To Crowdfund Research, Scientists Must Build An Audience For Their Work

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Abstract

As rates of traditional sources of scientific funding decline, scientists have become increasingly interested in crowdfunding as a means of bringing in new money for research. In fields where crowdfunding has become a major venue for fundraising such as the arts and technology, building an audience for one's work is key for successful crowdfunding. For science, to what extent does audience building, via engagement and outreach, increase a scientist's abilities to bring in money via crowdfunding? Here we report on an analysis of the #SciFund Challenge, a crowdfunding experiment in which 159 scientists attempted to crowdfund their research. Using data gathered from a survey of participants, internet metrics, and logs of project donations, we find that public engagement is the key to crowdfunding success. Building an audience or "fanbase" and actively engaging with that audience as well as seeking to broaden the reach of one's audience indirectly increases levels of funding. Audience size and effort interact to bring in more people to view a scientist's project proposal, leading to funding. We discuss how projects capable of raising levels of funds commensurate with traditional funding agencies will need to incorporate direct involvement of the public with science. We suggest that if scientists and research institutions wish to tap this new source of funds, they will need to encourage and reward activities that allow scientists to engage with the public.

Introduction

Rise of science crowdfunding and the decline of public research funding

Over the past five years, a new method of Internet-based fundraising known as crowdfunding has exploded in popularity [1]. In the first six months of 2013 alone, almost US$200 million was raised for technology and arts-related projects on just one leading crowdfunding website [2]. But what role can crowdfunding play in the sciences? How must science adapt to take advantage of this growing pool of available funding?

The rise of crowdfunding comes at a time when scientists are facing increasing competition for declining sources of public funding [3]. Interest in science crowdfunding is largely driven by recent steady downturns in government funding for science, particularly in the United States. Indeed, well before crowdfunding began to catch on among scientists, Gaggioli and Riva [4] suggested "crowd-funding as a possible strategy to cope with the lack of investments in research, as well as to increase democratization in the sciences". Crowdfunding democratizes science funding by using a model for supporting projects that charities have long used: combining small donations to achieve a common goal. The arrival of dedicated Internet platforms truly democratized this fundraising model by removing the need for substantial infrastructure and manpower traditionally needed for charity fundraising. Crowdfunding now allows a wider range of potential users, including scientists, to ask for and receive small donations. These users then become involved in science by helping shape what projects get funded and by maintaining their personal investment in new fields of scientific inquiry.

This new investment could not come at a better time, as traditional sources of funding for scientific research in the United States are becoming increasingly strained. Between 1992 and

49   2012, state appropriations fell by 15% at the U.S. public research universities with the largest

50   research and development funding inflows [5]. Further, U.S. federal funding for research in most

51   physical sciences, mathematics, and engineering has declined or remained relatively flat in

52   inflation-adjusted purchasing power for several decades [6]. A recent National Research Council

53   report concluded that federal funding for university research has been unstable overall, and is

54   declining in inflation adjusted dollars [7]. As one consequence, the average age of principal

55   investigators receiving their first major research grant (R01) from the National Institutes of

56   Health is an astonishing 42 years old [8].

57   Crowdfunding serves a further need beyond merely funding science. Crowdfunding

58   provides a crucial conduit for communication between scientists and the public. To create a

59   crowdfunding proposal, scientists must talk about their work in a way that appeals to people

60   outside of the academy. They must be good science communicators, and then are rewarded for

61   their efforts with money for their research.

62

63   Theoretical context: crowdfunding and science communication

64   Little is understood about how crowdfunding works and whether the lessons of the

65   science communication literature can provide a roadmap for successful efforts. The nascent

66   literature on the entire field of crowdfunding is found largely in popular journals and the

67   blogosphere. Analysis of what drives successful campaigns are largely case studies of the most

68   successful projects [9]. A small number of recent articles focus on crowdfunding within the

69   context of new Securities and Exchange Commission regulations [10,11], and new opportunities

70   for entrepreneurs and small businesses [1,12,13,14].

71   The literature documents some best practices that have been gleaned through informal

72   observations of crowdfunding websites. Hughes [15], for example, emphasizes the benefits of

73   creating a fan base for your research through crowdfunding, which can lead to increased

74   visibility and other opportunities down the line. Ordanini et al. [1] recognize the importance of

75   family, friends, and extended social networks as the initial investor base for a successful

76   crowdfunding campaign. Wheat et al. [16] focus on science crowdfunding and, in particular,

77   discuss the nuts and bolts of how researchers should run crowdfunding campaigns.

78   The advent of science crowdfunding also builds on recent trends in science

79   communication toward online and electronic public dissemination of science. Across the

80   disciplines in higher education there have been increasing calls for more publicly and socially

81   engaged research agendas; scholarship that asks socially pertinent questions, science that

82   incorporates the participation of the objects of science in experimental design (particularly in

83   policy-relevant and health sciences); and science that is disseminated to and connects with the

84   public in new ways [17,18,19,20]. This study contributes to these literatures by systematically

85   illustrating the important links between science communication, public engagement, and the

86   burgeoning crowdfunding phenomenon.

87

88   Successful science crowdfunding: what does it take?

89   In fields where crowdfunding is now a significant source of funds, such as in the arts and

90   technology, it took 3–5 years before participants were able to successfully fund projects in range

91   of hundreds of thousands to millions of dollars [21]. This raises the question: what steps must

92   individual researchers and research institutions take to develop the ability to leverage these large

93   amounts of funds for science?

94   Successful crowdfunding relies on broad appeal and engagement with a large audience.

95   Examples of this dependence can be seen from a leading crowdfunding site where many projects

96   in 2012 raised over a million dollars [21]. Many of the most successful projects come from

97   artists with huge fanbases (e.g., musician Amanda Palmer, who set a crowdfunding record for

98   music [9], has over a million followers on Twitter; https://twitter.com/amandapalmer) or for

99   extensions of extremely popular products with a built-in audience (e.g., a watch for smartphones

100   [22] or sequels to the Ultima video games [23]). The same dynamic between audience size and

101   crowdfunding success appears to hold for science. For example, the British charity Cancer

102   Research UK routinely raises over £50,000 for individual research projects via crowdfunding

103   (Table S1). Cancer Research UK and its predecessor organizations have spent decades building

104   an audience for their work. It follows that their success in research crowdfunding stems from

105   leveraging an extensive existing donor base. As with Cancer Research UK, the individuals

106   behind these projects have built large audiences for their work over many years [9]. These

107   examples suggest that building an engaged online audience through outreach by scientists is key

108   to successful crowdfunding for research.

109   While attitudes among most scientists towards outreach and engagement are

110   unenthusiastic [24], the last decade has witnessed dramatic growth in the visibility of scientists

111   online [25]. Scientists are increasingly communicating their work to a public audience via online

112   means like blogs and Twitter [26,27,28].

113   To explore the potential link between online science engagement and successful

114   crowdfunding, we organized a crowdfunding for science initiative, the #SciFund Challenge

115   (hereafter #SciFund). We set up #SciFund with standardized conditions for participants, such as

116   project duration, so that we could use the data to investigate the factors influencing proposal

117   success. We collected data from patterns of web traffic, metrics from social media websites (e.g.,

118   Facebook and Twitter), donations, and from a survey of participating scientists. We used these

119   data for an analysis of the principles of crowdfunding success using a series of statistical models.

120   With well over a hundred crowdfunding projects taking place under the auspices of #SciFund,

121   this study is the most comprehensive analysis of science crowdfunding to date. Here we provide

122   results from #SciFund to demonstrate the link between online outreach and success in

123   crowdfunding for research dollars.

124

Methods

125

Structure of the #SciFund Challenge

126

127   #SciFund is a crowdfunding experiment for science. As part of #SciFund, we organized

128   scientists to run their own crowdfunding projects simultaneously for their research under the

129   #SciFund banner. #SciFund ran in a round-based format, with three rounds occurring between

130   July 2011 and December 2012. Each round lasted several months and was divided into three

131   phases: (1) soliciting proposals, (2) training participants, and (3) executing proposal

132   "campaigns". In the soliciting phase of each round, #SciFund organizers encouraged scientists

133   (across disciplines and countries) to participate in this crowdfunding exercise, via e-mail lists,

134   blog posts, and social media (e.g., Twitter and Facebook). This soliciting phase lasted three

135   months in the first round and one month each for the next two rounds. To ensure scientific

136   credibility, each scientist who signed up to participate was vetted, via an application form that

137   was evaluated by a science advisory board (at least two scientists evaluated every application). In

138   the training phase of each round, organizers trained the scientists to run a crowdfunding

139   campaign via instructional blog posts on our website (round 1: http:// scifund.wordpress.com;

140 afterwards: http://scifundchallenge.org), an online discussion group, and by encouraging

141 discussion and feedback on draft projects within a private online space. This training phase

142 lasted one month in each round. By the end of the training phase, participants had a fully formed

143 crowdfunding proposal ready to be deployed.

144   In the executing phase of each round, the #SciFund crowdfunding projects went "live" on

145 the Internet. All projects within a round launched simultaneously and ran for the same length of

146 time. Although all #SciFund projects were running under the same banner, each participating

147 scientist fundraised primarily for his or her own project (that is, there was no collective

148 fundraising, although during the campaign periods, the project organizers advertised and

149 promoted the #SciFund Challenge more broadly). Most projects each had a single scientist

150 behind them, but there were several multi-researcher projects in each round. The total number of

151 projects and the number of days of fundraising varied with each round (Round 1: 49 projects, 45

152 days, Nov. 1–Dec. 15, 2011; Round 2: 75 projects, 31 days, May 1–May 31, 2012; Round 3: 35

153 projects, 33 days, Nov. 11–Dec. 15, 2012). A wide range of scientific disciplines were

154 represented (Table 1), although most projects focused on ecology or conservation biology,

155 reflecting the professional networks of the #SciFund organizers.

156   These projects were hosted on a special section of the crowdfunding platform RocketHub

157 (http://scifund.rockethub.com). Resulting funds were directly disbursed by RocketHub to the

158 recipients designated by the participants (generally the participant's home institution or affiliated

159 nonprofits). The only charges that #SciFund participants incurred were RocketHub's customary

160 fees for crowdfunding projects running on their site (8–12% of the total raised, depending on

161 whether they achieved their funding goal). #SciFund participants received funds even if they did

162 not reach their financial targets, unlike the funding model for some crowdfunding platforms,

163 where funds are disbursed only if the project is fully funded. It should be noted that several of

164 this paper's authors (Walker, Byrnes, and Faulkes) ran individual crowdfunding projects under

165 the #SciFund banner in round one. The organizers of #SciFund were not paid by RocketHub nor

166 did they receive any funds, either directly or indirectly, from #SciFund participants or donors

167 (other than the donor funds Walker, Byrnes, and Faulkes received from their individual projects).

168

169 Data Sources

170 After each of the three #SciFund rounds, we compiled data from three sources to analyze

171 the factors that led to successful crowdfunded projects. First, we acquired the web visit and

172 donation logs of each project from RocketHub. Second, we collected publicly available

173 information from the Internet, including the number of tweets on Twitter (http://twitter.com) and

174 "Likes" on Facebook (http://facebook.com) for each #SciFund project page, and the number of

175 times project videos were viewed [29,30,31].

176 Last, we designed a survey for all #SciFund participants to measure: (1) strategies used to

177 create crowdfunding materials, (2) strategies used to promote crowdfunding campaigns, (3)

178 social network size (i.e., number of Facebook friends), and (4) various aspects of ongoing online

179 outreach activities (e.g., Do they have a blog?); see Table S2 for a complete list of questions.

180 Questions and survey protocols were approved by the UCSB Human Subjects Committee,

181 protocol 12-776 with the title *Evaluation of the #SciFund Challenge*. Participants gave their

182 written consent for use of their data. This survey was completed by #SciFund participants in the

183 first few weeks after their crowdfunding project finished. The survey was answered by 47 of the

184 49 #SciFund round one participants, 48 of 75 round two participants, and 22 of 35 round three

185 participants. The survey instrument for rounds two and three differed in some ways from the

186   instrument we used for round one. Specifically, we changed the requested response for several

187   questions from a Likert scale selection to a specific quantitative answer (see Table S2 for

188   complete list of changes). For example, questions regarding the number of tweets, Facebook

189   posts, Google+ posts, and e-mails made by participants required a numerical response in the

190   survey instruments for rounds two and three (where they had required a Likert scale selection in

191   the round one survey).

192   In addition to quantitative data, the surveys asked opened-ended questions that collected

193   qualitative data about participants' experiences during the #SciFund Challenge, such as what

194   types of outreach and engagement they thought were most and least effective in their campaigns,

195   and overall satisfaction with the experience. These data were compared to the statistical models

196   to determine if participant perceptions about crowdfunding success and failure matched the

197   results of the statistical models.

198

Factors influencing success of #SciFund projects

200   To determine the chain of events that attracted donations for the #SciFund projects, we

201   explored four questions using statistical modeling with the data from round one. We then took

202   the fit models, and challenged them with the data from rounds two and three to verify their

203   conclusions. The questions were: First, what effect did the number of donors have on

204   crowdfunding success? Second, where were donations coming from? That is, were donations

205   merely due to scientists somehow drawing attention to their projects, or did personal connections

206   generated through online social networks play a role? Third, was the attention a project received

207   generated from existing social networks or other forms of "buzz" generated by the #SciFund

208   campaign itself? Fourth, did long-term scientific outreach via blogging increase scientists'

209   outreach-generated social networks? Thus, we hoped to examine the influence of a scientist's

210   public presence on crowdfunding success.

211   As we were dealing with count data in many of the analyses, most data were modeled

212   using generalized linear models with linear or log links [32] and a quasi-Poisson error

213   distribution to account for over dispersion [33]. All models were fit using the base package in R

214   Version 2.14.2 [34]. To examine the amount of variance in the response variables retained by our

215   statistical models, we calculated the R^2 of the relationship between predicted and observed

216   values of response variables [35]. Note that different pieces of the analysis had different sample

217   sizes depending on whether survey respondents included answers or not. Sample sizes are

218   reported with each analysis.

219   To examine the relationship between number of donors and total amount raised, we fit a

220   linear relationship as described, but set the intercept at zero, as zero contributions meant zero

221   dollars were raised by definition. We hypothesized that several factors could influence the total

222   number of contributors and fit a model accordingly. First, the number of times a project was

223   viewed should directly influence the number of contributors. Because projects had clear financial

224   goals, and because the probability of someone viewing a project after it hit its funding goal may

225   change, we separated pre- and post-goal page views. Second, the size of someone's personal

226   social network may influence the number of contributors, as friends and family may be more

227   likely to donate to a project. Last, the size of a scientist's online social network generated by

228   previous online outreach activities may also influence the total number of contributors; this was

229   measured by number of Twitter followers.

230   For this and other analyses incorporating project page views, we excluded a single

231   outlier. One project had an enormous number of project page views: 38,131, compared to the

232 mean of 2,217.75 and median of 1,070. The next highest number of page views was 6,702. The

233 number of page views in the most viewed project was due to promotion on two highly popular

234 web sites that other projects did not have. This outlier exerted an enormous leverage on the

235 analysis and was therefore excluded. Analyses with this outlier project were qualitatively the

236 same, but quantitative results and amount of variance retained were quite different. In analyses of

237 future rounds, should there be a larger sample size in the 7,000-30,000-page-view range, we

238 would be better able to detect linear or nonlinear relationships involving this data point. For this

239 round, the 38,131 data point was excluded for analyses involving page views.

240   We next evaluated the relationship between page views and three predictors of project

241 popularity: the size of one's social network (Facebook friends), the size of their outreach

242 generated social network (Twitter followers), and the ability of a scientist to cultivate interest in

243 a project as measured by the number of people who had clicked the "Like on Facebook" button

244 on a project's web page. Again, we split pre- and post-goal views. For pre-goal project page

245 views, we fit a model as above. For post-goal project page views, we only analyzed the subset of

246 projects that met their goal. Additionally, a number of projects met their goal during the final

247 days of #SciFund. Most of these projects had no post-goal project page views. We therefore fit a

248 model with a log rather than linear link function.

249   Last, to explore whether ongoing online outreach efforts by scientists increased their

250 Twitter followers, we looked at the relationship between Twitter followers and the average

251 number of monthly blog posts by #SciFund scientists who had established blogs. We assumed

252 the direction of causality went from monthly blog posts to number of Twitter followers, because

253 it seemed unlikely that researchers would blog more often because they had more Twitter

254 followers. Rather, we hypothesized that the more frequently a researcher posted to their blog, the

255   more likely they would be to attract a larger following on Twitter. For participants who did not

256   have a blog, we set their number of monthly posts to 0. The age of these blogs ranged from a few

257   months to nearly ten years. As blog age and posting frequency were highly correlated (r=0.68),

258   we did not include them as independent measures of online outreach.

259

260   ## The Role of Effort

261   After re-evaluating the models fit during round one with round two and three data, we

262   noted a discrepancy in the link between audience size and number of page views (see Results).

263   We also noted that the difference in effectiveness of pre- versus post-goal page views was much

264   weaker. We therefore revised a question in our survey in order to better assess participant effort

265   for rounds two and three. We were thus able to ask, how does effort modify the effect of

266   audience size on the ability of a researcher to bring people to view their project? For this model,

267   we looked at audience size and number of posts on Twitter and Google+ as well as how the two

268   interacted. We also estimated parameters for the effect of number of people contacted via email

269   and the number of people contacted in the press. We fit models with a Gaussian error term, as the

270   data did not meet the assumption of a mean-variance scaling relationship from a Poisson or

271   quasi-Poisson error distribution. We removed one outlier data point, as its number of press

272   contacted was two orders of magnitude larger than any other data point, and was likely a typo on

273   the form or a misunderstanding of the question (post-hoc requests for verification from the

274   participant yielded no response). We fit this model both for total page views and pre- and post-

275   goal page views. However, due to the smaller sample size for post-goal page views (27) and the

276   high number of parameters for the model (k=10), we elected to drop the parameters assessing the

277   impact of Google+, as they were not different from 0 in the initial model and contributed to an

278 exceedingly high variance inflation factor in the post-goal page views model. Last, we fit a

279 simple model examining to what extent post-goal page views were merely explained by pre-goal

280 page views, as none of our predictors appeared to explain variability adequately. After analysis

281 of our increased sample size, we also recognized that Facebook "likes" are often an

282 epiphenomenon of people visiting projects, not a causal driver. Indeed, they were highly

283 correlated with variables that were more causally related to effort, such as number of press

284 contact (r=0.76), number of Tweets (r=0.61) or number of Facebook posts (r=0.81).

285

Results

287 Money raised through the #SciFund Challenge

288   Over three rounds, #SciFund raised US$252,811 from 3,904 donors funding 159 projects.

289 The timing of donations was relatively similar for all three rounds and conformed to what has

290 been observed in other crowdfunding campaigns [36]: a large amount of funds raised early in the

291 campaign, a gradual leveling out, and then a sudden burst of funding activity at the end (Fig. 1).

292   The first round of #SciFund raised US$76,230 over 45 days from at least 1,195 donors

293 (donor counts for rounds one and two are likely to be underestimates, as donor names in those

294 rounds were used to identify unique donors and multiple donors may have had the same name).

295 There was a large range in the financial targets of the 49 #SciFund projects (range: US$500–

296 20,000; median: US$3,500; average: US$4,601). Similarly, there was a large range in the amount

297 received by the projects, as measured by total dollars (range: US$122–10,171; median:

298 US$1,104; average: US$1,556). The project that raised the most, both in terms of dollars raised

299 and percentage of goal (US$10,171 raised on a US$6,000 goal, 170% of target fundraised), was

300   an outlier, as the second-highest amount fundraised was less than half of the first-place take

301   (US$5,085). Ten projects matched or exceeded their targets (20% of projects); all six projects

302   that asked for US$1,200 dollars or less met or exceeded their target.

303   Round two's 75 projects raised US$100,345 over the course of 31 days with 44% of

304   participants achieving or exceeding their funding goal. At least 1,579 donors contributed to

305   round two (likely an underestimate, as with round one, due to shared donor names). The financial

306   targets of round two projects tended to be much lower than for round one and the range of dollar

307   targets was also narrowed (range: US$333–12,000; median: US$2,000; average: US$2,215). A

308   major reason for these lower funding goals was that #SciFund organizers, based on round one

309   experience, strongly recommended that round two participants lower their financial targets. The

310   amounts raised in round two were within a tighter band than in round one, but the median

311   amount raised remained relatively steady (range: US$30–5,688; median: US$1,046; average:

312   US$1,341).

313   Round three's 35 projects raised US$75,978 over 33 days with 46% of projects achieving

314   or exceeding their goal. Round three had contributions from 1,130 donors (an exact count, unlike

315   with rounds one and two). The financial targets of round three projects generally rose from the

316   levels found for round two, though they were still lower than the targets for round one (range:

317   US$380–10,000; median: US$2,500; average: US$3,083). In terms of the amounts actually

318   raised, round three projects were on average the most successful of the three rounds (range:

319   US$0–8,645; median: US$1,476; average: US$2,177). This is likely because the training that the

320   Round 3 participants received was refined based on Rounds 1 and 2, and thus more accurate and

321   effective.

322

Exploratory Modeling of Factors Influencing Success of Round One #SciFund Projects

Overall, in our exploratory analysis for round one, we found a relationship between online outreach efforts and funding. The number of contributors influenced total amount raised (Fig. 2, Likelihood Ratio χ^2=567.95, DF=1, p<0.001, n=47): for every contributor, projects raised a mean of US$54.19 (S.E. = 3.19). 86.9% of the variance in money raised was retained by the model. The number of Facebook friends and page views, both before and after a project goal was reached, influenced total number of contributors (Table 2, n=30, Fig. 3). The number of Twitter followers, however, did not. 85.3% of the variation in number of contributors was retained by the model. Before a project hit its initial goal, an average of 108 views was needed to generate one contribution. After a project hit its goal, only 21 page views were necessary to generate an additional contributor. Projects had one contributor for every 53 Facebook friends the research had.

Both Twitter followers and Facebook "Likes" influenced the number of project page views before reaching a goal (Table 3, n=30, Fig. 4). Projects received a mean of 0.78 (S.E. = 0.28) page views per follower. They also received roughly 10 additional page views per Facebook "Like." 78.3% of the variation in post-goal page views was retained in this model. For projects that met their goal, only Facebook "Likes" appeared to influence the number of page views (Table 3, n=7, Fig. 5). This model retained 83.7% of the variation in post-goal page views.

Posting frequency predicted Twitter followers (Fig. 6, Likelihood Ratio χ^2=10.944, DF=1, p<0.001, n=35). For every monthly post, participants picked up a mean of 52.66 (S.E.=19.96) additional followers. Only 34.4% of the variation in number of Twitter followers was retained by the model. Thus, we suggest that there are additional factors not quantified by

346   our survey instrument that led to scientists aggregating an online following.

347

348   Confirmatory Model of Factors Influencing Success of Rounds Two and Three

349   #SciFund Projects

350   The broad message of the model from round one—that engaging audiences aided in

351   funding—was retained in our analysis of further rounds. However, we found several

352   discrepancies that were not supported in our confirmatory model analysis. Furthermore, our

353   analysis of rounds two and three revealed a substantial role for effort. Overall, we find that effort

354   on multiple fronts to engage a large audience was important for crowdfunding success. We found

355   that the model suggested by the round one analysis held only insofar as dollars were linked to

356   contributors (Slope=57.04 ± 2.96 SE, t=19.29, p<0.001, R^2=0.83) which in turn was determined

357   by page views and weak support for Facebook network size (Table 4). The slope of the pre- and

358   post-goal page view relationship with number of contributors had weak support for being

359   different from one another (pre slope=0.018 ± 0.003, post slope=0.037 ± 0.010, t-test for

360   difference t=1.82, DF=66, p=0.07). However, both pre- and post- goal page views had no

361   relationship with Twitter network size when using models developed from round 1 (p>0.50 for

362   both). Clearly, the models we developed for project page views in round one did not hold for

363   round two or three.

364

365   The Role of Effort

366   Our initial hypotheses had anticipated that both effort on the part of a researcher and their

367   network size should contribute to the success of their project. Our models incorporating effort

368 (Table 5, Fig. 7, S4) demonstrated that contacting people via email is extremely effective with

369 1.72 visits per person emailed pre-goal. Pre-goal page views were also enhanced by number of

370 press contact (~93 page views per press contacted). Intriguingly, there was an interaction

371 between Twitter network size and number of tweets, such that for every ~75 followers, 1 tweet

372 would bring in 1 page view. Assuming each click is an independent person, thus two tweets a

373 day would ensure that roughly 80% of a scientist's Twitter network has viewed their project.

374 Overall, our effort model provided modest explanatory power for pre-goal page views (R^2=0.67).

375 Post-goal page views seemed to be relatively uninfluenced by all factors (Table 5b). Instead, a

376 simple model where post-goal page views was explained by pre-goal page views (i.e., a popular

377 project continues to be popular) appears to provide some explanation for post-goal page views

378 (LR χ2 = 7.09, DF=1, p=0.008, slope=0.113 ± 0.047 SE, intercept=118.283 ± 88.942 SE,

379 R^2=0.20).

380

381 ## Researcher impressions of what contributed to success and failure

382 In the survey, participants were asked about their impressions of "what worked" and "what did

383 not work" in making their crowdfunding campaigns successful (see Table S2 for question list).

384 Answers were open-ended, and several participants identified multiple factors in their answers.

385 Overall, 14 reasons were identified for what worked (Table 6), and 15 for what did not work

386 (Table 7). For the most part, participants' opinions about the sources of their crowdfunding

387 success matched the outcomes of the statistical models. Across all three rounds, participants

388 identified the following three factors as the main contributors to their success (both in terms of

389 direct giving to, and generating interest in, the project): family and friends (36%), personal

390 networks (36%), and online networks (31%). These most frequently cited opinions are in synch

391 with the results of the statistical analysis in that Facebook networks and sending out e-mails to

392 social networks were among the most important drivers of a successful crowdfunding campaign.

393   The other component of a successful campaign, according to the statistical analysis, is

394 press contacts. However, this was not considered a key reason for success by the majority of

395 participants. Less than 5% of the sample across the three rounds identified #SciFund publicity

396 (4%), national media (2%), and local media (1%) as being important to their success.

397   Among the factors that did not work according to the participants, 19% of the sample

398 thought that engaging their online networks (Facebook, Twitter, blogging, and Google) was

399 unsuccessful. Related to this, 13% of the participants thought that they did not promote their

400 project enough (to a variety of potential networks and press outlets). The third most cited factor

401 considered to be unsuccessful was having a small or non-existent online network or social media

402 presence. These impressions are in line with the statistical analysis in that the most frequent

403 answers to this question were related to engaging social networks.

404

405 Discussion

406   Our analysis shows that engagement of broad audiences is the key to successful science

407 crowdfunding. To engage, a scientist must first build an audience for their work, hopefully well

408 before their crowdfunding campaign begins, such as through the Twitter and Facebook networks

409 we quantified here. Once the crowdfunding begins, a scientist must then put effort into

410 maintaining the connections between these networks and their science, such as through tweets or

411 direct contact via email. Some activities, such as reaching out via the press, even accomplish

412 goals of both building a wider audience while connecting them to crowdfunding proposals all in

413 one fell swoop. Engagement via science communication then leads to research dollars by

414 bringing people to view project pages. In turn, those views translate into contributions for new

415 scientific work (Fig. 8; see Fig S1 for a full path diagram with coefficients, and S2 and S3 for a

416 similar visualization from round 1). In short, audience multiplied by outreach effort equals

417 successful public engagement, and successful science crowdfunding.

418

419 ## The Role of Audience

420   Our analyses show that the pathway to raising money via crowdfunding in science

421 requires building a network of people interested in one's work and engaging that audience and

422 additional members of the public interested in a specific project. This occurs largely before the

423 crowdfunding campaign begins, and time invested in engagement yields a larger audience and

424 proportionately greater funds raised. For example, our analyses suggested that Twitter and

425 Facebook network size influences project success. Additional forms of outreach to build one's

426 scientific fan base not measured by our survey (e.g., involvement with museums, public lectures,

427 media history, etc.) quite likely help in crowdfunding a project. These kinds of community

428 engagement activities may facilitate access to local mailing lists as well as the likelihood of a

429 press contact translating into an article. All of these forms of audience building demonstrate the

430 importance of building and maintaining a consistent public presence for raising money through

431 crowdfunding.

432

433 ## Effort: You are Not Shouting Into the Void

434   Having an audience alone is not enough to be successful. If a scientist launches a

435 crowdfunding campaign, but doesn't tell anyone in their vast audience about it, that audience

436   won't come. However, in the survey data, many scientists admitted to doubts that their efforts

437   were successful. The quantitative data, in contrast, shows that while promotion of a

438   crowdfunding project may at times feel like shouting into the void, the effort can and will lead to

439   success. During a crowdfunding campaign, more effort – that is more tweets, more emails sent,

440   more people in the press contacted - all led to higher funding. Crowdfunding takes effort.

441   Informally, some successful participants reported spending ½–1 hour per day on outreach during

442   their crowdfunding campaign period. Note, that this is after the time-intensive process of

443   producing crowdfunding materials, such as a short video, necessary to engage with a broad non-

444   expert audience. These activities are different from the traditional grant-writing models that are

445   comfortable for most scientists. Rather, these are the activities of a successful outreach program,

446   but with the added benefit of research funding for the time invested.

447

448   ## Differences between First and Subsequent Rounds

449   There were two main differences between our exploratory analysis of round one and the

450   results of our confirmatory analysis in rounds two and three. First, blogging was not important in

451   building an audience in rounds two and three. This may well reflect an artifact of participant self-

452   selection. In round one, science crowdfunding was new, and many of our participants had a long

453   history of engaging in online science outreach. Many were active bloggers with long-standing

454   followings (authors' personal observations), sometimes built up over years (mean blog age=28

455   months). In contrast, while many participants in later rounds had substantial Twitter audiences,

456   they often did not have the long experience blogging (mean blog age=14 months) despite having

457   a relatively similar fraction of bloggers (51%, 35%, 50%, respectively).

458   The second difference between the rounds emerged due to differing methodology. Simply

459   put, our Likert scale questions could not adequately capture effort in round 1. The shift to non-

460   Likert questions regarding effort in rounds two and three allowed us to quantify a phenomenon

461   we suspected was important given qualitative interviews, but had not been able to fully capture

462   quantitatively.

463

Moving Beyond the US$10K Barrier in Science Crowdfunding

465   Throughout #SciFund, we were commonly asked whether crowdfunding might someday

466   serve as a replacement for traditional sources of funding. The amounts raised by the #SciFund

467   projects were small compared to a typical National Science Foundation or National Institutes of

468   Health grant. However, they are very much in line with initial crowdfunding efforts in many

469   fields where crowdfunding is now a major source of revenue; a development period of a few

470   years seems to be required for larger amounts to be raised via this method in any given field [21].

471   Indeed for #SciFund, there is evidence that the audience is growing. For example, the percentage

472   of #SciFund projects meeting their goals increased each round (Figure S5), and after a recent

473   fourth round (run on a different platform, Experiment.com, and hence not included here for

474   analysis), scientists are now achieving a 62.5% success rate.

475   Furthermore, since the inception of #SciFund, several science crowdfunding projects

476   have raised substantially more money than the most successful #SciFund projects. Two projects

477   investigating the bacterial communities associated with humans each raised over US$300,000

478   [37,38]. A project to launch a space telescope raised over US$1,000,000 [39]. The difference

479   between these projects and #SciFund projects was rewards that directly involve citizens in the

480   scientific process. Donors funding the two microbial projects at a certain minimum level had

481   their very own bacterial communities analyzed by those projects. Funding the space telescope at

482   high levels gave funders direct access to time on the telescope.

483   Examples of US$100K+ science crowdfunding efforts reinforce the basic lessons of our

484   analyses. The scientists behind these high-earning crowdfunding campaigns also went to great

485   lengths to promote their work. But more importantly, they went to extreme lengths to engage

486   citizens in their scientific process. Audiences were captivated by taking part themselves in

487   microbial and space research. They will likely be engaged with those scientific groups for years

488   to come, potentially crowdfunding future projects.

489

490   ## The Future of Crowdfunding for Science

491   Will crowdfunding replace traditional funding sources? No. At the bare minimum,

492   science crowdfunding provides a tangible financial reward for outreach, enabling access to

493   untapped pools of research funds while removing the "waste-of-time" stigma of outreach [24].

494   Moreover, it opens up a new pool of funds for pilot or high-risk projects, allowing a scientist to

495   later leverage their engaged audience alongside preliminary data for larger pools of funds.

496   However, for projects that engage heavily with the public (i.e., provide opportunities for citizen

497   science) or emerge from labs who are deeply engaged with the community around them,

498   crowdfunding may provide a truly alternative funding mechanism for many kinds of research

499   projects.

500   A common concern is that crowdfunding will only be viable for projects with lowest

501   common denominator public appeal, such as projects with charismatic large animals ("panda

502   bear science"), a human health aspect, or some other element that has populist appeal, regardless

503   of the scientific importance of the project. Many successful #SciFund Challenge projects were on

504   topics that are not normally considered popular with the public, however (e.g., statistics, little

505   known invertebrates, etc.). This is not to say that all projects will have equal appeal, but that

506   persistent engagement can build an audience for many kinds of projects. The key to creating an

507   engaging proposal is communicating why the project sparks your passion, and why should it

508   matter to your audience.

509

510   ## Making crowdfunding part of a lab and university's funding portfolio

511   Our work suggests a clear path forward for individual researchers who wish to fund a

512   portion of their lab's work via crowdfunding. We suggest that researchers should begin by

513   cultivating an audience for their work over time. This can be through a variety of avenues:

514   become active in local public science efforts, foster connections with relevant non-governmental

515   organizations with their own audiences, launch a public science blog (potentially with

516   collaborators), build a Twitter following, and search out as many ways to easily communicate

517   your science to as broad an audience as possible. The skills for running a campaign are identical

518   to those needed to build an audience in the first place. A scientist who has built an audience will

519   therefore have an easier experience running their campaign. When it comes time to crowdfund a

520   project, these are the sources that can be tapped for research funding; this "fan base" will already

521   be invested and engaged in your work. More importantly, once you have crowdfunded your

522   work, maintain the connections with your funders. Keep them apprised of progress. Keep them

523   involved with the process and results of your science. This constant contact has two benefits:

524   first, it should enable more successful repeat crowdfunding, and potentially higher levels of

525   future funding. Second, and more importantly, it will yield direct social benefits by connecting

526   progressively more people to science.

527   In these times of stagnant traditional science funding, every piece of external funding

528 helps labs and universities move forward. Ultimately, if universities want to take advantage of

529 crowdfunding dollars, academic culture must embrace science engagement, in contrast to the

530 current climate of devaluing outreach in university hiring and promotion policies

531 [24,40,41,42,43,44,45,46,47,48,49,50,51,52,53]. To be competitive in the new and dynamic

532 crowdfunding environment, universities must find ways to develop and enrich policies and

533 practices that foster active outreach and engagement by their faculty.

534 #SciFund illustrates that fostering a strong connection between science and society within

535 the culture of academia can benefit both universities and scientists financially. But the benefits of

536 creating an academic climate that encourages science outreach are greater than a new source of

537 research funding. Outreach and engagement create public science literacy [54], new arenas of

538 public support for science, and new connections between scientists and the world that they are

539 trying to understand.

540

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548

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679

680

680

681 **Table Captions**

682 **Table 1:** Distribution of #SciFund crowdfunding projects (across rounds) by academic

683 discipline.

684

685 **Table 2:** Likelihood ratio tests (a) and coefficient estimates (b) evaluating predictors of number

686 of contributors in round 1.

687

688 **Table 3:** Likelihood ratio tests (a,b) and coefficient estimates (c,d) evaluating predictors of pre-

689 (a,c) and post-goal page views (b,d) in round 1.

690

691 **Table 4:** Likelihood ratio tests (a) and coefficient estimates (b) evaluating predictors of number

692 of contributors in rounds 2 and 3.

693

694 **Table 5:** Likelihood ratio tests (a, b, c) and coefficient estimates (d, e, f) evaluating predictors of

695 pre- (a, d) and post-goal page views (b, c, e, f) in rounds 2 and 3.

696

697 **Table 6:** Factors mentioned by SciFund project creators that **helped** with project fundraising.

698 Respondents could mention multiple factors. N refers to number of completed surveys.

699

700 **Table 7:** Factors mentioned by SciFund project creators that **hurt** project fundraising.

701 Respondents could mention multiple factors. N refers to number of completed surveys.

702

702

Figure Captions

Figure 1. Crowdfunding donation patterns. The daily time series of donations during the firth

three rounds of #SciFund.

706

Figure 2.Total dollars raised plotted against the number of contributors. Line represents

best fit from model described in the text. Shaded grey area represents the 95% confidence

interval around the fit relationship.

710

Figure 3. Factors affecting number of contributors to a project. Plot shows the number of

contributors plotted against the number of Facebook friends. Size of points shows the number of

page views before achieving success. Color shows the number of project page views after goals

were reached with blue representing no views to red representing many views. Line represents

best fit from generalized linear model between x and y. Shaded grey area represents the 95%

confidence interval around the fit relationship.

717

Figure 4. Relationship between Facebook "likes", number of Twitter followers, and project

page views before a project hit its goal. Line represents best fit from model described in the

text. Shaded grey area represents the 95% confidence interval around the fit relationship. Point

size is proportional to the number of Twitter followers.

722

Figure 5. Relationship between Facebook "likes" and the number of page views after a

project has achieved its funding goal. Line represents best fit from model described in the text.

Shaded grey area represents one standard error around the fit relationship.

726

Figure 6. Relationship between monthly blog posts and number of Twitter followers. Line represents best fit from model described in the text. Shaded grey area represents on standard error around the fit relationship.

730

Figure 7. Relationship between pre-goal page views, press contacts, number of people emailed, and effort times engagement on Twitter. Line represents best fit from model between press and pre-goal page views. Shaded grey area represents the 95% confidence interval around the fit relationship.

735

Figure 8. How online engagement leads to a crowdfunded research project.

737

Figure S1. The pathway of interactions leading to money raised for projects in round two and three. Diagram shows the relationships between different variables in our analyses. Only those relationships that explained significant amounts of variation are included (LR χ^2 test p≤0.05). Coefficients represent linear relationships and are in the units of variables described. Sample size varies between each analysis represented in the diagram below due to differences in respondent behaviour and the exclusion or inclusion of outlier data.

744

Figure S2. How online engagement leads to a crowdfunded research project based on results from round 1.

747

748 **Figure S3. The pathway of interactions leading to money raised for projects.** Diagram shows

749 the relationships between different variables in our analyses. Only those relationships that

750 explained significant amounts of variation are included (LR χ^2 test p≤0.05). Coefficients

751 represent linear relationships and are in the units of variables described with one exception. The

752 relationship between Facebook "likes" and post-goal page views is exponential, and is shown as

753 such. Sample size varies between each analysis represented in the diagram below due to

754 differences in respondent behavior and the exclusion or inclusion of outlier data.

755

756 **Figure S4. Component-residual plots showing the relationship between pre-goal page**

757 **views, press contacts, number of people emailed, and effort times engagement on Twitter in**

758 **rounds two and three.** Tweet reach = number of Twitter followers × number of tweets. Press2 =

759 number of people contacted in the press. Email = number of people contacted via email.

760

761 **Figure S5. Percent of projects hitting 100% of their funding goal over the first four rounds**

762 **of the #SciFund Challenge.**

Table 1.

Academic discipline	Number of #SciFund projects across rounds
Conservation biology and ecology	100
Psychology	8
Biomedical research	6
Organic chemistry	6
Human development	5
Evolution	4
STEM education	4
Climate science	3
Computer science	3
Genetics	3
Anthropology	2
Applied math	2
Open science	2
Astronomy	1
Business research	1
Cancer biology	1
Engineering	1
Neuroscience	1
Paleontology	1
Political science	1
Seismology	1
Toxicology	1

Table 2

(a)	LR χ2	Df	Pr(>χ2)
Twitter Followers	0.041	1	0.84
Facebook Friends	5.397	1	0.02
Pre-Goal Page Views	12.849	1	>0.001
Post-Goal Page Views	44.601	1	>0.001

(b)	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	4.497	3.925	1.146	0.263
Twitter Followers	-0.001	0.006	-0.224	0.825
Facebook Friends	0.019	0.008	2.301	0.03
Pre-Goal Page Views	0.009	0.003	3.544	0.002
Post-Goal Page Views	0.048	0.009	5.139	>0.001

Table 3

(a)

	LR χ2	Df	Pr(>χ2)
Twitter Followers	11.621	1	0.001
Facebook Friends	0.97	1	0.325
Facebook Likes	58.85	1	>0.001

(b)

Twitter Followers	0.307	1	0.579
Facebook Friends	1.463	1	0.226
Facebook Likes	8.466	1	0.004

(c)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	528.414	165.058	3.201	0.004
Twitter Followers	0.782	0.284	2.752	0.011
Facebook Friends	-0.345	0.355	-0.971	0.34
Facebook Likes	10.04	1.769	5.675	>0.001

(d)

(Intercept)	5.674	1.147	4.949	0.016
Twitter Followers	-0.001	0.001	-0.503	0.649
Facebook Friends	-0.003	0.002	-1.114	0.346
Facebook Likes	0.018	0.009	1.925	0.15

Table 4

(a)

	LR χ2	Df	Pr(>χ2)
Facebook Friends	2.981	1	0.084
Pre-Goal Page Views	58.206	1	0
Post-Goal Page Views	17.797	1	0

(b)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	6.523	2.504	2.605	0.011
Facebook Friends	0.011	0.006	1.816	0.074
Pre-Goal Page Views	0.018	0.003	6.524	0
Post-Goal Page Views	0.036	0.01	3.64	0.001

Table 5

(a)	LR χ2	Df	Pr(>χ2)
Google+ Followers	0.118	1	0.731
# of Google+ Posts	3.198	1	0.074
# of Twitter Followers	2.432	1	0.119
# of Tweets	0.189	1	0.663
# of People Contacted by Email	21.47	1	>0.001
# of Press Contacted	33.88	1	>0.001
Google+ Followers * Posts	0.12	1	0.729
# of Twitter Followers * Tweets	5.394	1	0.02
(b) # of Twitter Followers	0.839	1	0.36
# of Tweets	0.348	1	0.555
# of People Contacted by Email	0.072	1	0.788
# of Press Contacted	0.342	1	0.558
# of Twitter Followers * Tweets	0.249	1	0.618
(c) Pre-Goal Page Views	7.096	1	0.008

(d)	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	572.711	93.726	6.11	>0.001
Google+ Followers	0.003	0.097	0.028	0.978
# of Google+ Posts	-14.324	11.371	-1.26	0.214
# of Twitter Followers	-0.269	0.199	-1.354	0.182
# of Tweets	-5.025	4.06	-1.238	0.221
# of People Contacted by Email	1.72	0.371	4.634	>0.001
# of Press Contacted	92.645	15.917	5.821	>0.001
Google+ Followers * Posts	-0.001	0.002	-0.347	0.73
# of Twitter Followers * Tweets	0.014	0.006	2.323	0.024
(e) (Intercept)	156.213	57.159	2.733	0.012
# of Twitter Followers	0.005	0.21	0.023	0.982
# of Tweets	2.04	2.732	0.747	0.463
# of People Contacted by Email	-0.05	0.188	-0.268	0.791
# of Press Contacted	6.263	10.703	0.585	0.564
# of Twitter Followers * Tweets	-0.002	0.003	-0.499	0.623
(f) (Intercept)	118.283	88.943	1.33	0.194
Pre-Goal Page Views	0.114	0.043	2.664	0.012

Table 6

Factor	All rounds (n = 118)	Round 1 (n = 47)	Round 2 (n = 49)	Round 3 (n = 22)
Family and friends giving	43 (36%)	17 (36%)	18 (37%)	8 (36%)
Personal networks	43 (36%)	13 (28%)	23 (47%)	7 (32%)
Online networks	37 (31%)	20 (43%)	7 (14%)	10 (45%)
Effective video	13 (11%)	7 (15%)	4 (8%)	2 (9%)
Social relevance of project	8 (7%)	6 (13%)	2 (4%)	0
General SciFund publicity	5 (4%)	4 (9%)	0	1 (5%)
Small financial goal	4 (3%)	4 (9%)	0	0
National media	2 (2%)	2 (4%)	0	0
Tastemaker involvement	2 (2%)	2 (4%)	0	0
Local media	1 (1%)	1 (2%)	0	0
Luck	1 (1%)	1 (2%)	0	0
Merton effect	1 (1%)	0	1 (2%)	0
Rewards	1 (1%)	1 (2%)	0	0
Specific project goals	1 (1%)	1 (2%)	0	0

Table 7

Factor	All rounds (n = 118)	Round 1 (n = 47)	Round 2 (n = 49)	Round 3 (n = 22)
Blogging or social media (Facebook, Google+, Twitter) did not work for me	23 (19%)	10 (21%)	7 (14%)	6 (27%)
Did not promote enough	15 (13%)	8 (17%)	5 (10%)	2 (9%)
Had no online network or online media presence	14 (12%)	8 (17%)	4 (8%)	2 (9%)
Could not engage professional discipline or relevant organizations	10 (8%)	3 (6%)	3 (6%)	4 (18%)
Could not get press	10 (8%)	3 (6%)	6 (12%)	1 (5%)
Project focus or topic not good	8 (7%)	6 (13%)	2 (4%)	0
Tastemaker involvement not effective	7 (6%)	4 (9%)	3 (6%)	0
Friends and family would not donate	6 (5%)	4 (9%)	2 (4%)	0
Rewards were not a draw	5 (4%)	3 (6%)	1 (2%)	1 (5%)
Bad video or problems with video	4 (3%)	2 (4%)	1 (2%)	1 (5%)
Cold calls and reaching out to strangers not effective	4 (3%)	0	4 (8%)	0
Being faculty as opposed to student	1 (1%)	0	1 (2%)	0
Dollar goal too high	1 (1%)	1 (2%)	0	0
Male voice on video not effective	1 (1%)	1 (2%)	0	0
Timing of the campaign and national events	1 (1%)	0	0	1 (5%)

Figure 1: **The history of #SciFund.** The daily time series of donations during the run of #SciFund Round 1
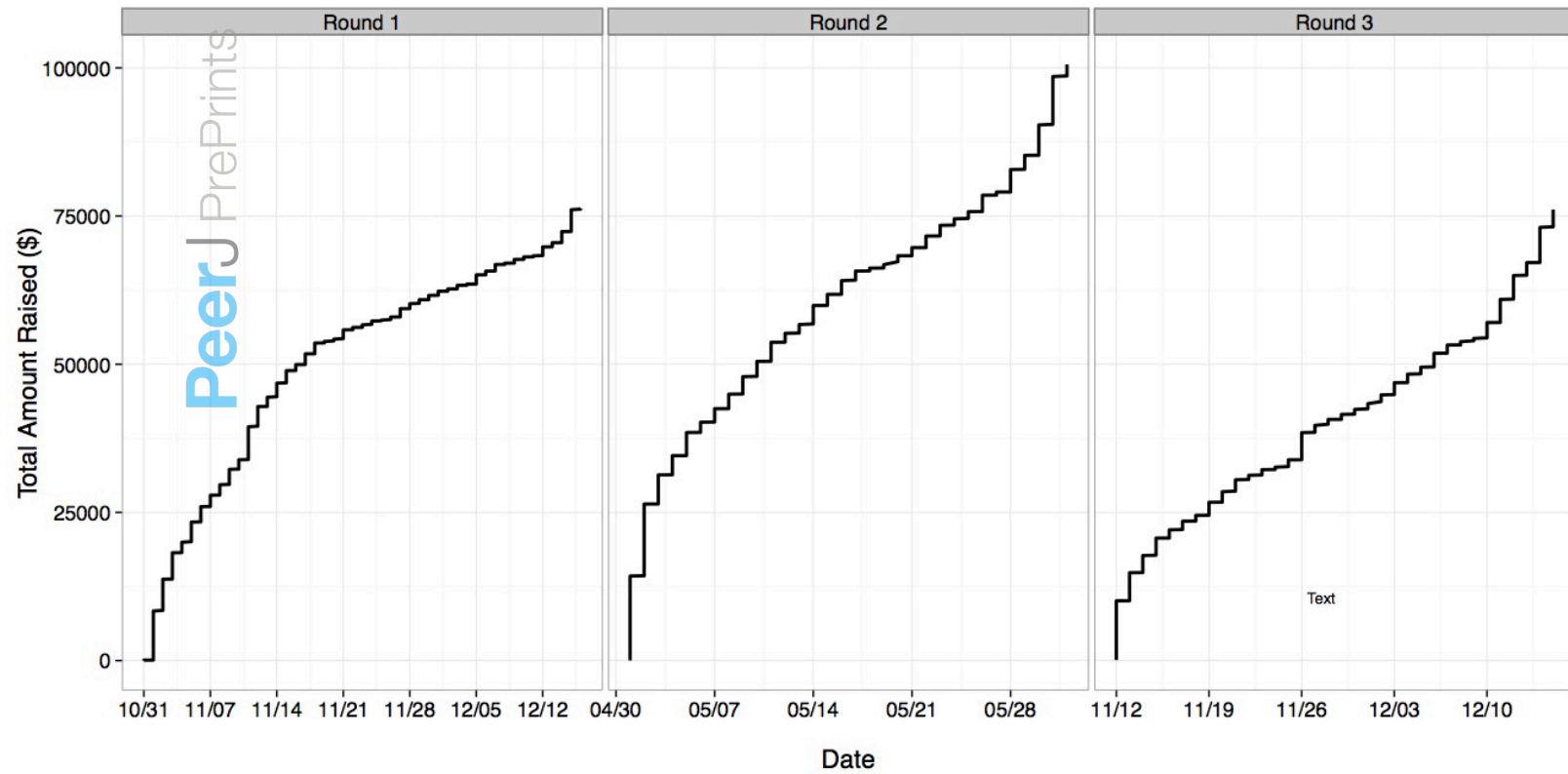
Figure 2: **Total Dollars Raised plotted against the number of contributors.** Line represents best fit from model described in the text. Shaded grey area represents the 95% Confidence Interval around the fit relationship.
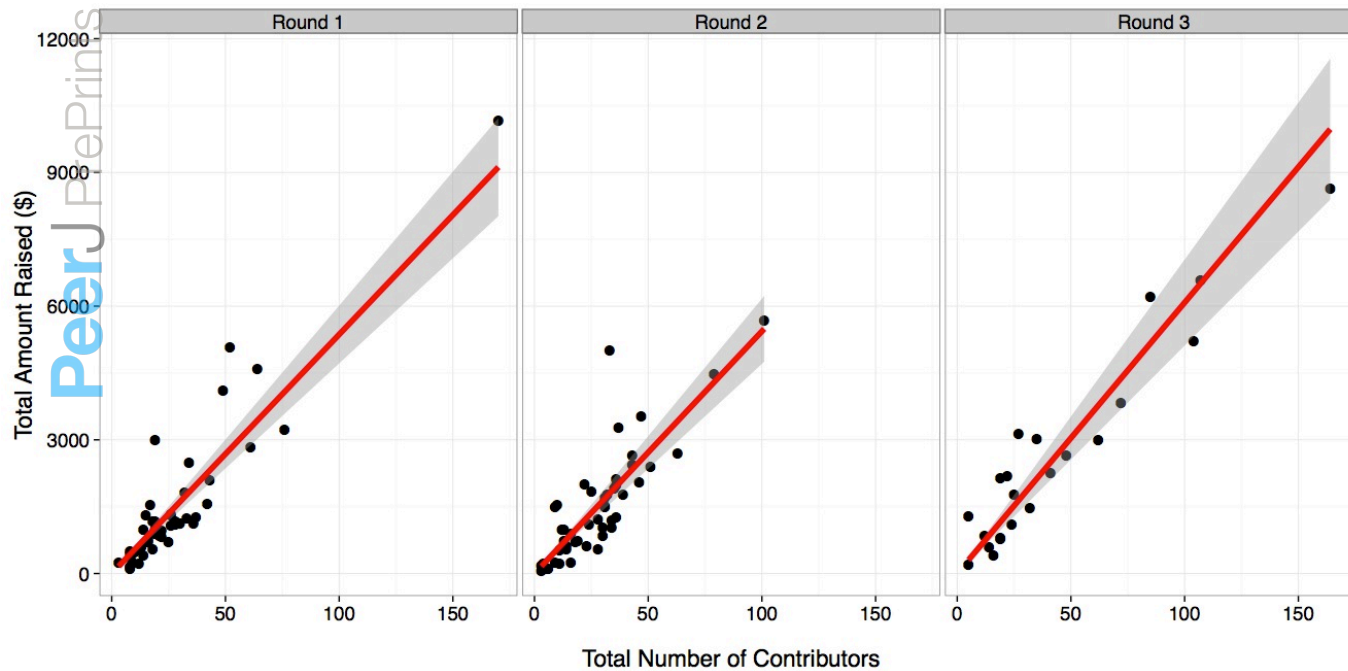
Figure 3: **The factors affecting number of contributors to a project.** Plot shows the number of contributors plotted against the number of Facebook Friends. Size of points shows the number of page views before achieving success. Color shows the number of project page views after goals were reached with blue representing no views to red representing many views. Line represents best fit from generalized linear model between x and y. Shaded grey area represents the 95% Confidence Interval around the fit relationship.
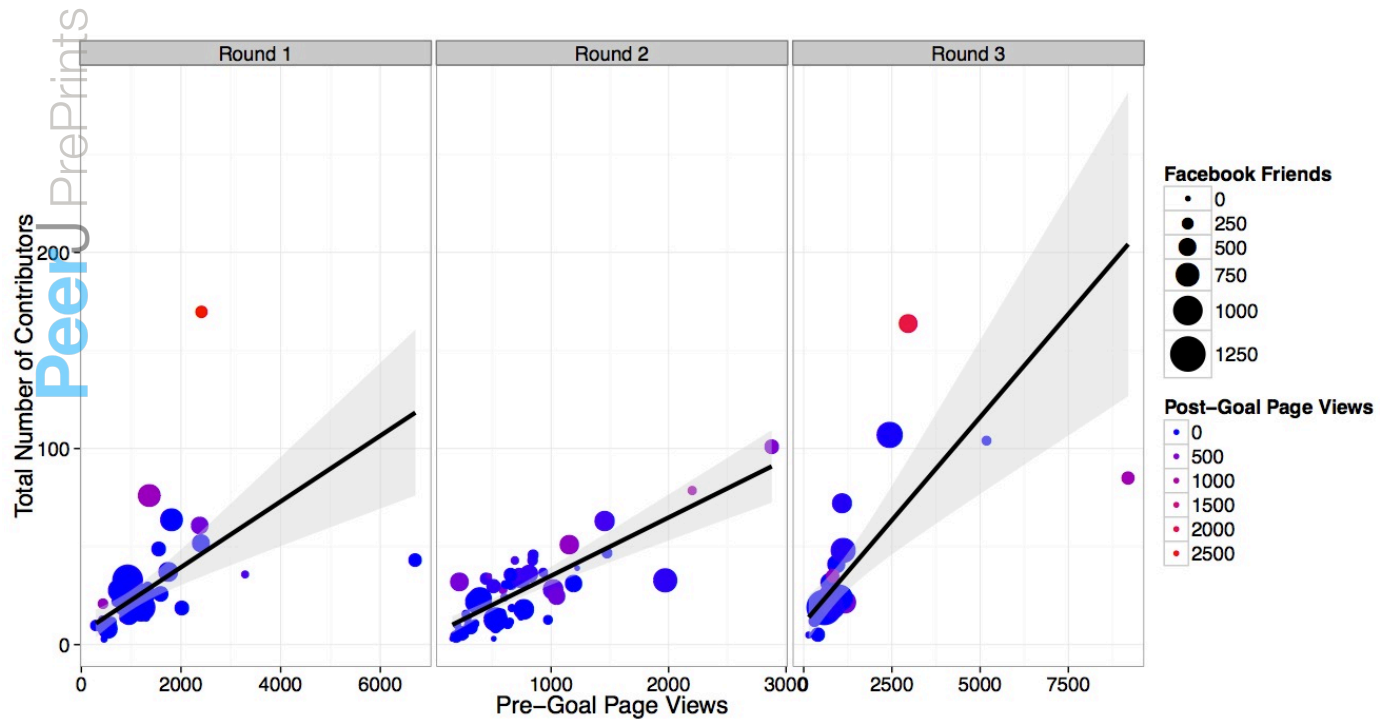
Figure 4: **The relationship between Facebook Likes, number of Twitter Followers, and project page views before a project hit its goal.** Line represents best fit from model described in the text. Shaded grey area represents the 95% Confidence Interval around the fit relationship. Point size is proportional to the number of Twitter Followers.
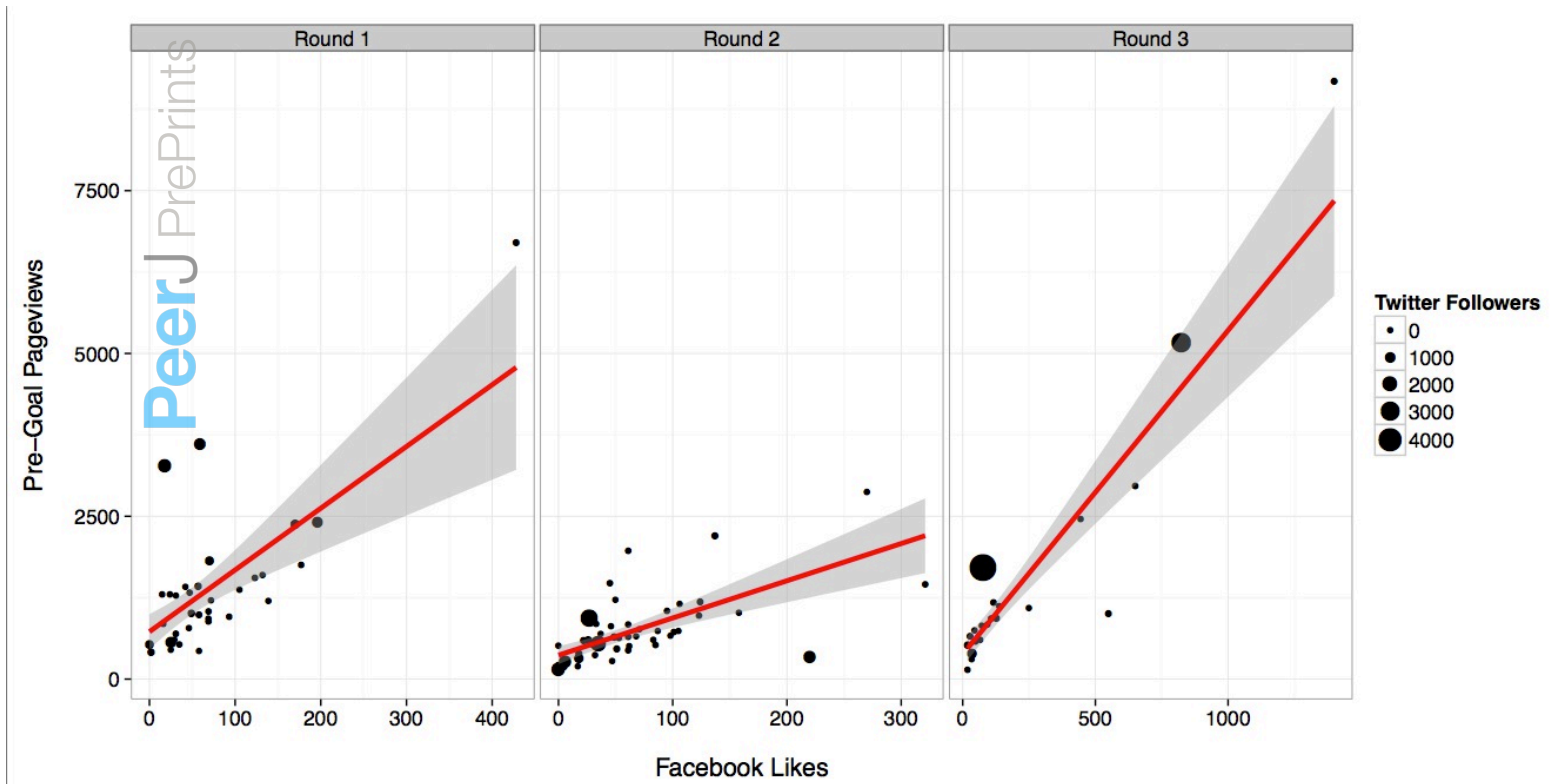
Figure 5: **The relationship between Facebook Likes and the number of page views after a project has achieved its funding goal.** Line represents best fit from model described in the text. Shaded grey area represents 1 Standard error around the fit relationship.
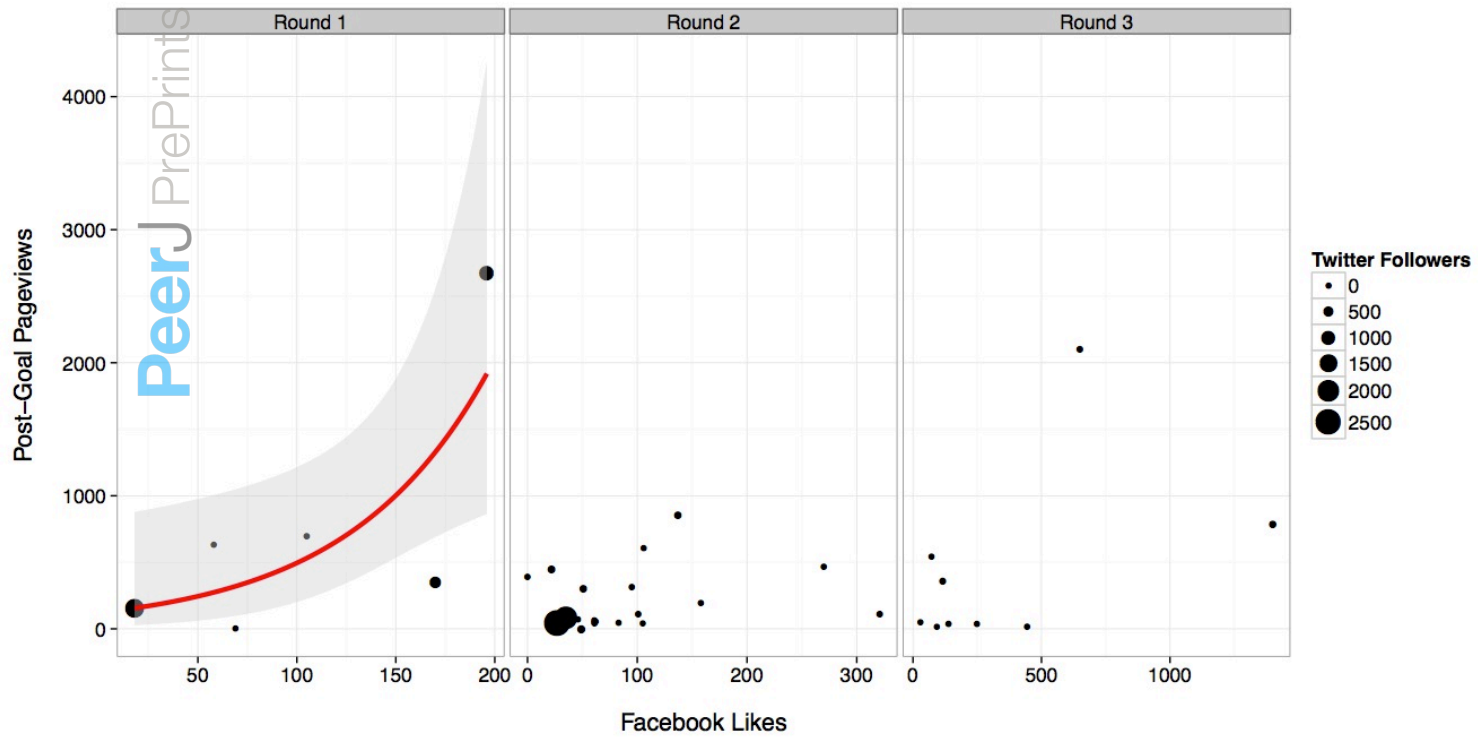
Figure 6: **The relationship between monthly blog posts and number of twitter followers.** Line represents best fit from model described in the text. Shaded grey area represents 1 Standard error around the fit relationship.
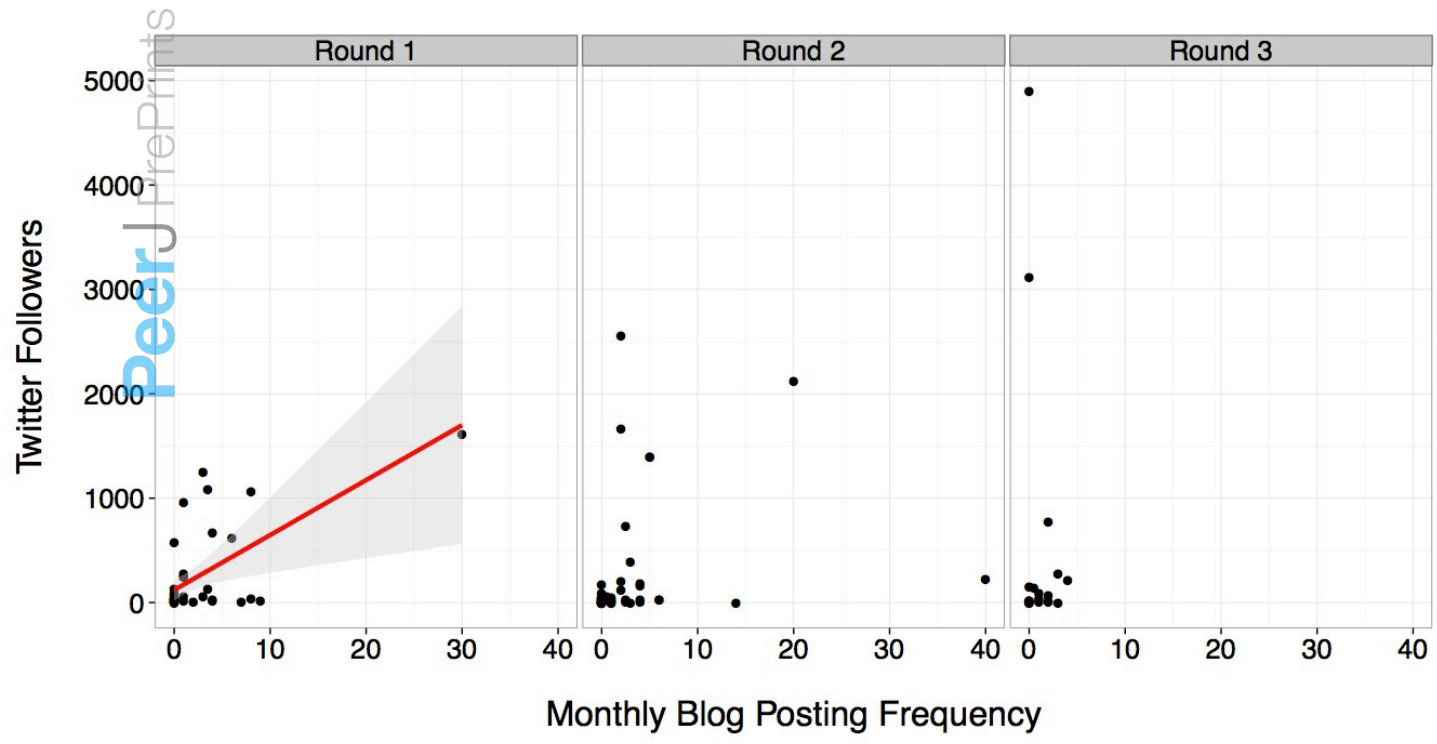
Figure 7: **The relationship between pre-goal page views, press contacts, number of people emailed, and effort * engagement on Twitter.** Line represents best fit from model between press and pre-goal page views. Shaded grey area represents the 95% Confidence Interval around the fit relationship.
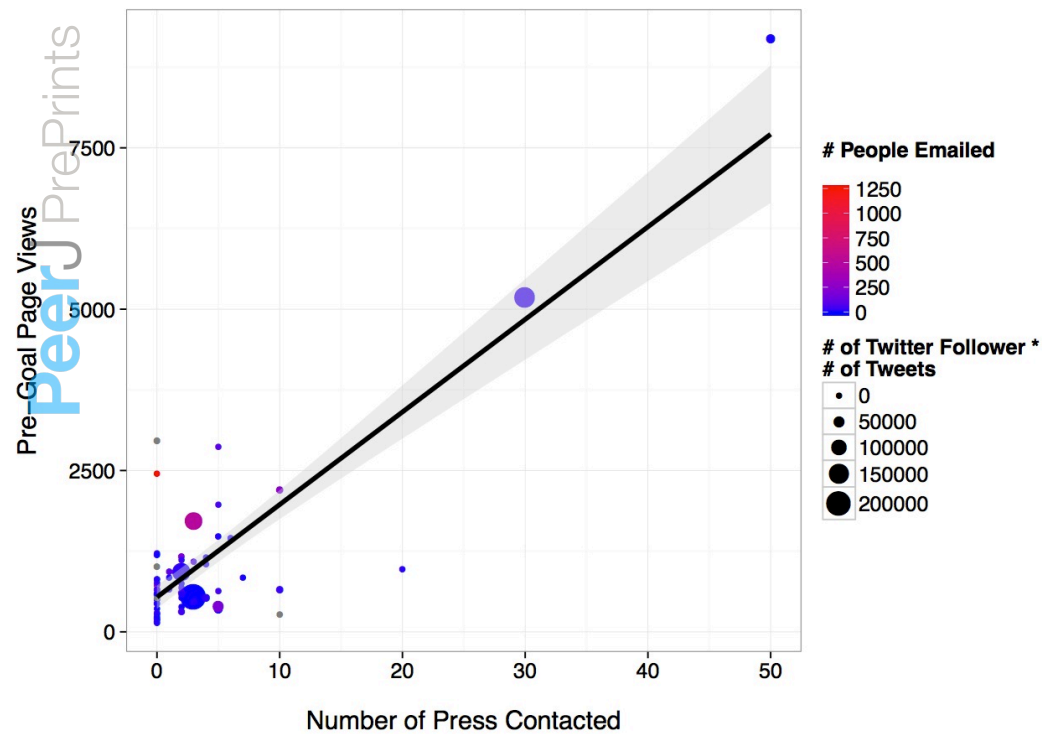
Figure 8: **How online engagement leads to a crowdfunded research project.**