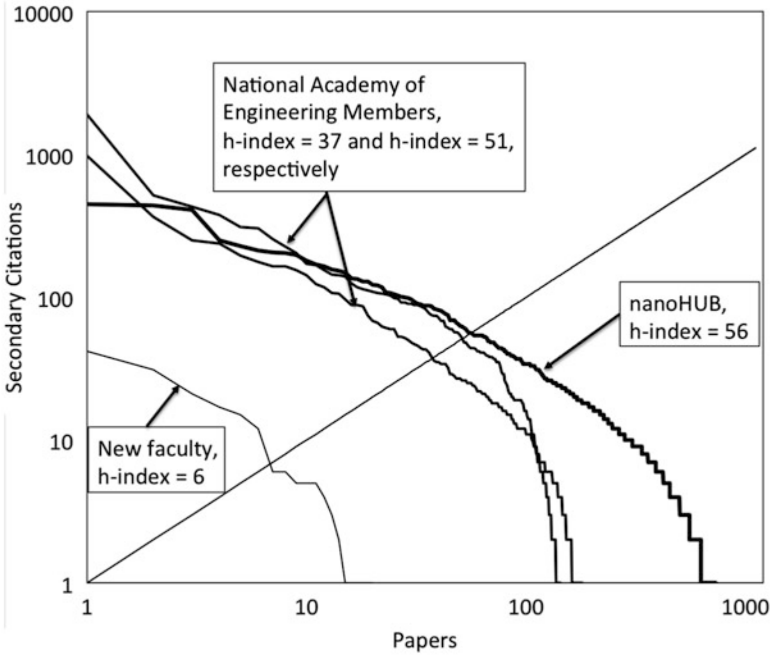

Fig. 8 Utilizing secondary citation counts, an h-index can be determined for nanoHUB-related papers and compared to both typical young researchers and high-achieving researchers, such as members of the U.S. National Academy of Engineering. This plot illustrates that nanoHUB collectively compares quite favorably to high-level researchers

A new generation of capabilities that exploit the active nexus will prompt nanoHUB more strongly into the role of a knowledge-generating participant within its community. User explorations based on simulation tools will be used as templates from which to interpolate and extrapolate, producing knowledge as nanoHUB automatically fills in gaps between parameter ranges explored by users and extends their ranges beyond the regions they tested. nanoHUB will proactively inform users of interesting discontinuities and local optima. Further, users will be able to explore the parameter spaces studied by the community as a whole, visually identifying areas of interest that have been sparsely explored, and allowing nanoHUB to optimize the detailed study of those areas of interest through uncertainty quantification approaches (Hunt et al., 2015). nanoHUB will enable new incremental publishing mechanisms where an anchor publication about a simulation tool may be automatically augmented by groups of users employing the same tool to study different regions of parameter space as they explore nanodevices under conditions not originally conceived by the anchor publication. The active nexus will allow systems like nanoHUB to do all of these things automatically; defining its place as a participant in the community.

The notion of the active nexus of interaction need not be unique to nanoHUB. Such nexuses are possible in many scientific disciplines, and therefore make it likely that the domain of science, rather than that of the everyday consumer, is where the social medium first will transform into a peer of a different sort. The social medium will become a ‘shaker’ rather than just a facilitator of the process of scientific discovery. It will participate in its community, fill in gaps, highlight interesting aspects of scientific phenomena, and assist with the dissemination of results within the community at rates not possible with human participation alone.

Acknowledgments Mark S. Lundstrom founded nanoHUB.org in 1998. In 2005, Michael McLennan created the Rappture Toolkit and Rick Kennell wrote the scalable middleware of HUBzero that, respectively, enable and power interactive nanoHUB simulations. The Network for Computational Nanotechnology (NCN) manages nanoHUB.org and has been funded by various NSF Awards Nos. EEC-0228390, EEC-1227110, EEC-0228390, EEC-0634750, OCI-0438246, OCI-0832623 and OCI-0721680.

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