Motivations for Contributions in an Online Scientific Community: Virtual Rewards, Social Messages and 'Observation Cues'*

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Abstract

Online communities such as Science HUBs, Gateways, or Portals foster the research and education oriented dissemination of rapidly evolving information and break new ground in the publication process. These communities live by the hosting of high quality community contributions. Understanding the motivations for community participation is critical for the communities' further development. However, there is a lack of experimental data to guide the development process since these science HUBs are considerably different from other types of online communities. We conducted a field experiment in the world's largest virtual nanotechnology user facility, *nanoHUB.org*, which serves over 10,000 registered and over 165,000 unregistered users annually. We investigate the effect of awarding virtual points as compared to social messages and 'observation cues' on user participation. 30,000 registered users are randomly selected into one of several treatments, and receive e-mails soliciting their participation in an online survey. In one treatment, users receive virtual points for filling out the survey. In another treatment, users are exposed to a visual observation cue previously shown to increase pro-social behavior. Finally, we vary the social message, either emphasizing the private benefit to the user or the social benefit to the community of completing the survey. We find that participation and completion rates are increased for groups receiving the virtual points or the private benefit messaging The visual observation cue does not have a significant effect. Unlike previous studies, which generally target leisure communities, our study targets a scientific community. Additional survey results suggest that users of this community may participate more due to self-interest than social interest.

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1. Introduction

Online communities, such as discussion groups, question and answer markets, collaborative workgroups and social spaces are important sources of information sharing, knowledge generation and social support for individuals. Online communities rely on many types of user contributions, from high-effort contributions such as usable informational content to low-effort contributions such as ratings of products or content. Many of the most popular online communities could not exist without sufficient user-contributed content; in fact, online communities often fail due to under-contribution (Beenen et al., 2004). The online community and engagement concept is well established in commercial and social contexts. In comparison to such communities, science and engineering oriented web communities for education and research are still in their infancy.

National research funding agencies support various science HUBs, Gateways, or Portals to advance broader dissemination of results for education and research impact. Such web-based communities are supposed to foster the dissemination of rapidly evolving information and alter the landscape of publishing. High quality user contributions are critical to the success of such communities. Understanding why individuals contribute to these communities, and how individuals can be impacted by carefully designed reward systems, reputation systems and prompts is critical for the communities' further development.

Science HUBs are considerably different from social online communities, and to date we face a lack of experimental data to guide the development process. Nevertheless, some insights can be gleaned from related research. Extensive research has been conducted on member-initiated or organization sponsored communities in which users maintain a social relationship with the community or in which contributions are seen as a transaction with others in the

community. Such studies followed from an active area of research in economics on helping behavior, reciprocity, public goods provision, and charity donations. Separate bodies of work have addressed improving contributions to question and answer sites (Rafaeli et al., 2007; Harper et al., 2007; Chen et al., 2007), contributions involving a high amount of effort (Yang et al., 2008; Adler et al., 2008; Chaterjee and Pye, 2008), and encouraging posting reviews online (Chen et al., 2009; Beenen et al., 2004; Ludford et al., 2004; Farooq et al., 2007). These studies have focused both on the effectiveness of existing systems in place and on the impact of new systems. Researchers have posited that at least a portion of contributions arise from intrinsically motivated users, who gain a sense of satisfaction for having helped the community (Raban and Harper, 2008; Raban and Rafaeli, 2007). The greatest benefit from a users' contributions is enjoyed by the rest of the community rather than by the contributor; therefore, there is incentive to under-contribute, 'free-riding' on the contributions of others. Carefully designed reward systems, reputation systems or social messages can alleviate this problem by providing an extrinsic motivation for contributing.

We conducted a field experiment in the world's largest virtual nanotechnology user facility, *nanoHUB.org*, which serves over 10,000 registered and 165,000 unregistered users annually. The experiment was designed to investigate the relative effects of several different ways in which users could be extrinsically motivated to contribute to this community. 30,000 registered nanoHUB users are randomly selected into several treatment groups, and receive e-mails soliciting their voluntary participation in an online survey. Participation benefits fellow community members and the host of the community, because user input is used to improve the site and secure future funding.

We do not claim that participation in an online survey is the same as, for example, answering a question posed by another nanoHUB user to the Q&A forum on the site. However, we propose that responding to the survey for the benefit of the community is an instrument, or proxy, for contribution and participation on the site itself. Prompts that are effective at eliciting survey responses may also be effective at eliciting other types of low-cost contributions of effort to the site.[1]

Related research has found evidence for the impact of awarding monetary incentives for contributions (Chen et al., 2007), for the positive effect of social information on contributions (Chen et al., 2009; Rashid et al., 2006; Ludford et al., 2004; Beenen et al., 2004), and for the value of recognizing contributors (Andreoni and Petri, 2004; Rege and Telle, 2004; Anderson and Stafford, 2009; Savikhin and Sheremeta, 2010). It has been posited that while monetary incentives entice participation, social incentives increase persistence (Raban and Harper, 2008).

We contribute to this literature by providing a direct comparison of a number of very different approaches on an individual's participation and completion of an online survey, comprising of awarding virtual points, including messages emphasizing private versus social benefits of contributing, and displaying visual 'observation cues.' All of these approaches could be effectively implemented on the site to motivate other types of low-cost contributions. Virtual points can be redeemed on the site for a limited number of rewards, and can therefore be interpreted as a quasi-monetary incentive to contribute.[2] The effect of private and social benefit messaging has been measured in leisure, but not science, communities. The effect of

[1] Note also that while filling out a survey may elicit a different psychological response than contributing directly to the site, and so survey participation rates may be different from other site-specific participation rates, we are interested in the treatment effect of the different prompts and target our evaluation using the randomized study.
[2] Specifically, filling out a survey (the action taken by participants in the experiment) results in being awarded 250 points. 2 items are available on the site, a gray t-shirt with the nanoHUB logo and a navy blue t-shirt with the nanoHUB logo. Each shirt costs 500 points, including shipping.

'observation cues' has been measured for monetary donations to charity, but has not been tested in this context.

Morover, compared to most research in this area, our experiment deals with a very different type of online community. The community we investigate, nanoHUB, is a scientific nanotechnology community that is beginning to serve as a beacon to many other similar communities in different fields of Science and Engineering. In fact, nanoHUB has spun out its underlying technology into an open-source package titled HUBZERO, which in turn powers 30 other HUBS. The study presented here many have implications for the design of incentive systems for this site as well as new Science and Engineering HUBs in the future.

We find that participation and completion rates are increased for the group receiving the virtual points. Participation, but not completion, is higher for the group exposed to the private benefit messaging as compared to the group exposed to the social benefit messaging. The observation cue does not have a significant effect. The different design aspects of systems aimed at increasing contributions, such as the type of information to display and types of incentives to provide, play an important role in determining the success of online communities.

2. Theory Development

The public goods framework (Ledyard, 1995) has addressed some of the most fundamental issues centered on contributions to society. We propose that a setting in which the user supplies content online, either by responding to a survey for the community, rating a transaction or by contributing information, can also be modeled using this framework. In a simple linear public goods game, N identical risk-neutral players choose a portion of their endowments e to contribute to a public good (Groves and Ledyard, 1977). Player i's contribution

c_i to the public good is multiplied by a marginal per capita return (MPCR), $m, \in (0,1)$ and split between *N-1* other players in the group.

Agents possess a limited amount of effort or time available to expend towards contributing, represented by *e*. Agents incur the cost of expending time and effort to develop and contribute content, represented by *c,* which is also the amount of effort contributed. The contribution of this content benefits the entire community. In this context, 'free riding' can be better described as 'lurking,' a passive form of participation that allows users to enjoy the benefits of the community, without incurring cost of contributing content.[3]

The value of the contribution to each community member, including to the contributor, is represented by the marginal per capita return (MPCR), *m*. Each individual may receive an additional MPCR that represents the private benefit of the contribution, represented by $q_i, \in (0,1)$. Thus, the payoff for player *i* is given by $\pi_i=e-c_i+q_ic_i+m\Sigma c_j$. The equilibrium is to contribute the full endowment of effort, $c^*=e$, as long as the benefit from contributing is greater than 1, or $(q_i+m)>1$. When $(q_i+m)<1$, the equilibrium prediction of this model is to contribute nothing or 'free ride', $c^*=0$. When $(q_i+m)=1$, the player is indifferent between any level of $c^* \in (0,e)$. q_i includes both intrinsic motivators (which can differ by individual) and extrinsic motivators (exogenously applied by the community designer). Intrinsic motivators include an increase in the agent's utility from contributing due to altruistic preferences. Extrinsic motivators to contribute include site-specific virtual points This model suggests that incorporating extrinsic motivators to contribute will increase the contribution level.

Conjecture 1: Virtual points increase the contribution level.

[3] Note, however, that researchers have found that 'lurkers' may become active members of the community after familiarization with the site (Soroka and Rafaeli, 2006).

Suppose that individuals have uncertainty about the values of q or m, because assessing the actual value of informational content is a complicated task. $f(q_i)$ and $g(m)$ are functions representing the values of marginal per capita return estimated by player i. Each player's profit vector is thus $\pi_i=e-c_i+f(q_i)c_i+g(m)\Sigma c_j$. In this case, individuals may use signals such as information provided by the website to infer these values. Information that increases the assessed value of the social benefit of a contribution increases $g(m)$, while information that increases the assessed value of the private benefit of a contribution increases $f(q_i)$. Thus, private benefit messaging directly affects the user's perceived private benefit to contributing and translates to a greater expected contribution level. The social benefit messaging affects the user's perceived benefit to the group from contributing.

It is widely acknowledged that individuals have heterogeneous social preferences, ranging from purely selfish to varying levels of altruism (Gintis et al., 2005). If the agent is altruistic, an increase in $g(m)$ may also indirectly increase $f(q_i)$. Our experimental study measures the effect of private benefit messaging relative to the effect of social benefit messaging. Unfortunately, due to logistical constraints we are unable to compare to a baseline without benefit messaging.

Conjecture 2: Private benefit messaging increases contributions by increasing $f(q_i)$ for all players, and will be more effective than social benefit messaging which increases $f(q_i)$ but only for players with altruistic preferences.

Research in evolutionary biology has found that humans are sensitive to the act of being observed and react by increasing their level of cooperation within their peer group. In addition, biologists find that human beings are sensitive to a certain type of 'observation cue' stemming from a physiological adaptation for facial recognition. Exposure to 'eyespot cues,' or drawings

of eyes or of dots representing eyes, activates the fusiform area of the brain, and may 'fool' the individual to unconsciously believe that he or she is being observed (Tong et al., 2003; Johnson and Morton, 1991). Several recent papers in economic psychology have harnessed this information, using treatments consisting of exposing potential donors to 'eyespot cues' and have found that such cues indeed increase monetary donations to charities, in particular for 'in-group' donors (Haley and Fessler, 2005; Rigdon et al., 2009; Bateson et al., 2006; Krupka and Croson, 2009). We posit that such an effect would work through an increase in the perceived private benefit of contributing, $f(q_i)$, This increase could occur due to reputational concerns, or due to a heightened realization of the existence of the community (which would cause altruistic individuals to have higher $f(q_i)$).

Conjecture 3: The observation cue will increase contributions.

3. Experimental Setting

Science and engineering HUBs typically have additional operational or user requirements beyond the classic web 2.0 online communities. They typically revolve around the hosting of nascent modeling and simulation tools or recent scientific data. These tools or data sets need to be accessible and usable by a broad set of users, rather than computational experts. Until recently, such user friendly HUBs were not available to the broader scientific and engineering community. In recent years, government agencies have supported the development of such HUB technologies and the contribution processes into these HUBs.

This field experiment was conducted on nanoHUB. nanoHUB is an online community for research, education and collaboration in nanotechnology. According to a community topology discussed by (Porter, 2004). *nanoHUB.org* is an organization-sponsored community in which

users maintain a professional relationship with the community. At the time of publication, nanoHUB had over 37,000 registered members. *Members* are students, university faculty and staff, government employees, or scientists in the private sector, and work predominately in the engineering or science fields. Over 10,000 of these registered users interacted with the site in the year 2010 alone. The site is a unique online infrastructure that facilitates a collaborative environment among nanoHUB members, including a discussion forum and user-contributed online resources and simulation tools (Klimeck et al., 2008; Strachan et al., 2010). Access to simulation tools requires a free user registration where users provide information about themselves such as name, affiliations, research interests, and an email address. nanoHUB served in total over 160,000 unique users / IP addresses in the year 2010 with other content items like nanotechnology courses, tutorials, and seminars. The huge discrepancy in numbers of unregistered and registered active users is indicative of engagement issues on nanoHUB.

Resources and simulations are actively contributed and used on nanoHUB, and similar to other online communities, the contribution pattern follows the power law distribution in which a large subset of users contribute nothing, and a few members perform most of the work (Adamic, 2000; Adamic et al., 2003). However, the discussion forum is very rarely used and tools are rarely reviewed, even by the most active members.

To date, over 780 individuals (2% of registered members) have published more than 2,500 total content items on nanoHUB. These resources represent high-effort contributions, such as simulation tools and course lectures, tutorials, and seminars. The contributors are motivated by a private benefit (visibility to the online community, publication space, and 'bragging rights.'), a teaching benefit for simple dissemination to their own class, supporting a research collaboration with a remote partner, or by a formal deliverable commitment due to government

funding. These high-effort content contributions provide in general a great social benefit to the nanoHUB community, as this content is used as part of new research and expanded educational activities. Usage data for each publication is provided to the contributors as a documentation of their public outreach program, which they in turn can use for new research grant applications.

Contributing low-effort content, such as answering questions on the discussion forum or rating simulation tools, provides much lower private benefit, yet great social benefit to the nanoHUB community. The ratings of resources allow the nanoHUB to deliver the most relevant and beneficial content to users, and enhance the scalability and viability of the HUB, yet less than 0.5% of users of a tool rate it (for example, the most popular simulation tool *PN Junction Lab* has had 4,426 users but only 1 review; the more frequently reviewed tool *QC Lab* has had 3,761 users but only 11 reviews; another slightly less popular tool *CNDO* has had 1,843 users and 0 reviews). In addition, answering a question on the site also has a great benefit, since lack of activity in the Q & A forum reduces its effectiveness. Only 13 questions were asked in the last month on the site, and of these only 2 had answers. While a tool may take months or years to develop and make compatible with the site, a rating takes 1-2 minutes of a user's time.

We conducted this research on what is considered a low-effort, low private benefit contribution, answering a survey on nanoHUB. Relative to high-effort contributions like posting simulation tools or lectures, answering surveys does not provide recognition, bragging rights or publication benefits, and takes significantly less time (a maximum of 15 minutes relative to several weeks or months). Relative to low-effort contributions such as rating a tool or answering a question, responding to the survey takes about the same amount of time or effort, while completing the survey is slightly more time consuming. In particular, we wanted to measure the

treatment effect of different extrinsic motivators on doing a low-effort, low-private benefit task for nanoHUB.org users.

4. Experimental Design

30,000 randomly selected community members with a *nanoHUB* account (thereafter called 'users') were randomized to receive one of six possible surveys. The surveys varied in three different ways. First, we varied whether users were eligible to receive site-specific virtual points (called "nanos" on nanoHUB) for completing the survey. Nanos can be exchanged for a limited number of rewards on the site's "online store" and each individual in this treatment received 250 nanos for completing the survey (equivalent to exactly half of an 500 point t-shirt, the only product on the site store). Second, we varied the type of social message: the message either emphasized the private benefit gained by the participant or the social benefit gained by the community from filling out the survey. The private benefit message read: '[…] evaluate how nanoHUB can better serve you […] help to make our site an even better information resource for you.' The social benefit message read 'evaluate how nanoHUB can better serve its users […] help make our site an even better information resource for your fellow nanoHUB community members.' Finally, we varied whether or not the user was exposed to the 'three dot' observation cue. As in related work, in the treatments with the cue, three dots in the eyes/mouth configuration were displayed using asterix (*) at the top of the email and in a small bitmap image at the top of the survey page – see Figure 1. In the treatments without the cue, the same three dots appeared upside down in both locations (Baseline).

Figure 1: Observation Cue

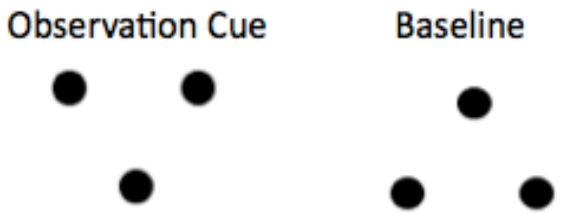


Table 1 summarizes the different treatment groups. PB-250nC versus PB-0-nC and SB-250-C versus SB-0-C were conducted in order to compare the effects of offering reward points for survey completion. PB-0-C versus SB-0-C and PB-0-nC and SB-0-nC were conducted in order to compare the effects of private versus social benefit messaging. PB-0-C versus PB-0-nC and SB-0-C versus SB-0-nC were conducted in order to compare the effects of the 'three dot' pro-social cue. Finally, we measure how pro-social cues interact with social benefit messaging by comparing SB-0-C, SB-0-nC and PB-0-C and PB-0-nC.

Table 1: Treatment Groups

	Social Cue	**No Social Cue**
Private Benefit, 250 nanos		**(PB-250-nC)** Sent to 5,000
Private Benefit, 0 nanos	**(PB-0-C)** Sent to 5,000	**(PB-0-nC)** Sent to 5,000
Social Benefit, 250 nanos	**(SB-250-C)** Sent to 5,000	
Social Benefit, 0 nanos	**(SB-0-C)** Sent to 5,000	**(SB-0-nC)** Sent to 5,000

We followed the same protocol for all treatments. Each survey was sent out on two different dates (a Saturday and a Tuesday in late August, 2010), for a total of 12 separate surveys that were sent out via e-mail. The surveys were sent on behalf of the nanoHUB assessment team, and users were not aware that they were participating in an experiment. Surveys were implemented using *SurveyMonkey.com*. Users received an e-mail solicitation that included a link to the

nanoHUB survey page. Users were uniformly informed that participation would take 'no more than 15 minutes of your time.' In order to complete the survey, respondents were instructed to click on the link, which took them to a nanoHUB welcome screen that repeated similar information to the email, and also contained a link to the *SurveyMonkey.com* survey. In treatments where respondents were eligible to receive reward points, upon completion of the survey, respondents re-visited the nanoHUB site to receive points. Respondents were not required to log into the nanoHUB site in order to complete the survey, but were required to do so to claim points upon completion of the survey. This methodology followed the existing practices for collecting survey information on nanoHUB. Some participants had participated in (non-experimental) surveys in the past.

4. Experiment Results

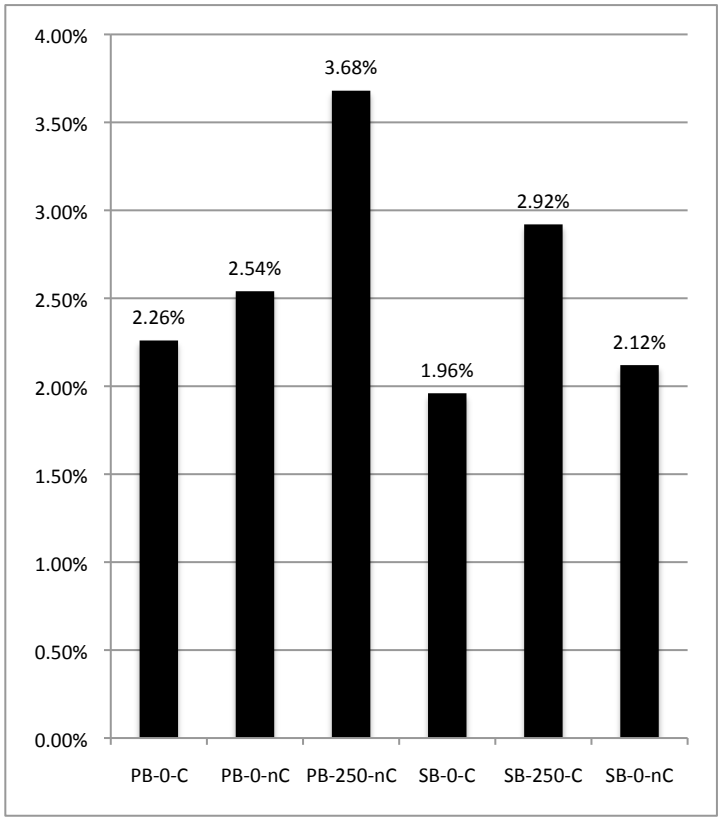
Table 2 summarizes the response rate, completion rate, and days to response for each treatment group. Response rates ranged from 1.96% in SB-0-C to 3.68% in PB-250-nC. We observed high completion rates – over 70% of surveys were completed across all treatments. Users took on average between 5 and 7 days to complete the survey. Figure 2 displays the response rate across treatment groups.

Table 2: Response Rate, Completion and Days to Response*

		Response Rate	Completion	Days to Response
1.	**PB-0-C**	**2.26%**	**73.45%**	**6.80** (7.11)
2.	**PB-0-nC**	**2.54%**	**76.38%**	**6.31** (6.74)
3.	**PB-250-nC**	**3.68%**	**85.87%**	**7.15** (7.60)
4.	**SB-0-C**	**1.96%**	**79.59%**	**6.96** (8.01)
5.	**SB-250-C**	**2.92%**	**84.93%**	**5.83** (4.92)
6.	**SB-0-nC**	**2.12%**	**80.19%**	**6.69** (7.73)
**Values in parentheses represent the standard errors*				

We find support for the conjecture that offering virtual points increases response and completion rates relative to not offering points. Response rates in groups receiving the offer of points were 27-31% higher relative to response rates in groups not receiving points. Comparing response rates of 3.68% in PB-250-nC with response rates of 2.54% in PB-0-nC, we find statistically significant differences (χ^2 test p-value < 0.01). Likewise, comparing response rates of 2.92% in SB-250-C with response rates of 2.12% in SB-0-nC, we find statistically significant differences (χ^2 test p-value = 0.01).

Figure 2: Response Rates by Treatment



Completion is also greater in the group receiving points, and this is significant for the private benefit treatments (χ^2 test p-value = 0.03 for PB-0-nC versus PB-250-nC and p-value = 0.28 for SB-0-C versus SB-250-C). Because participants could decline to answer questions, our best proxy for completion was to count any survey in which the at least one of the four questions

on the last page was filled out complete. Other definitions of completion (answering two out of four questions, etc.) yielded similar results. Combining all four treatments and conducting a probit regression on *completion*, we find a coefficient of 0.29 with *p*-value of 0.02 on the points variable, and no significance on the social versus private benefit control.

Result 1: Offering virtual points significantly increases online survey response and completion rates of registered nanoHUB users.

The finding that providing virtual points, which is a quasi-monetary incentive, increased response and completion rates is intuitive and is predicted by our theory. This result is also in line with results from many related studies in economics, which find support for the value of monetary and quasi-monetary incentives (Jobber et al., 2002; Chen et al., 2007). However, it is a non-trivial result. For example, the alternative theory of motivation crowding suggests that applying a monetary incentive to an activity that is considered morally or socially good may actually *decrease* contributions (Frey et al., 2001).

Offering monetary or quasi-monetary incentives can be costly or simply unaffordable for online communities and it may not always be cost effective in practice. We therefore also wished to test non-monetary systems to promote contributions. While our design does not test the direct impact of private or social benefit messaging due to logistical constraints, we compare the relative effectiveness of this social information for the nanoHUB community. We find support for the conjecture that private benefit messaging is more effective than social benefit messaging. Private benefit messaging increases participation rates by 13% - 17% relative to social benefit messaging. A probit regression on participation rates accounting for both observation cues and private benefit versus social benefit messaging shows differences that are significant at the 5% level (*beta* = 0.07, *p*-value < 0.05). However, individual tests comparing

PB-0-C to SB-0-C and PB-0-nC to SB-0-nC do not show statistically significant effects (χ^2 test *p*-value = 0.16 for PB-0-C versus SB-0-C and *p*-value = 0.29 for PB-0-nC versus SB-0-nC). While we did not include direct comparisons of private versus social benefit messaging in the groups receiving virtual points, these results may imply that the private benefit messaging is most influential when combined with virtual points.

Our finding that private benefit messaging is more effective than social benefit messaging in this scientific community contradicts the result of Rashid et al. (2006), who studied a leisure community. Rashid et al. (2006) found that in the leisure community in which users rate movies, private benefit messaging was *less* effective than social benefit messaging. In Rashid's study on *MovieLens,* users were 4.8% *less* likely to rate a movie on when they were shown 'smilie emoticons' that indicated a value to self than when they were shown 'smilie emoticons' that indicated value to peers. This difference can be explained by the difference in context: on *MovieLens,* individuals visit for leisure and may feel more socially connected to their peers, while on nanoHUB, individuals visit for intrinsically competitive educational and research purposes and may be more self-oriented and less socially connected.

Result 2: Private benefit messaging is significantly more effective than social benefit messaging at motivating registered nanoHUB users to participate in the survey (in treatments with points).

We also measured the impact of the observation cue, three dots, on participation and completion. We expected the observation cue to have a positive impact on participation and completion, in particular in treatments where social benefit was stressed. However, we do not find differences in the participation or completion rates with and without the observation cue in the direction we expect. Predicted response rates are in the opposite direction and the difference

is not significant (PB-0-C response rate 2.26%, PB-0-nC response rate 2.54%, χ^2 p-value = 0.36, and SB-0-C response rate of 1.96% and SB-0-nC of 2.12%, χ^2 p-value = 0.57).

Related work argued for the positive benefit of observation cues (Haley and Fessler, 2005; Rigdon et al., 2009; Bateson et al., 2006; Krupka and Croson, 2009). However, we do not find significant differences in participation rates with and without the observation cue. Several differences between our design and the experiments conducted in previous work may shed light on this discrepency. Krupka and Croson (2009) conducted a mail campaign soliciting donations for a local library, and found that the effect of the observation cue was driven primarily by donor type – only existing donor response rates were significantly affected by the eyespot treatment. Krupka and Croson (2009) posit that observation is effective among those individuals who are members of the group (i.e., previous donors), but not for those who are not.

While registered nanoHUB users are all members of this online community, only 2% have previously submitted high-effort contributions, and even a fewer percentage have submitted low-effort contributions to nanoHUB. Thus, our ability to determine an effect is diluted by non-contributors who participated in the experiment. While we do not have actual historical data of participants' contributions, we had only 11% of participants who self-reported that they have ever contributed a high-effort resource to nanoHUB in the past. We do not find that those who contributed in the past are more influenced by observation cues than those who haven't – approximately 9.7% of respondents in observation cue treatments have contributed in the past, and 11.9% of respondents in non-observation cue treatments have contributed in the past.

Because this is a scientific, rather than leisure, community, another explanation could be that these users may have greater social distance from the community and may not be as responsive to observation cues. If the observation cue works primarily by increasing response

rates of individuals who were already contributing, as in the library donations example, and (as evidenced by lack of response to social benefit messaging and few low-effort contributions on the site itself) many nanoHUB members are more self-oriented, the observation cue would not have an effect.

Result 3: The observation cue does not have a significant effect on survey participation for registered nanoHUB users.

We also conducted probit regressions, measuring the effect of social versus private benefit, observation cue, and presence of virtual points on participation and completion: the results are summarized in Table 3. The probit regressions provide additional support for Results 1-3. The "Reward Point" variable is positive and significant both for participation and completion, increasing the probability of participation by 17% and the probability of completion (given that the user participated) by 9%. The "Social or Private Benefit Messaging" variable is negative and significant for participation, increasing the probability of participation given the private message relative to the social message by 7%.

Table 3: Probit Model of Survey Participation and Completion

Dependent Variable:	**Participation**	**Completion**
Reward Point	0.17**	0.09**
(1 if yes, 0 if no)	(0.03)	(0.03)
Observation Cue	-0.04	-0.03
(1 if yes, 0 if no)	(0.23)	(0.03)
Social or Private Messaging	-0.07*	0.04
(1 if social, 0 private)	(0.05)	(0.03)
Surprise Reward		0.12
(1 if yes, 0 if no)		(0.07)
Observations	30,000	774

*** p<0.01, * p<0.05.*
Standard errors in parentheses.

5. Discussion of Survey Responses

We are interested in determining whether the different treatments draw different types of respondents. Our survey asked questions about gender, race, profession, frequency of visits to nanoHUB (our proxy for social distance), and reason for contributing to the site.

Previous work found that the observation cue was most effective for males as compared to females (Rigdon et al., 2009; Krupka and Croson, 2009). If social cues were more effective for males, we would find a greater proportion of males in PB-0-C relative to PB-0-nC and a greater proportion of males in SB-0-C relative to SB-0-nC. Table 4 summarizes demographic characteristics of respondents: we do not observe a greater proportion of males in treatments with observation cues relative to treatments without observation cues (χ^2 p-value = 0.73 for PB-0-C versus PB-0-nC and p-value = 0.81 for SB-0-C versus SB-0-nC). One reason for this could be that we simply do not have enough "previous contributors" in our experiment. Note that these high percentages of male respondents are due to the nature of nanoHUB: most engineering and nano-science researchers and students tend to be male. We also do not find differential effects of treatment on any demographic characteristic under study, including occupation, gender or age.

We do find that we have fewer faculty in our respondent sample overall relative to students, or that fewer faculty tend to respond to the survey than students, (52% versus 28%). While nanoHUB has not historically tracked occupation of users, tracking did begin several years ago for new registered users. Since that time, the ratio of student to faculty new registered users has been 1 to 10, suggesting that in fact there are much fewer faculty in the overall sample relative to students, and that faculty participation in the survey is much greater than student participation. We can only speculate why fewer students respond. One suggestion may that students may participate in nanoHUB for only a short time as part of a class, and may be less

interested in maintaining a long-term relationship with nanoHUB. In addition, the survey was conducted in the summer, and some of the registered student users may have stopped checking their school/university e-mail addresses, or those e-mail addresses may have been deactivated.

Table 4: Gender of Respondents

		% Male = 86%	**Birth Yr. = 1977**
1.	**PB-0-C**	**82%** 93% responding	1977 86% responding
2.	**PB-0-nC**	**84%** 91% responding	1976 80% responding
3.	**PB-250-nC**	**88%** 93% responding	1978 87% responding
4.	**SB-0-C**	**85%** 94% responding	1980 82% responding
5.	**SB-250-C**	**87%** 92% responding	1977 88% responding
6.	**SB-0-nC**	**86%** 94% responding	1976 83% responding

Table 5: Occupation of Respondents

		Student = 52%	**Faculty = 28%***
1.	**PB-0-C**	53% 88% responding	26% 88% responding
2.	**PB-0-nC**	47% 88% responding	37% 88% responding
3.	**PB-250-nC**	53% 90% responding	30% 90% responding
4.	**SB-0-C**	59% 92% responding	24% 92% responding
5.	**SB-250-C**	51% 88% responding	25% 88% responding
6.	**SB-0-nC**	47% 88% responding	23% 88% responding
** Note that the remaining 20% of respondents work in industry or government.*			

We asked individuals how satisfied they are with the nanoHUB site on a scale of 1 through 4, where 1 is “Very Dissatisfied” and 4 is “Very Satisfied.” Table 5 summarizes satisfaction levels

for each treatment: satisfaction is high among all respondents. Our intuition suggests that that more satisfied individuals would be more reciprocal, and that some less satisfied users did not respond. We wanted to investigate whether more satisfied individuals would perhaps feel more reciprocal toward nanoHUB and therefore be more affected by the social messaging. However, satisfaction was not significantly different across treatment groups.

Table 6: Satisfaction Levels of Respondents

		Satisfaction
1.	**PB-0-C**	3.04 (0.90)
2.	**PB-0-nC**	3.09 (0.96)
3.	**PB-250-nC**	3.15 (0.97)
4.	**SB-0-C**	2.85 (1.03)
5.	**SB-250-C**	2.97 (1.02)
6.	**SB-0-nC**	3.13 (0.84)

We wished to discover whether the majority of respondents contribute content for self-motivated or altruistic reasons. Because very few low-effort content contributions exist on nanoHUB, we asked participants why they generally contribute *high effort content* to nanoHUB instead – most responses, such as 'to publicize my work' and 'for a class' are self-motivated, while the response 'to help the nanotechnology community' is other-regarding. Of the respondents who participated in and completed the survey, we had 76 (11%) who said they have ever contributed a high-effort resource to nanoHUB in the past. Overall, only 8.8% (68) of respondents said they ever contribute to nanoHUB. Out of these, a total of 30% (21) contributed to help the nanotechnology community, while 70% contributed for self-motivated reasons. 12 of the socially-motivated respondents were in the private benefit treatments, while 9 of the socially-motivated respondents were in the social benefit treatments. We conclude that respondents are more likely to contribute to nanoHUB due to self-interest rather than social motivation. This

additional evidence highlights the importance of considering the context of the community when designing effective reward systems.

5. Conclusion

We investigated the effect of awarding virtual points as compared to private and social benefit messaging and observation cues on user participation in a science and engineering online community. We conducted a field experiment in the online collaborative community nanoHUB. 30,000 users were randomly selected into one of several treatment groups, and received e-mails soliciting their participation in an online survey. In one treatment, users received virtual points for completing the survey, which could be used to purchase items on the site. In another treatment, users were exposed to an observation cue previously shown to increase pro-social behavior and contributions. Finally, we varied the social message, either emphasizing the private benefit to the user or the social benefit to the community of completing the survey.

Participation and completion rates were increased for groups receiving the virtual points or the private benefit messaging, while the observation cue did not have a significant effect. Virtual points had the highest effect: offering virtual points increased response rates by 27-31% relative to not offering virtual points. This result has important practical implications for designers of online communities: virtual points are often significantly cheaper than monetary incentives to implement, but are effective at increasing contributions. Future work could investigate the relative effect of virtual points as compared to monetary incentives.

Our study differed in a key way from previous work – while most in-depth studies of this type focus on leisure-oriented communities, such as *MovieLens,* our study focused on a research-oriented community. Thus, it is not surprising that our results are different from related work in

leisure-oriented communities - we find that private benefit messaging is more effective than social benefit messaging, and that the observation cue does not have a significant effect. Individuals participating in intrinsically competitive research-oriented communities may have greater social distance to their community members and may be more self-oriented as compared to members of leisure-oriented communities. Additional survey response evidence supports the conjecture that users of this site contribute more due to self-interest than due to social interest. Therefore, such users would be less likely to be strongly affected by the social benefit messaging or by the observation cue. This conjecture may have important practical implications: designers of online communities should be careful to consider the types of users who visit the site, prior to selecting a system aimed at increasing contributions. The typology of the community (as in Porter, 2004) may play an important role in determining which system will succeed and which will fail at increasing contributions. It seems that providing users with messages about the positive impact they are making for society may not work equally well across different types of communities. On a practical note, nanoHUB should now begin stressing the private benefit to users of completing certain tasks, and awarding virtual points for key types of contributions.

Our results, which differ from results of related work in leisure-oriented communities, highlight the need for more research in the area of incentivizing users to contribute to research-oriented communities. Future work will include conducting a similar series of treatments in a leisure community to investigate if these members respond differently to social benefit messaging and observation cues as we expect.

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Appendix: Survey Recruitment E-mail Examples

SB-250-C

Subject: nanoHub Survey! Help the community and earn 250 points!

* *
*
Dear nanoHUB user,

We have invited you to evaluate how nanoHUB can better serve its users. Your responses will help to make our site an even better information resource for your fellow nanoHUB community members.
Please complete a brief survey. The survey should take no more than 15 minutes to complete.
We'll give you 250 points for completing the survey!
Your responses are completely anonymous.
Click here to complete the survey:

- the nanoHUB team

SB-0-nC

Subject: nanoHub Survey! Help the community!

*
* *
Dear nanoHUB user,

We have invited you to evaluate how nanoHUB can better serve its users. Your responses will help to make our site an even better information resource for your fellow nanoHUB community members.
Please complete a brief survey. The survey should take no more than 15 minutes to complete.
Your responses are completely anonymous.
Click here to complete the survey:

- the nanoHUB team

PB-0-C

Subject: nanoHub Survey!

* *
*
Dear nanoHUB user,

We have invited you to evaluate how nanoHUB can better serve you. Your responses will help to make our site an even better information resource for you.
Please complete a brief survey. The survey should take no more than 15 minutes to complete.
Your responses are completely anonymous.
Click here to complete the survey:
- the nanoHUB team