Exploratory study
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Citizen Science: An Introduction

Exploratory study commissioned by the Swiss Science and Innovation Council SSIC

By Dr. John Bendix

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Schweizerischer Wissenschafts- und Innovationsrat
Conseil suisse de la science et de l'innovation
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Swiss Science and Innovation Council

The Swiss Science and Innovation Council

The Swiss Science and Innovation Council SSIC is the advisory body to the Federal Council for issues related to science, higher education, research and innovation policy. The goal of the SSIC, in conformity with its role as an independent consultative body, is to promote the framework for the successful development of the Swiss higher education, research and innovation system. As an independent advisory body to the Federal Council, the SSIC pursues the Swiss higher education, research and innovation landscape from a long-term perspective.

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John Bendix is an American political scientist who has lived in Switzerland since 2008. For the last seven years, he has taught courses on U.S. and Swiss politics at the Institut für Politikwissenschaft, Universität Zürich. His academic training was at Amherst College, where he graduated magna cum laude in history and psychology, the University of California at Berkeley, where he received his Master's in public policy, and at Indiana University, Bloomington, where he received his Ph.D. in political science, with a focus on comparative politics and public administration. He has worked as an editor and translator for the SSIC since 2011, and has enjoyed the opportunity to delve into Citizen Science.

Table of Contents

Preface by the SSIC

The Swiss Science and Innovation Council SSIC has commissioned a series of exploratory studies as part of its Working Programme 2016–2019. The following publication on Citizen Science – or on the democratisation of science – is one of the studies. The author John Bendix, however, makes it clear at the beginning of his research (part 1) that the notion of 'democratisation of science' could be misleading and simply calls the study 'Citizen Science: An introduction' (part 2).

The SSIC discussed the study at its Council meeting of 23 January 2017. The discussion was framed by two keynote speeches by scientists who either use Citizen Science themselves (Kevin Schawinski, ETH Zurich) or who have examined and critically assessed the current sudden spread of citizen science (Bruno J. Strasser, University of Geneva and Yale University).

In view of the inflationary trend of referring to 'alternative facts' or to a 'post-factual world', Citizen Science has become more timely than ever in recent months. The SSIC will therefore continue to closely monitor Citizen Science and address the topic in a policy paper. The Council recommends this exploratory study as an introductory discussion.

Préface du CSSI

Dans le cadre de son programme de travail 2016–2019, le Conseil suisse de la science et de l'innovation CSSI a commandé une série d'études exploratoires. La présente publication sur le thème «Citizen Science» (sciences participatives, sciences citoyennes ou sciences collaboratives) ou «démocratisation du savoir» en fait partie. L'auteur John Bendix insiste d'emblée (partie 1) sur le fait que la notion de «démocratisation du savoir» peut induire en erreur et a simplement intitulé son étude «Citizen Science: An introduction» (partie 2).

Le CSSI a débattu de cette étude lors de sa séance du 23 janvier 2017. La discussion a été encadrée par les exposés de deux scientifiques, dont l'un fait lui-même usage des sciences participatives (Kevin Schawinski, EPFZ) et l'autre est auteur d'études critiques sur l'essor des sciences participatives (Bruno J. Strasser, Université de Genève et Yale University).

Le discours inflationniste sur les «faits alternatifs» ou le monde «post-factuel» ne fait qu'ajouter à l'actualité des sciences participatives. Le CSSI se propose dès lors de vouer une plus grande attention à cette démarche scientifique et de continuer à traiter ce sujet dans une analyse liée aux politiques. Il recommande la présente étude comme introduction à cette thématique.

Vorwort des SWIR

Der Schweizerische Wissenschafts- und Innovationsrat SWIR hat im Rahmen seines Arbeitsprogramms 2016–2019 eine Reihe von explorativen Studien in Auftrag gegeben; die hier vorliegende Publikation zur Citizen Science, zum Thema der Demokratisierung der Wissenschaft ist eine davon. Der Autor John Bendix hat allerdings gleich zu Beginn seiner Recherche (Teil 1) klar gemacht, dass der Begriff ‹Demokratisierung der Wissenschaft› irreführend sein könnte und die Studie schlicht ‹Citizen Science: An Introduction› (Teil 2) genannt.

Der SWIR hat die Studie anlässlich seiner Ratssitzung vom 23. Januar 2017 diskutiert. Eingerahmt war die Diskussion durch zwei Vorträge von Wissenschaftlern, die entweder selbst Citizen Science betreiben (Kevin Schawinski, ETH Zürich) oder den aktuellen Wachstumsschub der Citizen Science untersucht und kritisch reflektiert haben (Bruno J. Strasser, Universität Genf und Yale University).

Angesichts der inflationären Rede von ‹alternative facts› oder einer ‹post-faktischen Welt› ist die Bedeutung der Citizen Science in den letzten Monaten noch gewachsen. Deshalb wird sich der SWIR auch weiter und vertieft in einer Politanalyse mit Citizen Science beschäftigen. Die hier vorliegende Studie empfiehlt er gerne als einführende Auseinandersetzung mit dem Thema.

Prefazione del CSSI

Nel quadro del suo programma di lavoro 2016–2019, il Consiglio svizzero della scienza e dell'innovazione (CSSI) ha commissionato una serie di studi esplorativi, tra cui quello che ha prodotto la presente pubblicazione, concernente la «Citizen Science» e la democratizzazione della scienza. Fin dall'inizio delle sue ricerche (prima parte) John Bendix, autore della ricerca, ha però deciso, per ragioni di chiarezza, di intitolare il suo lavoro «Citizen Science: An introduction» (seconda parte).

Il CSSI ha discusso i risultati dello studio in occasione della sua riunione del 23 gennaio 2017. Il dibattito è stato introdotto dalle relazioni di due specialisti: Kevin Schawinski, del Politecnico federale di Zurigo, attivo nell'ambito della «Citizen Science», e Bruno J. Strasser, delle Università di Ginevra e Yale, che studia e indaga criticamente i rapidi sviluppi in atto in questo settore.

Visto l'imperversare, negli ultimi mesi, delle discussioni sui «fatti alternativi» o sul «mondo post-fattuale» la «Citizen Science» diventa ancora più di attualità: Il CSSI intende perciò approfondire ulteriormente gli aspetti legati a questa tematica in una pubblicazione, e segnala il presente studio per il suo valore introduttivo.

Executive summary

Democratization of Science

The standard connotations of the notion of ‘democratization’ are overwhelmingly political, and this can lead to dramatic formulations (e.g., ‘freeing oneself from the stranglehold scientists have on knowledge or information’). But this is quite misleading with respect to Citizen Science, where it is more appropriate to think of ‘democratization’ as ‘relating to, appealing to, or available to the broad masses of the people’.

Background

The practices now called ‘Citizen Science’ partly existed in the past, but they only became widespread after the mid-1990s. That is due to technological changes brought about through the rapid increase in mobile means of communication and the interactivity among users.

Volunteers

Those who volunteer their time or other resources to participate in research projects are typically motivated by the same curiosity and desire to advance science and understanding as the scientists. Scientists, in turn, can tackle tasks (such as classifying hundreds of thousands of images) for which they otherwise lack personnel, money, or time.

Contributions of volunteers

Citizen Science involves activities which vary by type, scope, and intensity as well as by discipline. Efforts to define such activities range from lists of verbs to sophisticated surveys of the dimensions involved. These ‘citizen’ are members of the general public who volunteer their time or resources to help with scientific research projects, and while sometimes called ‘non-professional scientists’, such volunteers are usually assumed to have ‘no specific scientific training’. What they provide varies, but in many Citizen Science projects, scientists set the task and volunteers contribute observations or send in samples. Volunteers also tackle more difficult tasks, as when they are asked – typically after a tutorial or other instruction – to decipher, annotate, complete, or transcribe partial information. In that sense, they help ‘fill in the gaps’ and collaborate.

Differing views

Both contributory and collaborative project fit into one of the two principal ways such activities have been conceptualized since the mid-1990s. In the view associated particularly with Rick Bonney in the U.S., Citizen Science serves to increase trust in the scientific enterprise, improve scientific literacy and enhance the public understanding of science. The other view, associated most with Alan Irwin in the UK, sees Citizen Science as 'based upon the presumed emancipatory benefits of active public input on the direction of scientific research agendas'. Here the involvement of citizens, including in bottom-up efforts, is meant to be linked to community needs or policies, and is associated with the idea of 'democratizing' research.

Impact

To understand impact, it is necessary to delimit what 'Citizen Science' encompasses. Studies of the occurrence of 'Citizen Science' and related terms in Scopus and Web of Science show strong recent growth – particularly in published peer-reviewed articles – which helps strengthen its legitimacy. Methodology and validation are important, because there are 'buckets of resistance' to Citizen Science due to fears about the poor quality of data provided by citizen volunteers.

Legitimacy

A focus on data quality can be a way to question the legitimacy of the Citizen Science enterprise as a whole, if not even to discredit what it (potentially) can contribute. One can take a more pragmatic approach, and suggest Citizen Science is one of a variety of methodological approaches which can be taken depending on the questions being asked and who is asking them.

Guidelines

Two Swiss academics have been instrumental in conceptualizing and formulating guidelines for scientists who engage in Citizen Science projects at European research universities (e.g., LERU) to use. These guidelines also are meant to serve as policy recommendations for research funders, policy-making bodies, and universities (Wyler and Grey 2016). Some Swiss institutions or organizations (as well as individuals) also belong to the European Citizen Science Association.

In Switzerland

Domestically, some Citizen Science web portals have emerged. While some have a specific or narrower focus (OpenNature; MMOS), portals such as Citizen Cyberlab (supported by UNIGE, CERN, and UNITAR) or the Citizen Science Network Switzerland (its parent, Science et Cité, is supported by ETHZ, UZH, UNIGE, and the Swiss Academies of Arts and Sciences) have both broader ambits and broader ambitions. The most recent effort, underway since February 2017, has been to create a 'Competence Center for Citizen Science' (a joint UZH/ ETHZ venture).

Reflection

Scientists (and institutions) are not in agreement about how involved they should be in public controversies about scientific issues. There is ambivalence as well about Citizen Science. On the one hand, it can be helpful to scientists in completing onerous tasks associated with large datasets, save costs, and can help in 'reaching out' to the public; it is also valued by volunteers who feel involved, are excited about scientific discovery, and are pleased to be in contact with 'real' researchers. On the other hand, it evokes skepticism about the quality of data provided by amateurs unsophisticated about science, raises concerns about the exploitation of freely-offered labor (or concern at robbing student assistants of work), and is bedeviled by an assumption that the greater costs and effort needed for Citizen Science projects may not match the assumed – or asserted – benefits.

Conclusion

Above all, what Citizen Science does is to raise questions about the nature of 'the scientific enterprise' itself. Public enthusiasm for scientific research is a valuable asset, yet scientists' cautions and concerns are equally important.

Executive summary

Demokratisierung der Wissenschaft

Der Begriff ‹Demokratisierung› wird überwiegend mit politischen Bedeutungen assoziiert, was zu etwas extremen Formulierungen führen kann (z.B. ‹Wissen und Information aus dem Würgegriff befreien, in dem die Wissenschaftler/innen sie halten›). In Bezug auf ‹Citizen Science› (die Bürgerwissenschaft) ist diese Vorstellung jedoch etwas irreführend, denn Demokratisierung ist hier vielmehr so zu verstehen, dass das Wissen die breite Masse von Menschen betrifft, anspricht oder ihr zur Verfügung gestellt wird.

Hintergrund

Die Praktiken, die heute unter Citizen Science zusammengefasst werden, existierten zum Teil schon früher, fanden aber erst Mitte der 1990er-Jahre stärkere Verbreitung. Grund dafür ist der technologische Wandel infolge der rasanten Zunahme der mobilen Kommunikationsmittel und der Interaktivität zwischen Nutzerinnen und Nutzern.

Freiwillige

Wer freiwillig Zeit oder andere Ressourcen investiert, um sich an Forschungsprojekten zu beteiligen, tut dies häufig aus denselben Motiven wie die Forschenden: aus Neugier und weil er oder sie die Wissenschaft voranbringen und das Verständnis fördern möchte. Forschende wiederum können Aufgaben (wie die Klassifizierung von Hunderttausenden von Bildern) in Angriff nehmen, für die ihnen sonst Personal, Geld oder Zeit fehlen.

Beiträge der Freiwilligen

Citizen Science beinhaltet Tätigkeiten, die sich nach Art, Ziel, Intensität und Fachbereich unterscheiden. Ansätze zur Definition solcher Tätigkeiten reichen von Verblisten bis hin zu ausgeklügelten Umfragen zu den betroffenen Dimensionen. Bei den ‹Citizens› handelt es sich um Menschen aus der breiten Öffentlichkeit, die zur Unterstützung von Forschungsprojekten freiwillig Zeit oder Ressourcen aufwenden. Obwohl sie manchmal als ‹nicht professionelle Forschende› bezeichnet werden, wird in der Regel davon ausgegangen, dass sie über keine spezifische wissenschaftliche Ausbildung verfügen. Sie leisten sehr unterschiedliche Beiträge, in vielen Citizen-Science-Projekten legen die Forschenden jedoch die Aufgabe fest und die Freiwilligen liefern anschliessend Beobachtungen oder schicken Proben ein. Freiwillige können aber auch komplexere Aufgaben übernehmen, beispielsweise wenn sie – üblicherweise nach einem Tutorium oder einer anderen Anleitung – partielle Informationen entziffern, kommentieren, ergänzen oder transkribieren sollen. In diesem Sinne helfen sie, Lücken zu schliessen, und arbeiten so mit.

Unterschiedliche Sichtweisen

Sowohl Projekte, die Beiträge nutzen, als auch solche, die auf Mitarbeit setzen, entsprechen einer der beiden Hauptstossrichtungen, wie solche Tätigkeiten seit Mitte der 1990er-Jahre verstanden werden. Nach der einen Sichtweise, die insbesondere von Rick Bonney in den USA geprägt wurde, dient Citizen Science dazu, das Vertrauen in die wissenschaftliche Forschung zu stärken sowie die wissenschaftlichen Kenntnisse und das öffentliche Verständnis für die Wissenschaft zu verbessern. Aus der anderen Perspektive, die hauptsächlich auf Alan Irwin aus dem Vereinigten Königreich zurückgeht, stützt sich Citizen Science auf den vermuteten emanzipatorischen Nutzen aktiver öffentlicher Beiträge zur Ausrichtung der Forschungspläne der Wissenschaftlerinnen und Wissenschaftler. Demgemäss werden die Bürgerinnen und Bürger, u.a. in Bottom-up-Bestrebungen, vor allem aufgrund gemeinschaftlicher Bedürfnisse und Politiken eingebunden, womit die Forschung ‹demokratisiert› werden soll.

Einfluss

Um ihren Einfluss zu verstehen, muss Citizen Science klar abgegrenzt werden. Untersuchungen zur Häufigkeit des Begriffs Citizen Science und verwandter Begriffe in Scopus und im Web of Science zeigen eine starke Zunahme in letzter Zeit – insbesondere in Artikeln, die nach einer Peer Review veröffentlicht wurden. Das stärkt die Legitimität von Citizen Science. Die Methode und Validierung von Citizen-Science-Projekten sind wichtig, da ihnen aufgrund von Befürchtungen, die Qualität der von den Freiwilligen gelieferten Daten sei ungenügend, starker Gegenwind entgegenbläst.

Legitimität

Wird der Fokus auf die Datenqualität gelegt, kann die Legitimität von Citizen Science als Ganzem infrage gestellt, wenn nicht sogar ihr (potenzieller) Beitrag diskreditiert werden. Aus einer pragmatischeren Perspektive wäre Citizen Science als einer von vielen methodologischen Ansätzen zu betrachten, der sich anbietet je nachdem, wer welche Fragen stellt.

Richtlinien

Zwei Schweizer Akademiker leisteten einen Beitrag zur Konzipierung und Formulierung von Richtlinien für Forschende, die sich an Citizen-Science-Projekten europäischer Forschungsuniversitäten (z.B. LERU) beteiligen. Diese Richtlinien sollen auch als politische Empfehlungen für Forschungsförderer, politische Entscheidungsträger und Universitäten dienen (Wyler und Grey 2016). Einige Schweizer Institutionen und Organisationen (sowie Privatpersonen) sind zudem Mitglied der European Citizen Science Association.

In der Schweiz

Hierzulande gibt es mittlerweile einige Webportale für Citizen Science. Während einige einen spezifischeren bzw. engeren Fokus haben (OpenNature; MMOS), fassen andere wie Citizen Cyberlab (unterstützt von der UNIGE, dem CERN und UNITAR) oder das Citizen Science Network Switzerland (dessen Gründer, Science et Cité, von der ETHZ, der UZH, der UNIGE und den Akademien der Wissenschaften Schweiz unterstützt wird) den Anwendungsbereich und die Zielsetzungen weiter. Die neuste, seit Februar 2017 laufende Initiative betrifft die Schaffung eines ‹Competence Center for Citizen Science› (ein Joint Venture der UZH und der ETHZ).

Reflexion

Wissenschaftlerinnen und Wissenschaftler (und Institutionen) sind sich uneinig darüber, wie stark sie sich in öffentliche Diskussionen über wissenschaftliche Fragen einbringen sollen. Auch in Bezug auf Citizen Science herrscht diesbezüglich Uneinigkeit. Einerseits kann sie für Forschende nützlich sein bei der Ausführung kostspieliger Aufgaben im Zusammenhang mit grossen Datensätzen, sie kann Kosten einsparen und helfen, die Öffentlichkeit zu erreichen; und sie wird auch von den Freiwilligen begrüsst, die damit das Gefühl haben, einbezogen zu werden, die sich über wissenschaftliche Entdeckungen freuen und den Kontakt zu ‹echten› Forschenden schätzen. Andererseits stösst Citizen Science auf Skepsis in Bezug auf die Qualität der von wissenschaftlichen Laien gelieferten Daten, sie löst Befürchtungen einer Ausbeutung von Freiwilligenarbeit aus (indem man studentische Hilfskräfte ihrer Arbeit beraubt) und ihr haftet gewöhnlich der Ruf an, die höheren Kosten und der grössere Aufwand für Citizen-Science-Projekte würden den erwarteten – oder geltend gemachten – Gewinn übersteigen.

Fazit

Citizen Science wirft in erster Linie Fragen auf zur eigentlichen Natur der wissenschaftlichen Forschung. Die öffentliche Begeisterung für die Forschung ist wertvoll, die Warnungen und Bedenken der Wissenschaftlerinnen und Wissenschaftler gilt es aber ebenso ernst zu nehmen.

Démocratisation de la science

Les connotations majoritairement politiques du terme «démocratisation» donnent parfois lieu à des définitions radicales (p. ex. fait de se défaire de la mainmise des scientifiques sur le savoir et l'information). Une telle approche ne s'applique par contre pas aux sciences citoyennes, où la notion de démocratisation se réfère plutôt à l'idée de «créer des liens, faire appel à autrui, rendre accessible au plus grand nombre».

Contexte

Les pratiques regroupées sous le terme de «sciences citoyennes» existaient déjà dans le passé, mais elles ne se sont vraiment généralisées qu'à partir de la seconde moitié des années 90 de par les changements technologiques dus au développement rapide des moyens de communication mobiles et à l'interactivité entre utilisateurs.

Volontaires

Les personnes qui investissent du temps ou d'autres ressources pour participer à des projets de recherche sont en général animées par la même curiosité et la même envie que les scientifiques de faire avancer la science et la compréhension que nous en avons. Les scientifiques, pour leur part, ont la possibilité de s'atteler à des tâches, telles que la classification de centaines de milliers d'images, pour lesquelles ils n'auraient sinon ni le personnel, ni l'argent, ni le temps.

Contributions des volontaires

Les sciences citoyennes recouvrent des activités qui diffèrent les unes des autres aussi bien au niveau du type, de l'objectif et de l'intensité qu'en termes de discipline. Les tentatives pour définir ces activités vont de l'élaboration de listes de verbes à des enquêtes sophistiquées sur les dimensions que ces activités comportent. Ces «citoyens» qui apportent leur contribution à des projets de recherche en y consacrant du temps ou d'autres ressources font partie du grand public et, même s'ils sont parfois appelés «scientifiques non professionnels», ils n'ont pas en principe un bagage spécifique en science. Leurs contributions varient d'un projet de sciences citoyennes à l'autre, mais en général, les chercheurs définissent les tâches, et les volontaires doivent faire part de leurs observations ou envoyer des échantillons. Les volontaires peuvent être aussi amenés à accomplir des tâches plus complexes comme déchiffrer, commenter, compléter ou transcrire des informations partielles en respectant un protocole ou d'autres instructions. Ce faisant, ils collaborent et aident à combler les lacunes.

Points de vue différents

Que les projets soient contributifs ou collaboratifs, ils correspondent à l'une des principales acceptions qui ont été données à ce type d'activités depuis le milieu des années 90. Selon le point de vue plus spécialement représenté par Rick Bonney aux Etats-Unis, les sciences citoyennes permettent d'augmenter la confiance dans la recherche scientifique, de développer une culture scientifique et d'améliorer la compréhension du travail scientifique par le grand public. L'autre point de vue, principalement défendu par Alan Irwin au Royaume-Uni, part du principe que les sciences citoyennes sont axées sur l'intérêt émancipatoire que sont supposées présenter les contributions du public pour l'orientation des agendas de recherche scientifique. L'engagement des citoyens, y compris dans les activités *bottom-up*, est alors censé faire écho aux besoins et aux politiques de la communauté et s'inscrire dans une démarche de démocratisation de la recherche.

Impact

Pour comprendre l'impact des sciences citoyennes, il faut délimiter ce qu'elles recouvrent. Il ressort des résultats de recherche du terme *citizen science* et des termes voisins dans Scopus et Web of Science que le nombre d'occurrences a fortement augmenté ces derniers temps, notamment dans les articles publiés après avoir été révisés par des pairs. Ce constat contribue aussi à légitimer l'équivalent français, à savoir «sciences citoyennes». Méthodologie et validation sont deux axes essentiels face aux «poches de résistance» qui existent encore vis-à-vis des sciences citoyennes, certaines personnes doutant de la qualité des données fournies par les citoyens volontaires.

Légitimité

Mettre l'accent sur la qualité des données peut être un moyen de remettre en cause la légitimité des sciences citoyennes dans leur ensemble ou tout au moins de discréditer leur impact (potentiel). Une approche plus pragmatique serait de considérer les sciences citoyennes comme une méthode parmi tant d'autres que l'on peut adopter en fonction des questions posées et de ceux qui les posent.

Directives

Deux académies suisses ont concouru à la conception et à la formulation de directives à l'intention des scientifiques qui participent à des projets de sciences citoyennes au sein des universités de recherche européennes (p. ex. LERU). Le but de ces directives est également de servir de recommandations aux investisseurs, aux organes décisionnaires et aux universités pour la définition de leurs stratégies (Wyler et Grey 2016). Certaines institutions et organisations suisses (de même que des individus) font également partie de l'ECSA (*European Citizen Science Association*).

En Suisse

Plusieurs portails Internet consacrés aux sciences citoyennes ont vu le jour à l'échelle nationale. Alors que certains de ces portails s'intéressent à un sujet spécifique, voire très pointu (OpenNature, MMOS), d'autres tels que Citizen Cyberlab (soutenu par l'UNIGE, le CERN et l'UNITAR) ou le Réseau des sciences citoyennes en Suisse (Science et Cité, à l'origine de ce réseau, est soutenu par l'EPFZ, l'UZH, l'UNIGE et les Académies suisses des sciences) ont une portée et des ambitions plus larges. L'action la plus récente a été l'inauguration en février 2017 du *Competence Center for Citizen Scienc*e, créé par l'UZH et l'EPFZ.

Réflexion

Les scientifiques (et les institutions) ne sont pas d'accord entre eux pour savoir jusqu'à quel point ils doivent participer aux controverses publiques sur des sujets scientifiques. On retrouve la même ambivalence concernant les sciences citoyennes. D'une part, le fait de faire réaliser des tâches prenantes impliquant le traitement de volumes de données importants peut soulager les chercheurs et leur permettre de réduire les coûts tout en leur donnant la possibilité de toucher le public; les volontaires apprécient également cette démarche, car ils ont vraiment l'impression d'apporter leur pierre à l'édifice et sont enthousiastes à l'idée de faire des découvertes scientifiques et d'être en contact avec de «vrais» chercheurs. D'autre part, qui dit sciences citoyennes dit scepticisme quant à la qualité des données fournies par des amateurs possédant des connaissances scientifiques élémentaires, préoccupations quant à l'exploitation du travail bénévole (ou concernant le travail qui est volé aux assistants universitaires) et supposition se faisant toujours plus insinueuse selon laquelle les coûts et actions liés aux projets de sciences citoyennes pourraient ne pas être compensés par les bénéfices que l'on pense, ou que l'on sait, pouvoir en retirer.

Conclusion

Les sciences citoyennes visent avant tout à soulever des questions sur la nature de la démarche scientifique en soi. Si l'intérêt du grand public pour la recherche scientifique est un atout précieux, les réserves et les préoccupations des scientifiques doivent également être prises en compte.

Democratizzazione della scienza

Il concetto di «democratizzazione» viene spesso associato a definizioni di natura politica, il che può dare adito a formulazioni forti (p. es: liberare conoscenza e informazione dal controllo degli scienziati). Ciò, però, risulta piuttosto fuorviante per quanto riguarda la cosiddetta «scienza dei cittadini» (Citizen Science), dove è più appropriato pensare alla «democratizzazione» come un'idea che riguarda grandi masse di persone, le coinvolge o viene messa a loro disposizione.

Contesto

In parte, le pratiche oggi chiamate Citizen Science esistevano già in passato, ma hanno cominciato a diffondersi veramente solo dopo la metà degli anni '90, sulla scia dei cambiamenti tecnologici provocati dal rapido aumento dei mezzi di comunicazione mobile e dell'interattività tra gli utenti.

Volontari

Coloro che su base volontaria mettono a disposizione il proprio tempo o altre risorse per partecipare a progetti di ricerca sono solitamente spinti dalle stesse motivazioni degli scienziati, vale a dire la curiosità e il desiderio di far avanzare scienza e conoscenza. A loro volta, gli scienziati possono svolgere incarichi (p. es. classificare centinaia di migliaia di immagini) per i quali altrimenti non avrebbero il personale, i fondi oppure il tempo.

Contributi dei volontari

Le attività condotte in nome della scienza dei cittadini variano per tipo, ambito, intensità e disciplina. Si è cercato di definirle in vari modi, dai più semplici (liste di verbi) ai più complessi (studi articolati sulle dimensioni implicate). I cittadini in questione sono persone che, su base volontaria, dedicano tempo o risorse a sostegno di progetti di ricerca scientifici. Pur essendo talvolta chiamati «scienziati non professionisti», in generale questi volontari non hanno formazione scientifica in senso stretto. Il loro contributo è di varia natura, ma di norma sono i ricercatori che definiscono i compiti e in seguito i volontari formulano osservazioni oppure inviano campioni. I volontari si cimentano anche in attività più complesse, per esempio quando gli viene chiesto – attenendosi a istruzioni impartite in precedenza – di decifrare, annotare, completare o trascrivere informazioni parziali. Così facendo contribuiscono a colmare le lacune esistenti.

Punti di vista differenti

Sia i progetti contributivi che quelli collaborativi corrispondono a una delle due accezioni principali attribuite a queste attività fin da metà degli anni '90. Nell'approccio associato in particolare a Rick Bonney negli Stati Uniti, la Citizen Science aiuta ad aumentare la fiducia nell'iniziativa scientifica, migliorare le conoscenze scientifiche e accrescere la comprensione pubblica della scienza. L'accezione associata per lo più ad Alain Irwin nel Regno Unito concettualizza la Citizen Science come principalmente fondata su presupposti vantaggi emancipatori per l'orientamento delle priorità di ricerca scientifica, quando quest'ultima coinvolge anche cittadini. Questo coinvolgimento, incluse le iniziative che partono dalla base, risponde alle esigenze o alle politiche della comunità e rientra nella logica di «democratizzazione» della ricerca.

Incidenza

Per capirne l'incidenza è necessario circoscrivere la scienza dei cittadini. Dalle recenti analisi delle occorrenze, su Scopus e sul Web of Science, del termine inglese Citizen Science e di quelli correlati è emersa una frequenza in aumento, specialmente in articoli pubblicati dagli scienziati dopo essere stati rivisti dai colleghi. Ciò rafforza la legittimità del termine. Metodologia e convalida sono importanti perché, per timore che i dati forniti dai volontari siano di scarsa qualità, esiste una forte opposizione alla Citizen Science.

Legittimità

Concentrare l'attenzione sulla qualità dei dati può essere un modo per mettere in discussione la legittimità della Citizen Science nel suo insieme, se non addirittura screditarne il (potenziale) contributo. Si potrebbe adottare un atteggiamento più pragmatico e affermare che questo tipo di scienza è uno dei vari approcci metodologici al quale ricorrere a seconda delle domande in questione e di chi le solleva.

Linee guida

Due accademici svizzeri sono stati determinanti nel concepire e formulare delle linee guida per scienziati alle prese con progetti di Citizen Science presso poli di ricerca universitari europei (p. es. LERU). Le linee guida devono fungere da raccomandazioni strategiche per finanziatori della ricerca, organi decisionali e università (Wyler and Grey 2016). Anche alcune istituzioni od organizzazioni svizzere (nonché singoli individui) appartengono alla European Citizen Science Association.

In Svizzera

Nel nostro Paese sono nati vari portali web di Citizen Science. Alcuni vertono su tematiche più specifiche e circoscritte, come OpenNature e MMOS, mentre altri hanno obiettivi e orizzonti più ampi, come ad esempio Citizen Cyberlab – nato da un partenariato con UNIGE, CERN e UNITAR – o Citizen Science Network Switzerland, creato dalla fondazione Science et Cité in collaborazione con PFZ, UZH, UNIGE e con le accademie svizzere delle scienze. L'attività più recente, in corso da febbraio 2017, riguarda la creazione di un Competence center for Citizen Science (una joint venture tra UZH e PFZ).

Riflessione

Gli scienziati (e le istituzioni) non sono unanimi sul loro coinvolgimento nelle controversie pubbliche legate a questioni scientifiche. La situazione è poco chiara anche per quanto riguarda la Citizen Science. Da un lato, quest'ultima può aiutare gli scienziati a portare a termine incarichi onerosi che comportano considerevoli raccolte di dati e a contenere i costi, contribuendo inoltre ad aprirsi al pubblico; i volontari si sentono coinvolti, sono entusiasti delle scoperte scientifiche e apprezzano il contatto con «veri» scienziati. Dall'altro aleggia un certo scetticismo sulla qualità dei dati forniti da amatori alle prime armi con la scienza e vengono sollevate preoccupazioni sullo sfruttamento del lavoro offerto liberamente (o sul privare di lavoro gli assistenti universitari). Vige inoltre una certa diffidenza scaturita dalle supposizioni che i maggiori costi e sforzi necessari per i progetti Citizen Science potrebbero non corrispondere ai benefici presunti o rivendicati.

Conclusione

La Citizen Science suscita principalmente domande sulla natura della ricerca scientifica in sé. L'entusiasmo pubblico nei confronti di quest'ultima è una risorsa preziosa così come, però, lo sono anche le precauzioni e le preoccupazioni degli scienziati.

Some thoughts on the use of ‘Democratization’

1

Some thoughts on the use of 'Democratization'

If you look at how frequently the term 'democratization of politics' appears on Google, and compare it with 'democratization of science', the political use appears five times as often (2,710,000 for politics; 561,000 for science). If you do a Google Books Ngram search, you can see that the use of the term 'democratization' in publications follows global political developments, rising moderately during decolonization (mid-1950s to 1970) and then much more sharply beginning in the early 1980s (the collapse of East European communism) and lasting until the late 1990s (changes in Africa and Asia). At its peak in 1997, the term 'democratization' was used three times more often than in 1980. While it remains high, use of the term has subsequently declined somewhat – at least until 2007, the last year for which data is shown.

According to an Ngram comparison, the noun 'democratization', the thing itself, has also been used vastly more frequently than the verb 'to democratize', though the same is true of similar pairings (commercialization, commercialize; socialization, socialize; commoditization, commoditize) and may well indicate a general preference for nouns over verbs which is more related to how English itself developed (O'Grady 1997: 24–26) than, say, a preference for end-states over process. However, because 'democratization' is clearly most commonly understood with reference to politics, there is a question whether an alternate term would be more appropriate if it is to be used with reference to science – or whether using this term in the specific context of science and society requires greater specification.

One problem is that the current political understanding of 'democratization' often refers to moving away from, or replacing, forms of rule that are one-party or authoritarian, and giving more power to 'the people'. When translated to the context of science, the implication is that the knowledge science seeks is closely controlled or limited to experts, and more extremely, that what scientists do is unrelated to how 'the people' might benefit from it. Arguments about the justifications for, or utility of, science can be traced back at least to Francis Bacon, but it is also fair to say that scientists

> "cannot well lay claim to the privileges of the scientific community at work without some reference to the benefits to be derived from knowledge."
>
> Bendix 1988: 90

Those benefits, of course, accrue to 'society' (and hence to 'the people'), even as scientists also point to the need for the space to conduct basic research. Yet it certainly does not imply that scientists aim to withhold knowledge in the manner the elite in a one-party state, for example, is often tempted to do. Still, this is one implication of using 'democratization', a very politically oriented term, in the context of scientific research.

The other, perhaps less obvious, side has to do with who this 'democratization' actually benefits. There is a theoretical fuzziness to who 'the people' are meant to refer to in a democracy. Does this mean literally everybody? an undetermined large part? the lower classes? an organic whole? a greater part expressed by an absolute majority principle? a greater part expressed by a limited majority principle? (Sartori 1987: 21–25). All of these have been suggested as possibilities, and all have either theoretical or pragmatic limitations, though the last in this list often ends up as its clearest functionalist expression – even though any 'limited majority' ends up only expressing what some, but not all, in the demos actually want. In terms of 'democratization' (including in its more recent expressions in the Arab Spring) this may be a problem inherent to freeing oneself politically from a previous form of rule. It may not be so difficult for many disparate groups in society to agree on what they want to be free from, but it may be very difficult subsequently to agree on what they want to do with that newly-won freedom (e.g. negative vs. positive liberty; cf. Berlin 1969).

In the context of the 'democratization of science', this could be taken, perhaps a little drastically, to mean 'freeing oneself from the stranglehold scientists have on knowledge or information.' This freedom from, as Berlin suggested, does not answer the question of what one should now do with the newly-won access to knowledge or information – and the question 'who benefits?' from this 'democratization of science' takes on a particularly sharp edge if it is defined as 'who participates in Citizen Science?' It suggests that only a minority does or can:

> "A [2010] study found that 87 % of the participants in a volunteer computing project were men, while a similar bias was identified in ecological observations of birds. Moreover, white men aged 20–65 from well-to-do socioeconomic backgrounds are over-represented in Citizen Science."
>
> Haklay 2015: 16

Faced with this, there are two options: find an alternate term for 'democratization' that does not have such direct political connotations, or more precisely define what 'democratization' means in the context of Citizen Science. That context suggests terms such as 'participation' or 'cooperation' in scientific projects, or the 'pooling' of resources (esp. time to make observations and computing power), might be more accurate terms – not least because they better characterize many of the larger-scale projects (Galaxy Zoo, Foldit, Citizen Archivist, Eyewire, birdwatching/ bird counts, Flight Radar 24).

There also may be a degree of confusion if one takes 'citizen engagement' in science to essentially be equivalent to citizen engagement in politics: not all 'participation' in either politics or science projects is equally intense across all participants. There are certainly some projects with explicitly political agendas (e.g., the Extreme Citizen Science Group at UCL), political ambitions (e.g., pollution monitoring so as to influence policy-makers to take action), and political claims (Vayena and Tasioulas 2015), but these are extensions of the core activities of Citizen Science projects. It is an open question how much citizens involved in Citizen Science projects have explicitly political reasons for their participation, or favor, as it were, the citizen over the science. The available studies suggest that it is more usually the opposite motivation. Certainly genuine 'collaboration' of the sort that exists between scientists, say, in working together on an experiment at CERN, is a less common feature in many projects, and having 'crowd-crafted' or truly 'co-created' research between scientists and citizens seems, for the moment, to be more wished for than actually practiced.

Rather than substituting 'participation', 'cooperation' or 'pooling resources' for 'democratization', a different option is to be more precise about how the term is being used in the context of science/ society interactions or Citizen Science discussions. The Merriam-Webster Learner's Dictionary gives one definition of 'democratize' – here, again, the verb rather than the noun, and interestingly, explicitly as a 'simple definition' – as:

> "to make (something) available to all people: to make it possible for all people to understand (something)"[1]

Their 10th Collegiate Dictionary (1993) gives 'democratize' as 'to make democratic', and then under 'democratic', writes:

> "3: relating to, appealing to, or available to the broad masses of the people (~art)
> 4: favoring social equality: not snobbish"
>
> 10th Collegiate Dictionary (1993), p. 307

Perhaps one could suggest that how 'democratization' is being used in the context of discussions of Citizen Science is as 'relating to, appealing to, or available to the broad masses of the people', as this could help avoid some of the complications and confusions evoked by using a term whose connotations are overwhelmingly political rather than related to research in science.

1 http://www.merriam-webster.com/dictionary/democratize; accessed 22 Sept. 2016

Citizen Science:
An introduction

2

2.1 Knowledge effort in the information society

The discourse about knowledge as an economic resource received its major impetus half a century ago from Fritz Machlup.[2] He is credited with popularizing the idea of the 'information society', a term whose use has risen sharply since the 1970s.[3] Machlup thought of the information society as the result of a 'knowledge effort' – a pleasant coinage one can apply not just to Citizen Science but to Wikipedia and Linux as well.[4]

For many today, the Web is not only the primary source of information about the world but also the symbol, or global realization, of Machlup's information society. A comparable sharp rise has characterized the use of the Web since the 1990s, one made possible both by innovations in information and communication technologies (ICT), and in the technical ability and capacity to store, communicate, and compute information. While some heralded ICT at the turn of the millennium as an engine for economic growth and social development, or the key to creating a global knowledge-based society, it has become clearer in the intervening years that – like many tools – how ICT is used, and how effectively, depends on the intentions and abilities of its users.

Beginning this way emphasizes that Citizen Science, which is about knowledge and about interaction, both benefits from and depends on technological accomplishments that make a seamless flow of communication between strangers across distances possible. If one wants to revive an old image of society as a body, then the marriage of information society to the Web could be seen as creating a nervous system. The idea of a knowledge effort also revives far older questions about knowledge itself, its nature and its purposes.[5] For who demands and who supplies information (and about what) has become even more acute in an age where knowledge is – or more accurately, seems to be – available with a few keystrokes or taps on a screen.

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2 Machlup had been a student of Ludwig van Mises in Vienna. Machlup's major work was The Production and Distribution of Knowledge in the United States (1962).

3 This is based on Google Ngram Viewer comparisons. The use of 'information society' begins to rise in 1970, while 'knowledge society' only starts rising around 1990, and even today is used only one-fifth as often. Comparing 'information' and 'technology' yields similar results. The literature has other descriptors for society (transactional; networked; global) and economy (transnational; network; digital; internet), but using 'information' has the advantage of emphasizing content a little more than the medium or structures through which it flows.

4 Machlup's 'knowledge effort' had five components: research and development; education (at all levels); information services (e.g., libraries), information machines (computers, telecommunications, data processing) and communication (including through media such as books, journals, radio and TV, artistic creation and entertainment). He calculated that the sum of these components in the early 1960s were already responsible for 29 % of adjusted GNP – and were growing so rapidly they would reach 50 % by 1970.

5 Certain titles (Lynd's 1939 Knowledge for What? Lindblom's 1979 Usable Knowledge) make the point.

The information society flourishes in the open society.[6] Such a society has individualist thinking,[7] personal accountability and abstract social relations, a pluralist, transparent government, and is both literate and anonymous. An open society denies that a perfect society is attainable, asserts our understanding of the world is imperfect, and judges that while there may be many sources of knowledge, all are open to critical examination. If knowledge sources are plural and open, it supports a free flow of information – 'perhaps the most potent force for democracy, since it makes it difficult for governments to misinform the people' (Soros 1998: 111).

It isn't a large step from the open (democratic) society to the open (information) of the Web, nor from that to calls for more open scholarship (in access, in data, in science itself):

> "The power of the Internet comes from the fact that [its] connections are decentralised. No one of these machines, no cluster of networks, can be said to run the enterprise. *Democracy prevails:* I can publish a message on the Internet as readily as you. I can choose which topics to read about and switch off those that don't interest me. I can navigate the information space by making choices, running searches for keywords, and displaying content. Depending on my interests, I can become a content provider or remain a reader, meaning that what I get out of the Internet is very much a matter of personal preference."
>
> Glister 1997: 42 in Robinson and Bawden 2001: 171; my italics

Open scholarship, however, has its challenges, not only for science and research as hitherto practiced, but for scholars themselves (Jimenez 2008) – and some of these are reflected in the rise of Citizen Science.[8]

2.2 Citizen Science as an emergent phenomenon

While the practices now called 'Citizen Science' certainly existed in the past, they only became widespread after the mid-1990s.[9] That is due to technological changes brought about through the rapid increase in mobile means of communication (esp. cell phones) and the interactivity among users (esp. using portable computers) the Web makes possible. Far more than in the past, one can readily store, and work with, vast amounts of information ('big data') and rapidly process inputs – including from large numbers of individual users or citizens. These inputs also come in an era when politicians have become more critical about the benefits and costs of publicly-funded research and express concerns about 'value for money' or demand 'greater accountability'. Scientists and citizens, if differently, have also called for sharing research-generated knowledge more widely, through channels such as PLOS, PNAS, Dryad, DataONE, F1000 or FigShare (Graybeal 2013).

Those who volunteer their time or other resources to participate in research projects are typically motivated by the same curiosity and desire to advance science and understanding as the scientists who design them.[10] Volunteers often enjoy being able to interact with professional scientists and be involved in 'real' research; some (including retirees) see this as a valuable use of their leisure time. They may well also have the education necessary to understand the purpose of the research. Scientists, in turn, can tackle tasks (such as classifying hundreds of thousands of images) for which they otherwise lack personnel, money, or time.

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6 The locus classicus is Karl Popper's The Open Society and its Enemies (1945); for putting some of Popper's ideas in practice, see George Soros's Open Society Foundations. Robinson and Bawden (2001) have a good discussion of both men, along with some implications of making information open and available (in this case, through libraries).

7 Popper (and Soros) explicitly oppose(d) closed societies, totalitarian regimes, collectivist thinking, and emotional appeals to a 'lost group spirit of tribalism' (Popper).

8 Veletsianos and Kimmons (2012) emphasize the ideological underpinnings of open scholarship.

9 For a good overview of Citizen Science, see Haklay 2015. Other names include amateur, participatory or civic science, public participation in scientific research, and participatory action research. For a definition of the closely related term 'crowdsourcing', see Appendix 1.

10 Acheves-Bueno (2015) found 75 % of the motivation for citizens to participate was altruistic: to contribute to scientific knowledge itself. Other studies have found only a minority of volunteers (25 – 30 %) participate because they have an 'action' or political agenda (Geoghegan et al. 2016; Rotman et al. 2014; Raddick et al. 2010).

Citizen Science volunteers, in one characterization, 'can provide an inexpensive and potentially large labor force, … usually contribute at least indirectly to the costs of the research, and … themselves gain fulfillment and knowledge' (Silvertown et al. 2013: 136), thus improving the public understanding of science.[11] Wider geographic areas or time periods can be covered by enlisting volunteers, making comparison and trend-spotting easier, at least for some types of projects. It can also be a way to address a mandate, as 'outreach' is an increasingly significant criterion in grant applications.[12] Still, as misunderstanding exists on this point, 'Citizen Science' is neither an attack on research science nor an effort to replace it. It is instead an aid or support for parts of the scientific process, especially initial discovery or classification/ typology. It is also relatively uncommon, currently, to find 'action research' or explicitly policy-oriented projects.

2.2.1

Definitions, descriptions, distinctions, disciplines

Citizen Science involves activities which vary by type, scope, and intensity as well as by discipline. Efforts to define such activities range from lists of verbs to sophisticated surveys of the dimensions involved. These 'citizen(s)' are members of the general public who volunteer their time or resources to help with scientific research projects (Silvertown et al. 2013; Roy et al. 2012), and while sometimes called 'non-professional scientists' (Bui 2013a), such volunteers are usually assumed to have 'no specific scientific training' (Bonney et al. 2015).

Some definitions of Citizen Science

- 'collecting, categorizing, transcribing, or analyzing scientific data' (Bonney et al. 2015)
- 'citizens are … discovering, learning, initiating, developing, emerging, supporting, catalyzing, participating, using, collaborating, evaluating, appraising, changing, shifting, evolving research' (Socientize Consortium 2014: 32)
- passive sensing; volunteer computing; volunteer thinking; environmental observation; participatory sensing; community science (Hakley 2015: 5)
- collective intelligence; pooling of resources; data collection; analysis tasks; serious games; participatory experiments; grassroots activities (Socientize Consortium 2014: 9)
- collaborative science; crowd-crafting; participatory experiments; collective intelligence; volunteer thinking; volunteer sensing; volunteer computing; human sensing (Socientize Consortium 2013: 22)
- Citizen Science draws from different fields, such as environmental sciences, biological sciences, earth observation, crowdsourcing, do-it-yourself approaches, participatory science, environmental mapping, intelligent data-analysis, social sciences and artificial intelligence (Ceccaroni and Piera 2016)
- '… scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions' (OED definition, 2014)
- Citizen Science refers to the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources (Socientize Consortium 2013)

11 At least potentially: Riesch, Potter and Davis (2013: 2–3) have a brief survey of the debates and findings on this.

12 Educational or 'outreach' components are not specifically addressed here (but see Mueller, Tippins and Bryan 2012; Gray, Nicosia and Jordan 2014; Hidalgo-Ruz and Thiel 2013). Citizen Science is about the 'shared space where scientists can talk with citizens interested in working on or learning about their research projects', the SciStarter website notes, and this may or may not involve 'outreach' or educational components.

What they provide varies, but in many Citizen Science projects, scientists set the task and volunteers contribute observations (using sensors, mobile phones, or simply by eye) or send in samples (sometimes using project kits provided). Galaxy Zoo is the best-known example of a classification project; it was launched by a despairing postgraduate astronomer given the daunting task of classifying more than 900,000 galaxies on his own. Volunteers also tackle more difficult tasks, as when they are asked – typically after a tutorial or other instruction – to decipher, annotate, complete, or transcribe partial information (including near-illegible writing, fragmentary inscriptions, neural pathways, or nautical logbooks). In that sense, they help 'fill in the gaps' and collaborate.[13] Ambiguities in the data have prompted many projects to create feedback formats which allow volunteers to communicate directly not just with project coordinators but also among themselves (Daume and Galaz 2016). This helps improve the quality of what volunteers provide and can even alert scientists to new discoveries or previously overlooked anomalies. Volunteers participate in the science of discovery (Boyer 1990), and in that sense, collaborate.

Both contributory and collaborative projects (see the examples given below) fit into one of the two principal ways such activities have been conceptualized since the mid-1990s. In the view associated particularly with Rick Bonney in the U.S., Citizen Science serves to increase trust in the scientific enterprise, improve scientific literacy and enhance the public understanding of science.[14] Scientific knowledge is seen as a valuable social good on its own; scientists are to engage the public in such a way as to 'cultivate their enthusiasm and support' (Woolley et al. 2016: 3) for science.[15] This is a top-down model in which volunteers provide and contribute – but only to the very first stage of a process controlled by professional scientists.

The other view, associated most with Alan Irwin in the UK, sees Citizen Science as 'based upon the presumed emancipatory benefits of active public input on the direction of scientific research agendas' (Woolley et al. 2016: 4).[16] The involvement of citizens in science, including in bottom-up efforts,[17] is meant to be linked to community needs or policies,[18] and is associated with the idea of 'democratizing' research.[19] Scientific knowledge is valuable with respect to how it can be applied, in this view, not as an end in itself. Some projects of this kind may be crafted with an eye to policy relevance, such as when a project can (potentially) influence efforts to reduce pollution.[20] The bottom-up character here, though, can mean emphasizing the citizen more strongly than the science. This more applied view supports the idea of 'co-creating' projects, meaning finding a meeting place between bottom-up and top-down inputs, but there are few examples.[21] Those that exist (cf. Polymath, discussed below) may be better understood as professional rather than Citizen Science, or as examples of crowdsourcing among specialists.

Still, soliciting scientific observations from strangers has a long tradition, going back at least to 1715 when Edmund Halley used the pages of Philosophical Transactions to ask his readers to help him observe a total solar eclipse (Highfield 2015). The extensive correspondence-based networks researchers like Charles Darwin or Alexander von Humboldt maintained in the 19th century were a way to augment the (limited) observations a single individual could make.[22] These networks of the interested, of those keen on understanding the natural world, were not composed of trained 'scientists' – a term, it is worth remembering, first used only in 1833.

13 A sample of online Citizen Science directories (e.g., SciStarter, Zooniverse, CitSci, Scientific American Citizen Science List) classified 75 % of the projects as contributory and 9 % as collaborative; see Quarooni D. et al. 2016.

14 Bonney, Cooper and Ballard 2016; Bonney et al. 2015; Bonney et al. 2014; Miller-Rushing, Primack and Bonney 2012. For a more critical view, see Stilgoe, Lock and Wilsdon 2014.

15 Whether scientists wish to serve as missionaries in the cause of science is a more complex question. There is recurrent critique that the 'deficit' orientation either persists or is 'continually reinvented' (Stilgoe, Lock and Wilsdon 2014; Bucchi 2008). Sturgis 2014 sheds trenchant light here; for the 'deficit model', see Dickson 2005.

16 Irwin (1995: 4–5) is quite attached to a particular social stratum in arguing for this, noting that 'the depth, resilience and richness of working-class culture' is an 'uplifting and positive incentive' to seek a 'science for the people' (cited in Horlick-Jones 1997).

17 The emergence of the Safecast project in the aftermath of Fukushima is an interesting example. Originating in emails among friends asking after loved ones, and in questions about what levels of radiation were safe, Safecast tapped into 'hackerspace' for help in building radiation detection devises (e.g. bGeigie) to be used while travelling. Collected data was aggregated, analyzed, and publicly distributed (Kelly 2013a; http://blog.safecast.org/about/).

18 For recent arguments in this vein, see Barton 2012; Crabbe 2012; Burgess 2014. Examples can be found in Seifert et al. 2016; Kontokosta, Johnson and Schloss 2016; Townsend and Chisholm 2015. For an interesting analysis of activism in science and technology domains, see Parthasarathy 2010.

19 Making research more 'open' (open data, open access, open science) does not make it more democratic: it just makes it more potentially accessible.

20 See Kobori et al. 2016; Riesch, Potter and Davis 2013; McCormick 2012; Scott and Barnett 2009.

21 Quarooni et al. 2016 find only 9 % of their sample are co-created; Ramirez-Andreotta et al. 2015 is one of the few.

22 https://www.darwinproject.ac.uk/learning/universities/letters-primary-source/scientific-networks.

Observations of space (e.g., Halley) and nature (e.g., Darwin or Humboldt) remain the most frequent areas of investigation involving volunteers, with the Audubon Society's Christmas Bird Count (ongoing since 1900) usually cited as the first modern Citizen Science project. Comparable species counting efforts were launched in the mid-1970s, but it has only been since the 1990s that Citizen Science projects have taken off – and begun to move outside the disciplines already noted.

Nevertheless, disciplines remain very unequally represented, as one can see when comparing the number of Citizen Science projects devoted to biological or environmental topics versus those, say, in a social science. Of 303 projects listed at one government website,[23] for example, 75% were classified under 'nature and outdoors' (and 63% as 'biology') but only 11% could be called 'social science'.[24] Of the projects listed at scistarter.com, more than 300 were in 'biology', but only 5 were in 'social science'.[25] The humanities are just as under-represented: the Zooniverse currently lists 23 'nature' projects, but only 4 under the rubric 'literature'.

Still, there are caveats. One is that some disciplinary practices – having 'likely voters' respond to public opinion surveys in political science; asking students to participate in classroom experiments in economics; appealing to the interested to help with an archaeology dig – already enlist many volunteers (the use of student assistants and graduate students to gather and analyse preliminary data is common in many disciplines as well). Another is that disciplines with traditions of solitary scholarship may find it challenging to craft projects which call for the input of volunteers, though digitalization may change this reluctance (Kelly 2013b; Bui 2013d). Third, even disciplines commonly perceived as highly complex and requiring sophisticated levels of scientific understanding, such as particle physics or neurobiology, have launched serious Citizen Science projects – not least because the amount of data these fields generate nowadays surpasses their ability to process it within a reasonable amount of time.

2.2.2

Examples of Citizen Science projects

In Citizen Science projects different modes of cooperation, participation or of citizen engagement can be distinguished. Find here the three main modes:

Contributory projects

… in biology or environmental science vary not only by the subjects of interest, but also by the kind of activity volunteers engage in. Some projects call for *observing and documenting* phenomena at a particular time of year (Project BudBurst) or place (Great Sunflower Project), or at a particular time at a particular place (Bioblitz; Big Butterfly Count). They may ask for *evaluating* brief videos (Digital Fishers), *classifying* sound recordings (Bat Detective), or *identifying* images from camera traps (Snapshot Serengeti; Wildcam Gorongosa) or from satellites (Cyclone Center). Some ask volunteers to build homemade measuring sensors (SMAP;[26] Cicada Tracker), while others provide kits to *collect samples*, whether of microbes (The Wildlife or Our Homes; American Gut) or dirt (Drug Discovery from your Soil).

23 The U.S. citizenscience.gov website (accessed 30 October 2016).

24 This adds the categories 'science policy', 'geography', 'social science', and 'psychology' together.

25 Website consulted 10 November 2016.

26 http://digitalcommons.calpoly.edu/star/368/.

Astronomy has been a particularly fertile field, as the following example shows:

Galaxy Zoo

The origin of Galaxy Zoo lay in a very large task postgraduate astronomer Kevin Schawinski faced in 2007: to classify the images of more than 900,000 galaxies. If he worked around the clock, it would take him several years to classify them all. This was a 'data deluge' problem – the quantity of information literally astronomical[27] – and both time and manpower were inadequate to the task of classification. Inspired by ongoing NASA projects (Clickworkers; Stardust@home) that asked volunteers for help in a similar situation, Schawinski and fellow astronomer Chris Lintott launched an online appeal for help.

The response was overwhelming. By the end of the first year, more than 150,000 volunteers had made 50 million classifications (a mean of 38 classifications per galaxy), and the task was finished in 6 months rather than in several years.[28] There were social and educational effects, as volunteers had questions about the images; an online forum was soon set up to answer them.[29] That led to larger discussions and inquiries about the project, astronomy, and science more generally. Volunteers soon started calling themselves 'zooites', helping form the nucleus of what is now the Zooniverse community, 'the world's largest and most popular platform for people-powered research' where 'hundreds of thousands of people around the world … come together to assist professional researchers … to enable research that would not be possible, or practical, otherwise'.[30] The format allowed volunteers to discover two previously unknown galactic features: Hanny's Voorwerp and the 'green pea' galaxies.[31]

As of October 2016, 57 scientific papers have been published as a direct result of Galaxy Zoo. The original project was retired in 2009 but inspired many others, whether investigating the brightest galaxies, interacting galaxies, or galaxy formation (GZ2; GZ Mergers; GZ Hubble), or supernovae, radiowave and infrared images, and interactions between galaxies and starbursts (GZ Supernovae, GZ Radio, GZ Quench). The Zooniverse currently hosts projects to discover or examine planets (Planet Hunters; Planet Four) or stellar anomalies (The Milky Way Project;[32] Disk Detective), as well as many other Citizen Science projects in disciplines far removed from astronomy.

27 The images come from a robot telescope and are part of the Sloan Digital Sky Survey. The telescope produces about 200 gigabytes of data every night and thus far has generated photometric data on 500 million objects.

28 Clery 2011; https://www.galaxyzoo.org/#/story; 'Galaxy Zoo' on Wikipedia (accessed 23 November 2016).

29 When the forum for this project was closed in 2014, 650,000 posts had been received.

30 https://www.zooniverse.org/about (accessed 23 November 2016).

31 See Straub 2016; Garrett 2012; Keel et al. 2012; Izotov, Guseva and Thuan 2011.

32 See Beaumont et al. 2014.

Collaborative projects

... often involve more complex tasks, including *deciphering* and *transcribing* (AnnoTate; Shakespeare's World; Operation War Diary), *identifying* and *annotating* (Moon Mappers; Cell Slider; Higgs Hunters; Old Weather), or *characterizing* (VerbCorner). The very heterogeneity of projects has prompted efforts to characterize them more simply by the skill level typically required and how complex a typical task is (see Figure 1):

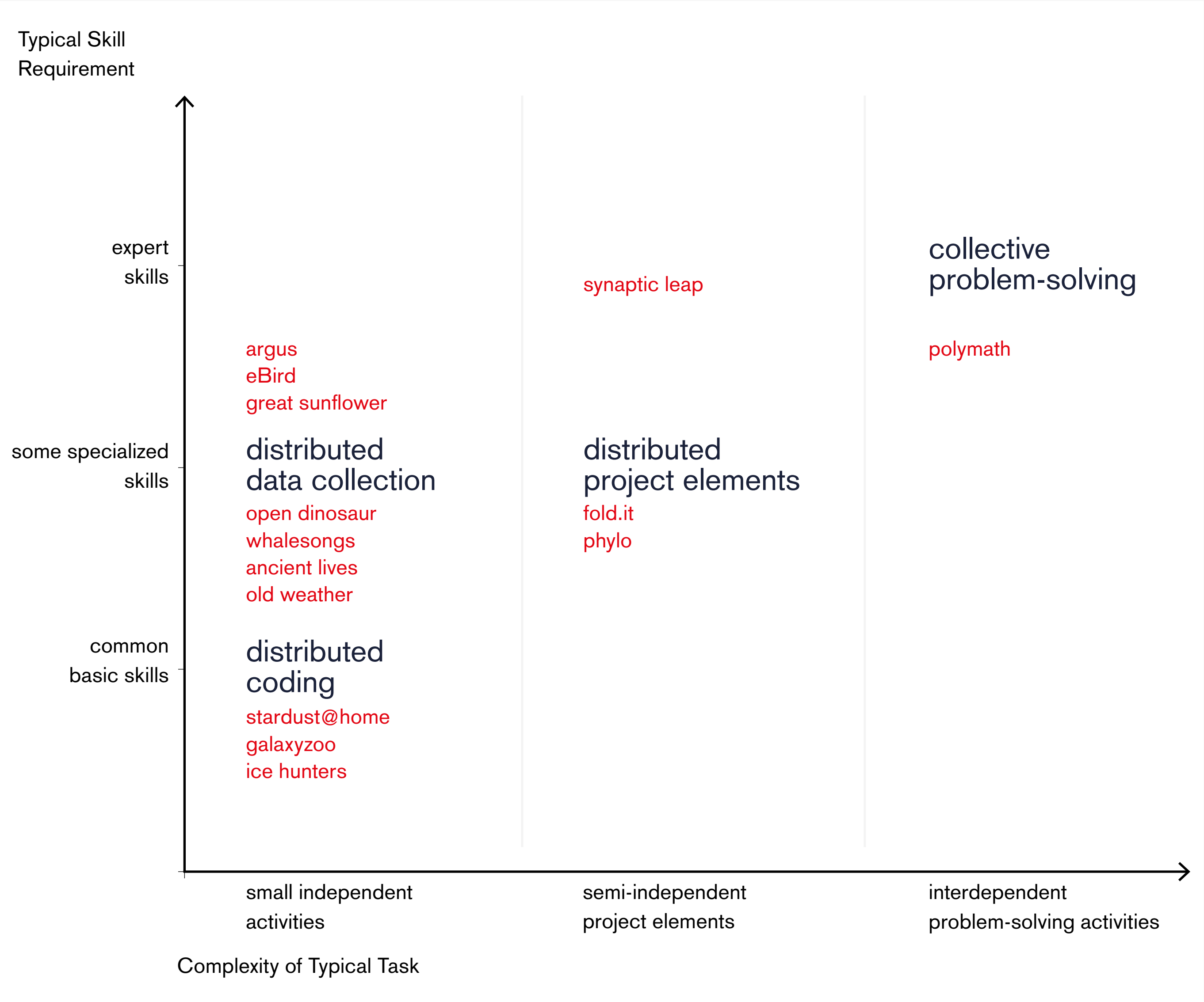


Figure 1: Heterogeneity among 'crowd science' projects (Franzoni and Sauermann, 2012: 12)

Complexity is defined here both by size of task and how interdependent tasks are. Many contributory projects (labelled 'distributed coding' in Figure 1), involve simple tasks which can be done quickly, independently of others, and do not call for more than basic skills.

One category of collaborative projects with 'semi-independent project elements' (located in the middle of Figure 1) requires considerably greater creativity, skill, and intelligence – though not in the discipline at hand. Being able to optimize protein (Foldit) or RNA folding (EteRNA) by finding better solutions than computer programs can, or optimizing DNA sequence alignments (Phylo) – often by using 'games' to interest and challenge participants[33] – calls for skill at three-dimensional visualization and manipulation, not knowledge of biochemistry or genetics. Some of these projects study *how* participants approach these tasks so as to improve existing computer algorithms – which may eventually obviate the need for volunteers …

Neuroscience has been a fruitful area for collaboration, as the following example shows:

Eyewire

Eyewire is a 'human-based computation game' to map retinal neurons – the brain has an estimated 80 billion neurons – which was developed at MIT using data generated at the Max Planck Institute for Medical Research.[34] Since December 2012, it has involved more than 200,000 people from around the world. After a tutorial, participants are shown a three-dimensional cube with a partially reconstructed single retinal neuron branch in it. The cube shown is generated from electron microscopy images, and the immediate task is to generate a volumetric reconstruction of the neuron. Participants do so by learning to 'color' inside the gray outline of that neuron branch; multiple players map each cube, and their work is compared (advanced players oversee the work, and can correct it by removing erroneous segments or extending branches). Eyewire works best with a high-speed internet connection, and no specialized knowledge of neuroscience is required, though participants are expected to be curious, intelligent and observant. To encourage engagement, Eyewire has also created a competitive, teamwork-based, brain mapping game which runs for a week, with the team doing the most mapping receiving the honor of naming 'their' neuron (Bui 2013b).

The larger goals of this mapping project are not just to identify specific cell types but to discover how neurons connect and process information in the retina. Not only is there a hope this will help determine how vision works, but more broadly, that the computational technology developed will eventually be of a kind which can detect brain 'miswiring', thought to be a possible root cause for schizophrenia or autism.

33 On this, see Greenhill et al. 2014; Bui 2013b; Bui 2013c; Iacovides et al. 2013; Cooper et al. 2010.

34 This section is based on the 'Eyewire' article on Wikipedia and https://www.scientificamerican.com/citizen-science/update-eyewire-mit/.

Genuinely co-created projects

… are rare; the term itself may be less useful than calling it collective problem-solving, as in Figure 1. Yet if that means problems posed can only be solved by experts, even if volunteering their time and effort, then we are quite far from how Citizen Science is ordinarily defined (see 'Some Definitions', above).

Instead, we are much closer to 'ordinary' scientific discourse, in which a hypothesis is suggested, discussed among colleagues, tested in various ways, and modified until a (provisional) consensus in the community about that hypothesis is reached. Typical Citizen Science volunteers who contribute observations or classifications, on the other hand, are not usually part of this kind of disciplinary discourse, even if some might wish 'to integrate the[ir] contributions … in an interactive fashion' (Franzoni and Sauermann 2012: 14). For interactivity to take place in projects between scientists and volunteers with 'no specific scientific training' means both parties need to chart and tread unfamiliar paths.

Polymath[35]

In 2009, British mathematician Timothy Gowers wrote on his blog that he wanted to see if it was possible to collectively find 'a solution [for a mathematical] problem with no single individual having to think all that hard'. The idea was to gather spontaneous reactions, with brief explanations of feasibility; initial reactions were favorable and encouraged Gowers to post the first problem. It attracted comments and feedback from fellow mathematicians, Ph.D. students, and teachers, and within six weeks the discussion had advanced[36] far enough for Gowers to announce the problem he had posed was probably solved. He and a few other mathematicians verified the work, drafted an article, and sent it in for publication – under the pseudonym D.H.J. Polymath – for publication in the Annals of Mathematics. Other questions in mathematics have been asked using a similar format, though not all of them have been as rapidly solved as the first, and it has spawned other versions (mini-polymath) and communication channels (mathoverflow) along with wider discussions about changing practices in mathematics. While the math questions posed are asserted to have 'some general appeal,' participants have tended to be 'experts in a specific field of mathematics' – though there has been the secondary goal 'of trying to understand the advantages and limitation of the polymath concept itself, and of trying to openly record the thought process of different participants towards the specific goal'.[37]

35 This summary is based on Martin and Pease 2013; Franzoni and Sauermann 2012; Cranshaw and Kittur 2011; Nielsen 2011; Gowers and Nielsen 2009.

36 Indeed, it branched out to such a degree that a wiki became necessary to keep track.

37 Quotes are from http://mathoverflow.net/questions/219638/proposals-for-polymath-projects (accessed 25 November 2016).

2.2.3

Impact and legitimation

So what has been the impact of Citizen Science? Some of its advocates argue that even when data generated by Citizen Science projects is trusted and used, it often has an 'invisible' aspect: it goes unacknowledged in publications.[38] Others look for ways to increase its impact (Bonney et al. 2014), including even by arguing that Citizen Science should be thought of 'as a distinct discipline or field of inquiry' (Jordan et al. 2015).

To understand impact, it is necessary to delimit what 'Citizen Science' encompasses; it proves to have a rather wide semantic field (see Appendix 2). Studies of the occurrence of 'Citizen Science' and related terms in Scopus and Web of Science show strong recent growth – particularly in published peer-reviewed articles (see Figure 2) – which helps strengthen its legitimacy. Interestingly, 'research on methodology and validation techniques preceded the rapid rise of publications of research outcomes based on Citizen Science methods' (Kullenberg and Kasperowski 2016: 1).

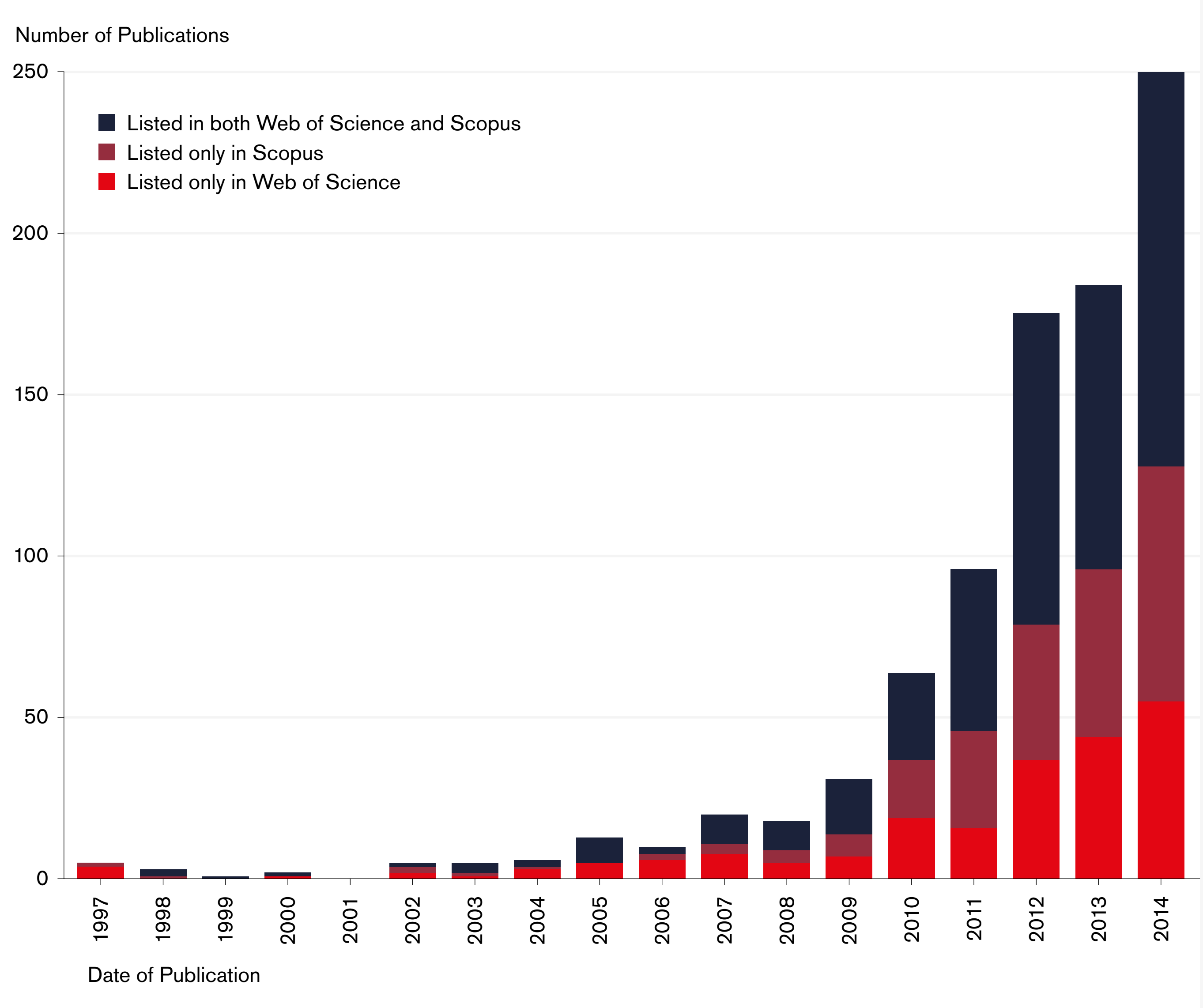


Figure 2: Published peer-reviewed articles on Citizen Science (Follett and Stresov 2015: 6)

38 Cooper, Shirk and Zuckerberg 2014. Follett and Stresov's recent survey of the literature confirms this: 'the contribution of Citizen Science to science in general is significantly greater than [is] apparent from [the] literature on Citizen Science' (2015: 8).

Methodology and validation are important, because there are 'buckets of resistance' (Ottinger 2010)[39] to Citizen Science due to fears about the poor quality of data provided by citizen volunteers. This has been answered by studies which identify sources of bias (Courter et al. 2012) and factors affecting data collecting accuracy (Gardiner et al. 2012), or that suggest data validation protocols (Bonter and Cooper 2012) and methodological 'fixes' (Bird et al. 2014).[40]

Yet for some tasks, professionals may also want to be cautious about claiming expertise:

> "We tested the ability of volunteers relative to professionals in identifying invasive plant species, mapping their distributions, and estimating their abundance within plots. We generally found that *volunteers perform almost as well as professionals* in some areas, but that *we should be cautious about data quality in both groups*."
>
> Crall et al. 2011: 1; author's emphasis[41]

A focus on data quality can be a way to question the legitimacy of the Citizen Science enterprise as a whole, if not even to discredit what it (potentially) can contribute. 'Legitimacy' is often used to refer to accepting authority, and it can be rather difficult for those in positions of authority to accept that thosenot in such positions may have their own authority born of experience, observation, and knowledge. In this context, the question of how professional scientists and citizen volunteers *should* interact – or for that matter, what Citizen Science contributes to the debate about how science and society can, should, or ought to interact – is a subject which has generated a great deal of light, as well as not a little heat, in recent years.[42]

One can take a more pragmatic approach, and suggest Citizen Science is one of a variety of methodological approaches which can be taken depending on the questions being asked and who is asking them. As one can see from the detailed checklist provided in Appendix 3, it is worth being both clear and thorough in asking when a Citizen Science approach is appropriate. As Pocock et al. (2013) noted, 'this is because Citizen Science is most successful when the aim/ questions are clear; engagement with people is given a high priority; sufficient resources are available to begin and continue the project until its completion; the scale of sampling is relatively large (because it is often not cost-efficient to use a Citizen Science approach at small spatio-temporal scales); and the protocol required for data collection is not too complex.'[43]

39 This is my deliberate misreading: Ottinger refers to using buckets (to measure air quality) to influence policy processes or research directions, and her focus is the boundary-maintaining effects of standards.

40 Freitag and Pfeffer 2013 investigate what could be done to improve Citizen Science 'success'.

41 For a different context and task but a similar finding, see Salk et al. 2016.

42 Among many others, see Bela et al. 2016; Ceccaroni and Piera 2016; Loss et al. 2015; Ottinger 2015; Pew Research Center 2015; McQuillan 2014; Riesch and Potter 2014; Spruijta et al. 2014; Kelly 2013c; Cooper 2013; Lindskog 2008.

43 Jennett and Cox (2014) have made this process even easier by offering simple guidelines.

2.3
Constraints, opportunities, propositions

Constraint 1: Research traditions are difficult to build; Citizen Science projects are 'one-off'
Opportunity 1: As the experience of NASA or the Zooniverse indicate, finishing one project does suggest others (and indeed, volunteers themselves may move from one to a second, similar, project), and that creates continuity. It has also become far more feasible to link data, including very large sets, between projects.
Proposition 1: Isolation does not impede scientific discovery – as witnessed by volunteers finding Hanny's Voorwerp and the green pea galaxies.

Constraint 2: Very few disciplines account for the majority of Citizen Science projects
Opportunity 2: Institutional efforts could be undertaken to make under-represented disciplines better aware of the potential of such projects.
Proposition 2: Though there are disciplines which do not appear to lend themselves to employing large numbers of volunteers, it may be a matter of initiative (see Polymath) or time (see the rise of 'digital humanities' or projects like AnnoTate) until the potential – at least of using some digital opportunities – is realized.

Constraint 3: Recruiting (and keeping the interest of) volunteers who add value can be difficult
Opportunity 3: It is important to do so, given current public perceptions of science (Pew 2015), interested, educated volunteers can be found,[44] and explicit acknowledgement, symbolic rewards, and even 'gamification' can hold the interest of volunteers (Geoghegan et al. 2016).
Proposition 3: In projects which strain the capacities of undergraduate, graduate or postgraduate student help (see Galaxy Zoo), and which would be costly to carry out otherwise, citizen volunteers can be a viable or valuable alternative.

Constraint 4: Citizen Science projects add costs
Opportunity 4: While feedback between project coordinators and volunteers may increase tangible and intangible costs, there are tangible benefits in data quality and intangible benefits in the reputation of science as an enterprise.
Proposition 4: Careful study shows that costs, benefits, and quality issues may not be quite as they appear at first (see Gardiner et al. 2014).

44 White men aged 20–65 from well-to-do socioeconomic backgrounds are overrepresented among Citizen Science volunteers, Haklay noted (2015: 16).

2.4
Reflections

The EU's Horizon 2020 has a vision of 'engaging citizens and stakeholders in [the] co-creation of research agendas based on real and validated societal visions, needs and demands'.[45] The assumption that such 'visions, needs and demands' can be articulated and come from the bottom up is not misplaced if one looks at public concerns voiced in recent years about issues ranging from the safety of genetically modified foods or of vaccines, through the ethics of animal research (or of wearing animal furs), the pace of environmental degradation or the effects of climate change, to the consequences of offshore drilling. We live in an era of 'sustainable development'[46] which values local 'capacity building' and 'good practices', along with hitherto untapped 'local knowledge' (such as of which jungle plants are beneficial to human health), and of a positive valuation placed on 'citizens' initiatives', including examples like Safecast. Decision-makers in modern democracies are expected to listen to and engage with citizens, to relate to, appeal to, and be available to the broad masses – or face populist revolts if they don't.

These wider sociopolitical backdrops are the context for the proliferation of Citizen Science projects, though many projects do not directly address the kinds of public concerns noted above.[47] Or rather, one can draw a distinction between disciplines which do and disciplines which don't address these kinds of public concerns. In the first group, at least some research conducted is perceived as having a direct connection to people's daily lives, such as in the environmental sciences, in urban planning, or in medical studies. Hence projects in these disciplines are more likely to engender advocacy; they have the kind of 'emancipatory' potential Irwin (1995) and Wooley et al. (2016) noted. In the second camp, one finds curiosity-driven disciplines such as astronomy, neuroscience, history, or language, and there it can be more difficult to conceive what policy advocacy might look like, other than to argue for the benefits of basic research, as Rick Bonney might. The case for making a 'knowledge effort' remains, regardless.

Scientists (and institutions) are not in agreement about how engaged or disengaged they should be about what concerns the public – the gap between public and scientists' views about 'controversial' issues can be substantial, and mutual goodwill is declining (see Pew 2015) – just as they have not come down clearly on one side or another about open science, open access, or open data. There is ambivalence as well about Citizen Science. On the one hand, it can be helpful to scientists in completing onerous tasks associated with large datasets, save costs,

45 http://cordis.europa.eu/project/rcn/197909_en.html, accessed 18 October 2016.

46 First mentioned in an IUCN document in 1969, its current meaning was defined in the Brundtland Report (1987).

47 Exceptions include 'Extreme Citizen Science Group' at UCL whose agenda is to 'transform the world' (see https://www.ucl.ac.uk/excites), and the Mapping for Change project (also at UCL) whose agenda is to 'support organisations to take whatever next steps they choose' after citizens have measured and mapped local air quality (see http://mappingforchange.org.uk/services/citizen-science/).

and can help in 'reaching out' to the public; it is also valued by volunteers who feel involved, are excited about scientific discovery, and are pleased to be in contact with 'real' researchers. On the other hand, it evokes skepticism about the quality of data provided by amateurs unsophisticated about science, raises concerns about the exploitation of freely-offered labor (or concern at robbing student assistants of work), and is bedeviled by an assumption that the greater costs and effort needed for Citizen Science projects may not match the assumed – or asserted – benefits. Above all, what Citizen Science does is to raise questions about the nature of 'the scientific enterprise' itself.[48] Public enthusiasm for scientific research is a valuable asset, yet scientists' cautions and concerns are equally important.

The rise of Citizen Science in many countries calls for, and needs, reflection and consideration of where it could be most helpful.

48 A discussion of this requires a separate paper, but for some interesting thoughts on the subject, see Perkins-Gough (2007). The AAAS has a chapter on the topic at: http://www.project2061.org/tools/sfaaol/Chap1.htm.

2.5 Citizen Science in Switzerland

Internationally, two Swiss academics[49] have recently been instrumental in conceptualizing and formulating guidelines for scientists who engage in Citizen Science projects at European research universities (e.g., LERU) to use. These guidelines also are meant to serve as policy recommendations for research funders, policy-making bodies, and universities (Wyler and Grey 2016). Some Swiss institutions or organizations (as well as individuals) also belong to the European Citizen Science Association.[50]

Domestically, some Citizen Science web portals have also emerged.[51] While some have a specific or narrower focus (OpenNature; MMOS),[52] portals such as Citizen Cyberlab (supported by UNIGE, CERN, and UNITAR) or the Citizen Science Network Switzerland (its parent, Science et Cité, is supported by ETHZ, UZH, UNIGE, and the Swiss Academies of Arts and Sciences) have both broader ambits and broader ambitions. Indeed, the latest ambition is to create a 'Competence Center for Citizen Science' (a joint UZH/ ETHZ venture), which is to get underway in February 2017.[53]

Urban environments and the observations of urban residents, as in other countries,[54] have been the focus of some Swiss projects (Urbangene in Geneva from 2013 to 2015; StadtWildTiere in Bern, Zurich, St. Gallen and Winterthur); they are particularly interesting because their implementation may well involve both public authorities and private organizations.

49 Prof. Daniel Wyler (UZH) and Prof. François Grey (UNIGE) were the main authors.

50 According to the ECSA, they include the Foundation Science et Cité, Globe International, and FocusTerra ETHZ.

51 Like SciStarter or Zooniverse, these are usually meant both to provide general information as well as to connect volunteers to specific Citizen Science projects or resources. Other examples include the Canadian portal www.citizenscientists.ca and the German portal www.buergerschaffenwissen.de.

52 The coordinator fo OpenNature is This Rutishauser (UNIBE/SCNAT); the coordinators for MMOS are Bernard Ravaz and Attila Szantner (UNIGE).

53 http://www.schweiz-forscht.ch/de/aktuell/news/item/260-news (accessed 3 December 2016).

54 Such as the SLIME or RASCALS projects in Los Angeles, the Trees Please! project in Hamilton, Ontario, or the Urban Traffic Data Hackathon held in London.

It is the Swiss universities, however, which are more often the locus of projects, whether in archaeology (Bürgerforschungsprojekt Basel-Spitalfriedhof) or to help out quantum physics (Decodoku),[55] as well as where workshops about Citizen Science take place.[56] The instigator of Galaxy Zoo, Prof. Kevin Schawinski (Astrophysics, ETHZ), is here as well, and his 'greatest wish is to better establish Citizen Science in Switzerland',[57] a wish echoed in one of the Swiss Citizen Science web portals.[58]

Still, as one Swiss Citizen Science project put it, it is

> "… especially striking how prominent this [Citizen Science] trend is in North America. The number of projects is many times greater than what is available in Europe … Yet not all topics or questions are suited [to Citizen Science], for example when complex research techniques are used, when the work is very strenuous or protracted, or when … specialized knowledge is a precondition."[59]

As in the UK or the U.S., domestic projects in Switzerland are dominated by biology and studies of the environment.[60] Making close observations of nature has a long tradition in Switzerland, though in the case of the InfoSpecies databank, volunteers who submit observations are expected to have high levels of skill and sophistication (thus placing this particular example in the middle or upper third of Figure 1). Switzerland is only beginning to discover the potential of 'gamification' (though see MMOS as a first effort in this direction), and has yet to discover how useful volunteers could be in analyzing images. As elsewhere, humanities and social science Citizen Science projects are few and far between.

But the right questions are beginning to be asked. Prof. Bruno Strasser, a historian of science and coordinator of the Citizen Cyberlab in Geneva, noted at the 2015 Swiss Congress on Science Communication that 'Citizen Science demands of us that we rethink the relationship between scientists and amateurs', and in a slide presentation later that year formulated the challenges into four questions:

1. How do the 'Citizen Sciences' transform the relationship between science and the public?
2. Who are the participants in the 'Citizen Sciences'?
3. What moral economies sustain the 'Citizen Sciences'?
4. How do 'Citizen Sciences' impact the production of knowledge?

55 The coordinator of the former is Gerhard Hotz (IPNA, UNIBAS), of the latter, James Wooton (Physics, UNIBAS). Based on brief Google searches, as of mid-December 2016, researchers at the universities at Fribourg, Lausanne, Lugano, Luzern, Neuchâtel, and St. Gallen do not appear to be actively engaged in Citizen Science projects, discussions, or platforms – but the emphasis is on 'brief searches'.

56 In 2015 (22/23 January; 17 November), these were held under the auspices of the ETH's Institute of Molecular Systems Biology in Zurich. As part of Swissnex cooperation, an ETH event about Citizen Science was also held in 2016 (8 April) in San Francisco.

57 Franziska Schmid ‹Forschen Sie mit!› (www.ethlife.ethz.ch/archive_articles/130121_citizen_science_fs/index).

58 'There is great potential for Citizen Science in Switzerland – in all topics and formats'. http://www.schweiz-forscht.ch/de/citizen-science/citizen-science-in-der-schweiz (accessed 3 December 2016).

59 http://wildenachbarn.ch/projekt/citizen-science (accessed 21 December 2016).

60 Of the 24 projects currently listed at Schweiz forscht, 17 address environmental or biology topics; see http://www.schweiz-forscht.ch/de/citizen-science-projekte (accessed 3 December 2016). Most Citizen Cyberlab projects, by contrast, are international or have significant international components.

References

Aceves-Bueno, E. et al. (2015). Citizen Science as an Approach for Overcoming Insufficient Monitoring and Inadequate Stakeholder Buy-in in Adaptive Management: Criteria and Evidence. Ecosystems. doi: 10.1007/s10021-0 arXiv: 1406.2692.

Alsever, J. (2008). What is Crowdsourcing? MoneyWatch (7 March 2007). http://www.cbsnews.com/news/what-is-crowdsourcing/.

Barton, A. (2012). Citizen(s') Science. A Response to 'The Future of Citizen Science'. Democracy and Education 20(1): 1–4.

Beaumont, C. et al. (2014). The Milky Way Project: Leveraging Citizen Science and Machine Learning to Detect Interstellar Bubbles. Astrophysical Journal Supplement. doi: 10.1088/0067-0049/214/1/315-9842-4.

Bela, G. et al. (2016). Learning and the Transformative Potential of Citizen Science. Conservation Biology 30(5): 990–999. doi: 10.1111/cobi.12762.

Bendix, R. (1988). 'Science and the Purposes of Knowledge'. In: Embattled Reason, v. 1. New Brunswick: Transaction Books, pp. 83–104.

Berlin, I. (1969). 'Two Concepts of Liberty'. In: Four Essays on Liberty. Oxford: Oxford University Press.

Bird, T. et al. (2014). Statistical solutions for error and bias in global Citizen Science datasets. Biological Conservation 173: 144–154.

Bonney, R. et al. (2014). Next steps for Citizen Science. Science 343: 1436–1437.

Bonney, R. et al. (2015). Can Citizen Science enhance public understanding of science? Public Understanding of Science 1–15.

Bonney, R., Cooper, C. and H. Ballard (2016). The Theory and Practice of Citizen Science: Launching a New Journal. Citizen Science: Theory and Practice 1(1): 1–4. http://dx.doi.org/10.5334/cstp.65.

Bonter, D. and C. Cooper (2012). Data validation in Citizen Science: a case study from Project FeederWatch. Frontiers in Ecology 10(6): 305–307.

Boyer, E. (1990). Scholarship Reconsidered; Priorities of the professoriate. Carnegie Foundation for the Advancement of Teaching. San Francisco: Jossey-Bass.

Brabham, D. (2013). Crowdsourcing. Cambridge MA: MIT Press.

Bucchi, M. (2008). Of deficits, deviations and dialogues: theories of public communication of science. In: Bucci, M. and B. Trench, eds. Handbook of Public Communication of Science and Technology, pp. 57–76. New York: Routledge.

Bui, L. (2013a). Open science: resources for sharing and publishing Citizen Science research. http://blogs.plos.org/citizensci/2013/11/12/open-science-resources-for-sharing-and-publishing-citizen-science-research/.

Bui, L. (2013b). The brain mapping games. http://blogs.plos.org/citizensci/2013/03/06/the-brain-mapping-games-may-the-odds-be-ever-in-our-favor/.

Bui, L. (2013c). Playing with the building blocks of life. http://blogs.plos.org/citizensci/2013/07/12/playing-with-the-building-blocks-of-life/.

Bui, L. (2013d). Music lovers take note: Citizen Science music projects! http://blogs.plos.org/citizensci/2013/11/06/music-lovers-take-note-citizen-science-music-projects/.

Burgess. M. (2014). From 'trust us' to participatory governance: Deliberative publics and science. Public Understanding of Science 23(1): 48–52.

Ceccaroni, L. and J. Piera (2016). Analysing the Role of Citizen Science in Modern Research. Hershey PA: IGI Global.

Clery, D. (2011). Galaxy Zoo Volunteers Share Pain and Glory of Research. Science 333 (8 July).

Cooper, C. (2013). The Most Stressful Science Problem. http://blogs.plos.org/citizensci/2013/01/14/the-most-stressful-science-problem/.

Cooper, C., Shirk, J. and B. Zuckerberg (2014). The Invisible Prevalence of Citizen Science in Global Research: Migratory Birds and Climate Change. PLoS ONE 9(9): e106508.

Cooper, S. et al. (2010). Predicting protein structures with a multiplayer online game. Nature 466: 756–760.

Courter, J. et al. (2012). Weekend bias in Citizen Science data reporting: implications for phenology studies. International Journal of Biometeorology. doi: 10.1007/s00484-012-0598-7.

Crabbe, J. (2012). From Citizen Science to Policy Development on the Coral Reefs of Jamaica. International Journal of Zoology (article 102350). doi: 10.1155/2012/102350.

Crall, A. et al. (2011). Assessing Citizen Science data quality: an invasive species case study. Conservation Letters 4(6): 433–442.

Cranshaw, J. and A. Kittur (2011). The Polymath Project: Lessons from a Successful Online Collaboration in Mathematics. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 1865–1874). ACM.

Daume, S. and V. Galaz (2016). 'Anyone Know What Species This Is?' Twitter Conversations as Embryonic Citizen Science Communities. PLoS One 11(3): e0151387. doi: 10.1371/journal.pone.0151387.

Dickson, D. (2005). The case for a 'deficit model' of science communication (editorial). http://www.scidev.net/global/communication/editorials/the-case-for-a-deficit-model-of-science-communic.html.

Follett, R. and V. Strezov (2015). An Analysis of Citizen Science Based Research: Usage and Publication Patterns. PLoS ONE 10(11): e0143687. doi: 10.1371/journal.pone.0143687.

Franzoni, C. and H. Sauermann (2012). Crowd Science: The Organization of Scientific Research in Open Collaborative Projects. Paper prepared for the 2012 NBER Workshop on Scholarly Communication, Open Science, and its Impacts. http://ssrn.com/abstract=2167538.

Freitag, A. and M. Pfeffer (2013). Process, Not Product: Investigating Recommendations for Improving Citizen Science 'Success'. PLos ONE 8(5): e64079, doi: 10.1371/journal.pone.664079.

Gardiner, M. et al. (2012). Lessons from lady beetles: accuracy of monitoring data from US and UK citizen-science programs. Frontiers in Ecology and the Environment. doi: 10.1890/110185.

Garrett, M. (2012). Hanny's Voorwerp and the Antikythera Mechanism – similarities, differences and insights. Proceedings of Science. https://arxiv.org/ftp/arxiv/papers/1211/1211.5487.pdf.

Geoghegan H. et al. (2016). Understanding motivations for Citizen Science. Final report on behalf of UKEOF. http://www.ukeof.org.uk/resources/citizen-science-resources/MotivationsforCS REPORTFINALMay2016.pdf.

Glister, P. (1997). Digital Literacy. New York: Wiley.

Gowers, T. and M. Nielsen (2009). Massively collaborative mathematics. Nature 461: 879–881 (15 October). doi: 10.1038/461879a.

Gray, S., Nicosia, K. and R. Jordan (2012). Lessons Learned from Citizen Science in the Classroom. Democracy & Education 20(2): 1–5.

Graybeal, C. (2013). Open science: resources for sharing and publishing Citizen Science research. http://blogs.plos.org/citizensci/2013/11/12/open-science-resources-for-sharing-and-publishing-citizen-science-research/.

Greenhill, A. et al. (2014). Playing with Science: Gamised aspects of gamification found on the online Citizen Science project Zooniverse. eprints.port.ac.uk/15648.

Haklay, M. (2015). Citizen Science and Policy: A European perspective. Washington: Woodrow Wilson Center.

Hidalgo-Ruz, V. and M. Thiel (2013). Distribution and abundance of small plastic debris on beaches in the SE Pacific (Chile): A study supported by a Citizen Science project. Marine Environmental Research 87–88: 12–18.

Highfield, R. (2015). Three centuries of Citizen Science. https://blog.sciencemuseum.org.uk/three-centuries-of-citizen-science.

Horlick-Jones, T. (1997). Alan Irwin: 'Citizen Science' (book review). Science, Technology & Human Values 224(4): 525.

Iacovides, I. et al. (2013). Do games attract or sustain engagement in Citizen Science? A study of volunteer motivations. In: CHI '13 Extended Abstracts on Human Factors in Computing Systems, 1101–06. https://doi.org/10.1145/2468356.2468553.

Irwin, A. (1995). Citizen Science: a Study of People, Expertise, and Sustainable Development. London: Routledge.

Izotov, Z., Guseva, N. and T. Thuan (2011). Green pea galaxies and cohorts: luminous compact emission-line galaxies in the Sloan digital sky survey. The Astrophysical Journal 728: 2. http://iopscience.iop.org/article/10.1088/0004-637X/728/2/161/meta.

Jennett, C. and A. Cox (2014). Eight Guidelines for Designing Virtual Citizen Science Projects. https://www.aaai.org/ocs/index.php/HCOMP/HCOMP14/paper/viewFile/9261/9188.

Jimenez, A. (2008). Relations and Disproportions. The labor of scholarship in the knowledge economy. American Ethnologist 35(2): 229–242.

Jordan, R. et al. (2015). Citizen Science as a Distinct Field of Inquiry. Bioscience 65(2): 208–211.

Keel, W. et al. (2012). The History and Environment of a Faded Quasar: Hubble Space Telescope Observations of Hanny's Voorwerp and IC 2497. The Astronomical Journal 144: 2. http://iopscience.iop.org/article/10.1088/0004-6256/144/2/66/meta.

Kelly, A. (2013a). Hackerspaces and Hacking Science. http://blogs.plos.org/citizensci/2013/05/06/hackerspaces-and-hacking-science/.

Kelly, A. (2013b). Music, Mayans, Maps: Citizen Science and the digital humanities. http://blogs.plos.org/citizensci/2013/06/03/music-mayans-maps-citizen-science-and-the-digital-humanities/.

Kelly, A. (2013c). Citizen Science in Crisis Situations. http://blogs.plos.org/citizensci/2013/01/07/citizen-science-in-crisis-situations/.

Kobori, H. et al. (2016). Citizen Science: a new approach to advance ecology, education, and conservation. Ecological Research 31: 1–19. doi: 10.1007/s11284-015-1314-y.

Kontokosta, C., Johnson, N. and A. Schloss (2016). The Quantified Community at Red Hook: Urban sensing and Citizen Science in Low-Income Neighborhoods. Paper presented at the Data For Good Exchange conference, arXiv:1609.08780 [cs.CY].

Kullenberg, C. and D. Kasperowski (2016). What is Citizen Science? – A Scientometric Meta-Analysis. PLoS ONE 11(1): e0147152 doi: 10.1371/journal.pone.0147152.

Lindskog, R. (2008). Scientised citizens and democratized science. Re-assessing the expert-lay divide. Journal of Risk Research 11(1–2): 69–86. doi: 10.1080/13669870701521636.

Loss, S. et al. (2015). Linking place-based Citizen Science with large-scale conservation research: A case study of bird-building collisions and the role of professional scientists. Biological Conservation 184: 439–445.

Martin, U. and A. Pease (2013). Mathematical practice, crowdsourcing, and social machines. https://arxiv.org/pdf/1305.0900.pdf.

McCormick, S. (2012). After the Cap: Risk assessment, Citizen Science and Disaster Recovery. Ecology and Society 17(4): 31. http://dx.doi.org/10.5751/ES-05263-170431.

McQuillan, D. (2014). The Countercultural Potential of Citizen Science. M/C Journal 17: 6. http://journal.media-culture.org.au/index.php/mcjournal/article/view/919.

Miller-Rushing, A., Primack, R. and R. Bonney. (2012). The history of public participation in ecological research. Frontiers in Ecology and the Environment 10: 285–290. doi: 10.1890/110278.

Mueller, M., Tippins, D. and L. Bryan. (2012). The Future of Citizen Science. Democracy and Education 20(1): 1–12.

Nielsen, M. (2011). Reinventing Discovery: The New Era of Networked Science. Princeton: Princeton University Press.

O'Grady, W. (1997). Syntactic Development. Chicago: University of Chicago Press.

Ottinger, G. (2010). Buckets of Resistance: Standards and the Effectiveness of Citizen Science. doi: 10.1177/0162243909337121.

Ottinger, G. (2015). Is it good science? Activism, values, and communicating political relevant science. Journal of Science Communication 14(02): C02.

Parthasarathy, S. (2010). Breaking the expertise barrier: understanding activist strategies in science and technology policy domains. Science and Public Policy 37(5): 355–367.

Perkins-Gough, D. (2007). Understanding the Scientific Enterprise: A Conversation with Alan Leshner. Science in the Spotlight 64(4): 8–14.

Pew Research Center (2015). Public and Scientists Views on Science and Society. http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society/.

Pocock, M. et al. (2013). Developing a Strategic Framework to Support Citizen Science Implementation in SEPA. Final Report on behalf of SEPA. NERC Centre for Ecology & Hydrology.

Qaurooni, D. et al. (2016). Citizens for Science and Science for Citizens: The View from Participatory Design. In: Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (pp. 1822–1826). ACM.

Raddick, M. et al. (2010). Galaxy Zoo: Exploring the motivations of Citizen Science volunteers. Astronomy Education Review 9(1).

Ramirez-Andreotta, M. et al. (2015). Building a co-created Citizen Science program with gardeners neighboring a superfund site: The Gardenroots case study. International Public Health Journal 7(1): 139–153.

Riesch, H. and C. Potter (2014). Citizen Science as seen by scientists: Methodological, epistemological and ethical dimensions. Public Understanding of Science 23(1): 107–120.

Riesch, H., Potter, C. and L. Davis (2013). Combining Citizen Science and public engagement: the Open Air Laboratories Programme. Journal of Science Communication 12(3).

Robinson, L. and D. Bawden (2001). Libraries and open society; Popper, Soros and digital information. Aslib Proceedings 53 (3): 167–178.

Rotman, D. et al. (2014). Motivations Affecting Initial and Long-Term Participation in Citizen Science Projects in Three Countries. iConference 2014 Proceedings, pp. 110–124. doi: 10.9776/14054.

Roy, H. et al. (2012). Understanding Citizen Science & Environmental Monitoring. Final Report for UK-EOF. https://www.ceh.ac.uk/sites/default/files/citizensciencereview.pdf.

Salk, C. et al. (2016). Local Knowledge and Professional Background Have a Minimal Impact on Volunteer Citizen Science Performance in a Land-Cover Classification Task. Remote Sensing 8: 774. doi: 10.3390/rs8090774.

Sartori, G. (1987). The Theory of Democracy Revisited, Part I. Chatham: Chatham House.

Scott, D. and C. Barnett (2009). Something in the air: civic science and contentious environmental politics in post-apartheid South Africa. Geoforum 40(3): 373–382.

Seifert, V. et al. (2016). Community Partnership Designed to Promote Lyme Disease Prevention and Engagement in Citizen Science. Journal of Microbiology & Biology Education (March: 63–69). http://dx.doi.org/10.1128/jmbe.v17i1.1014.

Silvertown, J. et al. (2013). Citizen Science and nature conservation. In: D. Macdonald and K Willis. Key Topics in Conservation Biology 2 (John Wiley & Sons), Chapter 8 (127–142).

Socientize Consortium/European Commission (2013). Green Paper on Citizen Science. Socientize Consortium/European Commission (2014). White Paper on Citizen Science for Europe. www.socientize.eu/sites/default/files/white-paper_0.pdf.

Soros, G. (1998). The crisis of global capitalism; open society endangered. London: Little, Brown and Company.

Spruijta, P. et al. (2014). Roles of scientists as policy advisers on complex issues: A literature review. Environmental Science & Policy 40 (June): 16–25. http://dx.doi.org/10.1016/j.envsci. 2014.03.002.

Stilgoe, J., Lock, S. and J. Wilsdon (2014). Why should we promote public engagement with science? Public Understanding of Science 23(1): 4–15.

Straub, M. (2016). Giving Citizen Scientists a Chance: A Study of Volunteer-led Scientific Discovery. Citizen Science: Theory and Practice 1(1): 5, pp. 1–10. doi: http://dx.doi.org/10.5334/cstp.40.

Sturgis, P. (2014). On the limits of public engagement for the governance of emerging technologies. Public Understanding of Science 23(1): 38–42.

Surowiecki, J. (2005). The Wisdom of Crowds. New York: Anchor Books.

Townsend, A. and A. Chisholm (2015). Citizen Urban Science. New Partnerships for Advancing Knowledge. http://www.citiesofdata.org/wp-content/uploads/2015/08/CitizenUrbanScience.pdf.

Vayena, E. and J. Tasioulas (2015). 'We the scientists': a human right to Citizen Science. Philosophy & Technology 28(3): 479–485.

Veletsianos, G. and R. Kimmons (2012). Assumptions and Challenges of Open Scholarship. International Review of Research in Open and Distributed Learning 13(4). http://www.irrodl.org/index.php/irrodl/article/view/1313/2304.

Woolley. J. et al. (2016). Citizen Science or scientific citizenship? Disentangling the uses of public engagement rhetoric in national research initiatives. BMC Medical Ethics 17: 33. doi: 10.1 186/s 129 10-016-0117-1.

Wyler, D. and F. Grey (2016). Citizen Science at Universities: Trends, guidelines and recommendations (October), LERU Advice Paper No. 20 – October. http://www.leru.org/files/publications/LERU_AP20_citizen_science.pdf.

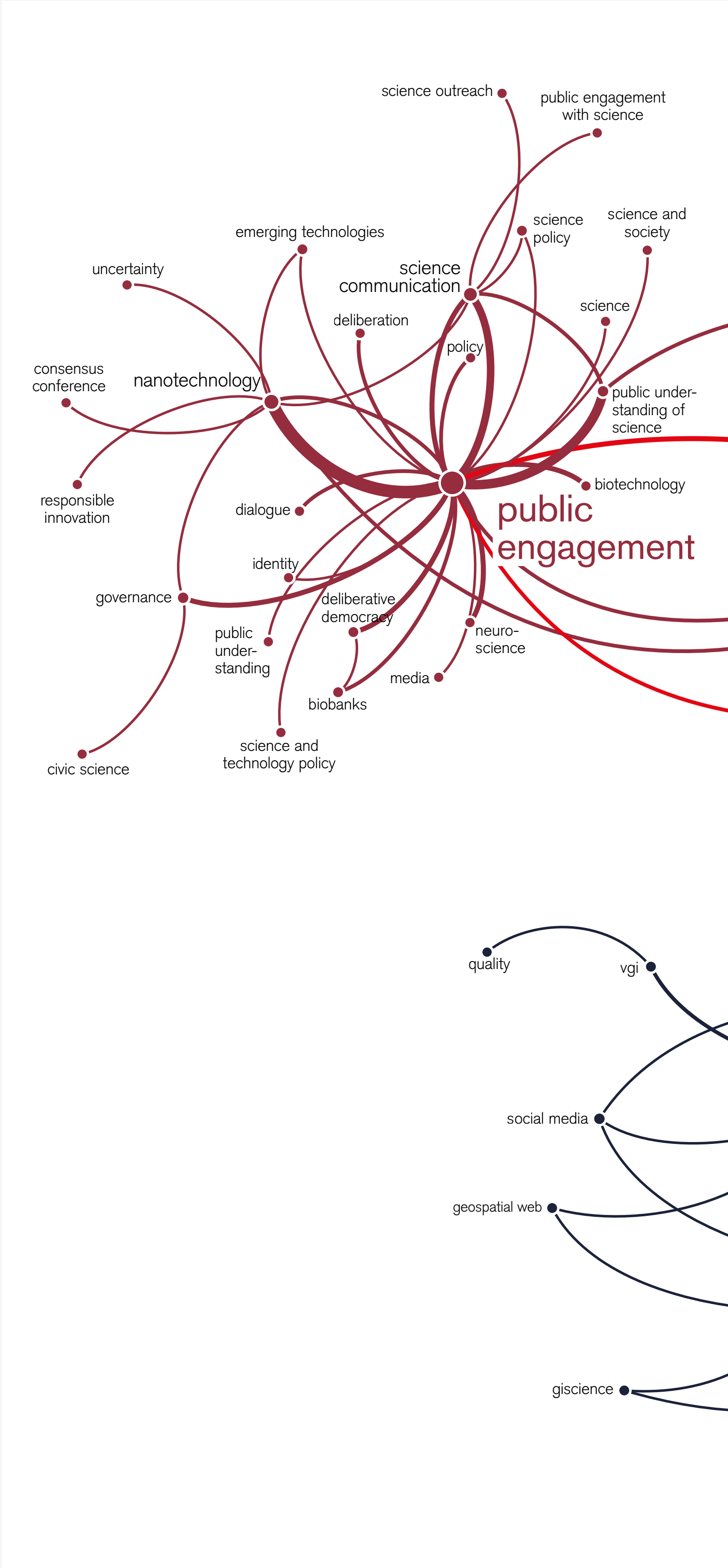
Appendices

Appendix 1: Crowdsourcing

A portmanteau word coined in 2005, it is the idea that free contributions of ideas, services or data can be solicited from individual internet users for both public and private purposes and projects. The contributions come from an anonymous 'online community' rather than a specific provider, as would be the case in 'outsourcing'. Crowdsourcing is often a mix of top-down and bottom-up processes, and while it can and has been used for small tasks which call for little skill, it has also been tapped to develop valuable common goods (e.g., Wikipedia or Linux) which rely both on individual expertise and on the benefits of collective intelligence.[61]

The advantages of crowdsourcing include minimizing information-gathering costs or research expenses, much greater speed in completing tasks in large or complex projects, the potential of achieving greater productivity, and the encouragement of innovation from previously untapped or unacknowledged sources. Members of the 'online community' who provide are ordinarily not motivated by money as much as by a sense of satisfaction at being part of something valuable or significant. They often only want a degree of recognition – but value their independence, which means they do ask for the time, attention, patience, good listening skills, transparency, and honesty from those to whom they are providing their inputs.[62]

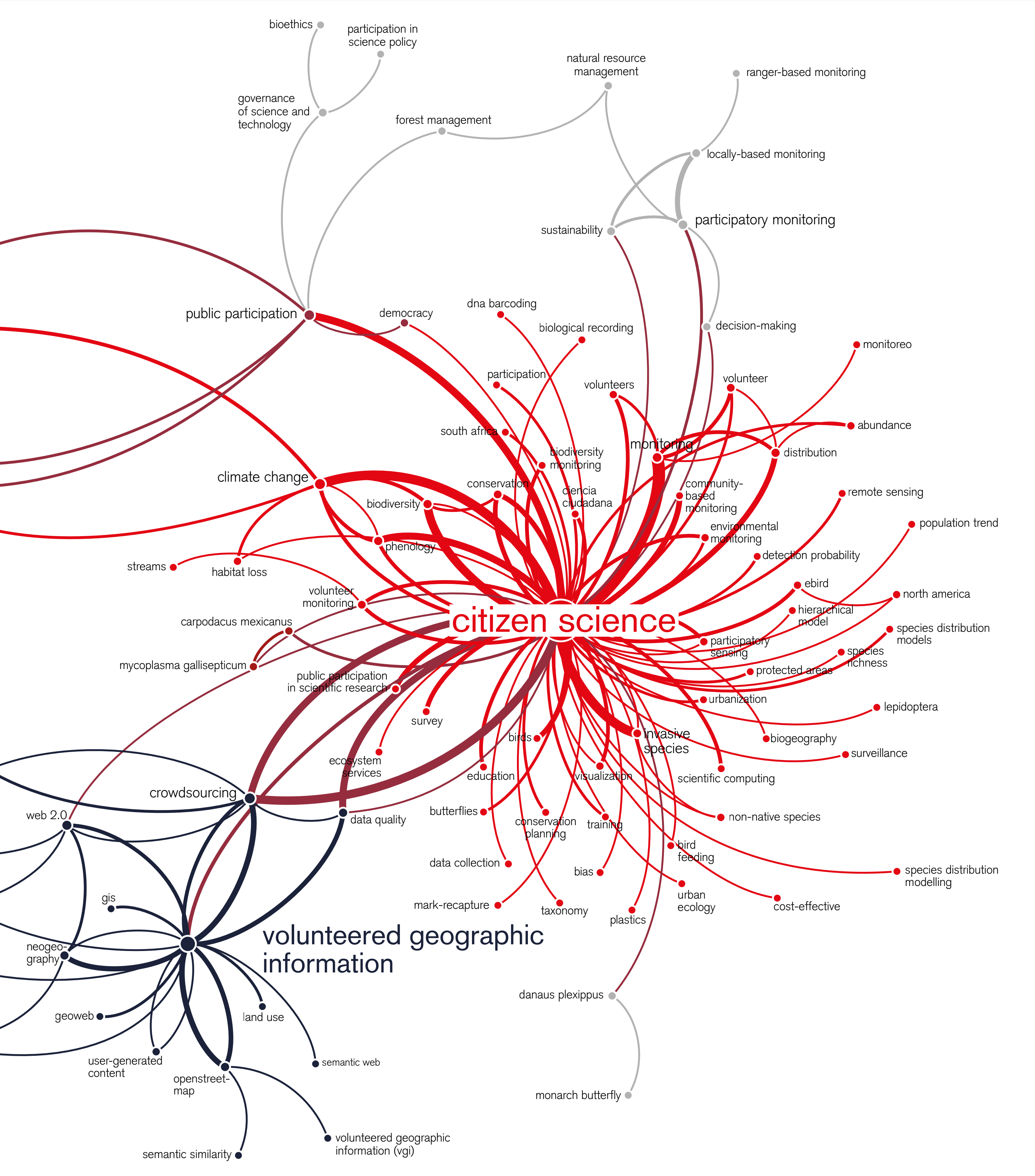
Appendix 2: Citizen Science word co-occurrence network



Kullenberg and Kasperowski 2016: 9
Based on keywords in Scopus and Web of Science
(created 17 December 2015; 1935 hits).

61 See Brabham 2013 and Surowiecki 2005.

62 See Alsever 2008 and the 'Crowdsourcing' Wikipedia article (accessed 27 November 2016).


bioethics
participation in science policy
governance of science and technology
forest management
natural resource management
ranger-based monitoring
locally-based monitoring
participatory monitoring
sustainability
public participation
democracy
dna barcoding
biological recording
decision-making
monitoreo
volunteer
volunteers
participation
south africa
biodiversity monitoring
monitoring
abundance
distribution
climate change
conservation
ciencia ciudadana
community-based monitoring
remote sensing
biodiversity
phenology
environmental monitoring
population trend
detection probability
streams
habitat loss
volunteer monitoring
ebird
north america
hierarchical model
carpodacus mexicanus
citizen science
species distribution models
participatory sensing
species richness
mycoplasma gallisepticum
public participation in scientific research
protected areas
urbanization
survey
lepidoptera
invasive species
birds
biogeography
ecosystem services
surveillance
education
visualization
scientific computing
crowdsourcing
web 2.0
data quality
butterflies
conservation planning
training
non-native species
bird feeding
data collection
bias
species distribution modelling
gis
urban ecology
cost-effective
mark-recapture
taxonomy
plastics
volunteered geographic information
neogeo-graphy
danaus plexippus
geoweb
land use
user-generated content
openstreet-map
semantic web
monarch butterfly
volunteered geographic information (vgi)
semantic similarity

Appendix 3: Suitability of a Citizen Science approach

Issues to be considered

Project objectives

Education/outreach	Appropriately designed, CS can be an effective tool if learning objectives and audiences are identified clearly
Project duration/legacy	Since CS incurs set-up costs, it is more cost-effective if the project is of long duration and/or a legacy effect is desirable. Resources for long-term monitoring must be in place
Accessibility of scientific objectives	The scientific rationale behind the project must be easily explainable to a lay audience in order to recruit the volunteers to participate using CS

Project budget

Overall cost	If low cost is an over-riding factor, CS may not be the cheapest option. Even if volunteers pay to participate (e.g. Earthwatch volunteers), they will require scientists' time and supervision, which will incur costs. Recognition of service must match volunteer expectations
Fixed costs	Staff time needs to be devoted to managing volunteers, which could be a cost burden on a small project or one that fails to recruit enough volunteers

Project design

Health and safety	Major safety issues may make CS unviable
Geographical area	The larger the area to be sampled, the more worthwhile it will be to invest in a CS approach
Sampling protocol	A robust and easy-to-apply protocol for CS volunteers must be devised
Data validation	Mechanisms must be in place to validate the data

Volunteers

Recruitment	Projects involving charismatic species or habitats attract volunteers, as do opportunities to help the environment, be part of a well-organized program learn something new, join a social group or affiliate with people with similar values. Is there a readily available pool of volunteers from which to recruit and obvious channels for recruiting them? Why do citizens volunteer for this project?
Skills, training and supervision	Are special skills required by volunteers? Is appropriate training provided? Can staff and/or experienced volunteers provide ongoing training and supervision? Is the research project organized effectively?
Feedback/recognition	How will feedback to volunteers be provided? Can a volunteer's personal contribution be tracked and recognized? Reward through recognition is how an organization expresses its thanks for the donated time, energy and expertise; recognition should be frequent and meet volunteer expectations.
Time commitment	How much time commitment is required from volunteers? Is there more than one role or level of involvement for volunteers? For long-term projects, how will interest be maintained?

Source: Silvertown, J. et al. (2013: 138 – Table 8.1. When is a Citizen Science approach appropriate?)

Appendix 4: Additional recent literature (2011–2016)

Brosnan, T., Filep, S. and J. Rock (2015). Exploring synergies: Hopeful tourism and Citizen Science. Annals of Tourism Research 53: 96–98.

Catlin-Groves, C. (2012). The Citizen Science Landscape: From Volunteers to Citizen Sensors and Beyond (review article). International Journal of Zoology. doi: 10.1155/2012/349630.

Chandler, M. et al. (2012). International Citizen Science: making the local global. Frontiers in Ecology 10(6): 328–331. doi: 10.1890/110283.

Chilvers, J. and M. Kearnes (eds.) (2015). Remaking Participation: Science, Environment and Emergent Publics. London: Routledge.

Collins, H. (2014). Are We All Scientific Experts Now? Cambridge: Polity.

Crain, R., Cooper, C. and H. Dickinson (2014). Citizen Science: A Tool for Integrating Studies of Human and Natural Systems. Annual Review of Environment and Resources 39: 641–665. doi: 10.1146/annurev-environ-030713-154609.

Crall, A. et al. (2012). The impacts of an invasive species Citizen Science training program on participant attitudes, behaviour, and science literacy. Public Understanding of Science 0(0): 1–20. doi: 10:1177/0963662511434894.

Czerniewicz, L. (2013). Power and politics in a changing scholarly communication landscape. Proceedings of the IATUL Conference. http://docs.lib.purdue.edu/iatul/2013/papers/23.

Davies, L. et al. (2016). Surveying the Citizen Science landscape: an exploration of the design, delivery, and impact of Citizen Science through the lens of the Open Air Laboratories (OPAL) programme. BMC Ecology 16 (Suppl1): 517. doi: 10.1186/s12898-016-0066-z.

Dickinson, J. et al. (2012). The current state of Citizen Science as a tool for ecological research and public engagement. Frontiers in Ecology 10(6): 291–297.

Eveleigh, A. et al. (2014). Designing for Dabblers and Deterring Drop-Outs in Citizen Science. CHI 2014 (Apr 26 – May 1), *ACM*. Toronto/On. http://dx.doi.org/10.1145/2556288.2557262.

Gawande, A. (2016). The Mistrust of Science. The New Yorker (June 10).

Jordan, R., Ballard, H. and T. Phillips (2012). Key issues and new approaches for evaluating citizen-science learning outcomes. Front Ecol Environ 10(6): 307–309.

Jordan, R. et al. (2011). Knowledge Gain and Behavioral Change in Citizen-Science Programs. Conservation Biology 25(6): 1148–1154.

Kuznetsov, S., Kittur, A. and E. Paulos (2015). Biological Citizen Publics: Personal Genetics as a Site of Scientific Literacy and Action. Paper presented at C&C 2015 (June 22–25), Glasgow. http://dx.doi.org/10.1145/2757226.2757246.

Martin, V. et al. (2016). Understanding drivers, barriers and information sources for public participation in marine Citizen Science. Journal of Science Communication 15(02), A02.

Newman, G. (2016). Leveraging the power of place in Citizen Science for effective conservation decision making. Biological Conservation (in press).

Newman, G. et al. (2012). The future of Citizen Science: emerging technologies and shifting paradigms. Front Ecol Environ 10(6): 298–304. doi: 10.1890/110294.

Peel, G. et al. (2015). Building Australia through Citizen Science. Occasional Paper Series 11 (July). http://www.chiefscientist.gov.au/wp-content/uploads/Citizen-science-OP_web.pdf.

Prainsack, B. (2016). Understanding Participation: The 'Citizen Science' of genetics. In: Prainsack, Schicktanz and Werner-Felmayer, eds. Genetics as Social Practice: Transdisciplinary Views on Science and Culture (New York: Routledge), pp. 147–165.

Rotman, D. et al. (2012). Dynamic Changes in Motivation in Collaborative Citizen-Science Projects. Paper prepared for the ACM Conference on Computer Supported Cooperative Work (Seattle, WA).

Scassa, T. and H. Chung (2015). Typology of Citizen Science Projects from an Intellectual Property Perspective: Invention and Authorship Between Researchers and Participants. https://www.wilsoncenter.org/sites/default/files/Typology_of_Citizen_Science_IP_Rights_Scassa.pdf.

See, L. et al. (2016). Crowdsourcing, Citizen Science or Volunteered Geographic Information? The Current State of Crowdsourced Geographic Information. ISPRS Int. J. Geo-Inf. 5(5): 55. doi: 10.3390/ ijgi5050055.

Shirk, J. et al (2012). Public participation in scientific research: a framework for deliberate design. Ecology and Society 17(2): 29.

Silvertown, J. et al. (2011). Citizen Science Reveals Unexpected Continental-Scale Evolutionary Change in a Model Organism. PLoS ONE 6(4): e18927. doi: 10.1371/journal.pone.0018927.

Smith, M. (2014). Citizen Science in Archaeology. American Antiquity 79(4): 749–762.

Soranno, P. et al. (2014). It's Good to Share: Why Environmental Scientists' Ethics Are Out of Date. Bioscience. doi: 10.1093/biosci/biu169.

Tinati, R. et al. (2014). Collective Intelligence in Citizen Science – A Study of Performers and Talkers. Collective Intelligence *2014*. https://arxiv.org/pdf/1406.7551.

Toomey, A. and M. Domroese (2013). Can Citizen Science lead to positive conservation attitudes and behaviors? Research in Human Ecology 20(1): 50–62.

Tulloch, A. et al. (2013). Realising the full potential of Citizen Science monitoring programs. Biological Conservation 165: 128–138.

Weitkamp, E. (2016). From planning to motivations: Citizen Science comes to life. Journal of Science Communication 15(3). http://eprints.uwe.ac.uk/28815.

Appendix 5: Abbreviations

CERN	Conseil Européen pour la Recherche Nucléaire
CS	Citizen Science
CSSI	Conseil suisse de la science et de l'innovation
CSSI	Consiglio svizzero della scienza et dell'innovazione
DataONE	Data Observation Network for Earth
DNA	Deoxyribonucleic acid
EU	European Union
ETH, ETHZ	ETH Zurich
F1000	Faculty of 1000
GNP	Gross national product
GZ	Galaxy Zoo
ICT	Information and communication technologies
LERU	League of European Research Universities
MIT	Massachusetts Institute of Technology
MMOS	Massively Multiplayer Online Science
NASA	National Aeronautics and Space Administration
OED	Oxford English Dictionary
Ph.D.	Doctor of Philosophy
PLOS	Public Library of Science
PNAS	Proceedings of the National Academy of Sciences of the United States of America
RNA	Ribonucleic acid
SCNAT	Swiss Academy of Sciences
SMAP	Soil Moisture Active Passive (SMAP) satellite
SSIC	Swiss Science and Innovation Council
SWIR	Schweizerischer Wissenschafts- und Innovationsrat
UCL	University College London
UK	United Kingdom
UNIBE	University of Bern
UNIGE	University of Geneva
UNITAR	United Nations Institute for Training and Research
U.S.	United States of America
UZH	University of Zurich

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T +41 (0)58 463 00 48
F +41 (0)58 463 95 47
swir@swir.admin.ch
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Swiss Science and Innovation Council SSIC
Einsteinstrasse 2
CH-3003 Bern

T +41 (0)58 463 00 48
F +41 (0)58 463 95 47
swir@swir.admin.ch
www.swir.ch