

Not So Passive: Engagement and Learning in Volunteer Computing Projects

LAURE KLOETZER, University of Neuchâtel, Institute of Psychology and Education, Switzerland

DANIEL SCHNEIDER, University of Geneva, TECFA, Switzerland

JULIEN DA COSTA, University of Geneva, TECFA, Switzerland

ABSTRACT

This paper focuses on an unexplored dimension of Citizen Science: the potential of Volunteer Computing (VC) for informal learning. VC has been one of the most popular forms of Citizen Science since its beginnings in 1997, when the first VC platforms, such as SETI@home, were created. Participation in VC is based on volunteers donating their idle computer resources to contribute to large-scale scientific research. So far, this has often been considered as a rather passive form of participation, compared to other online Citizen Science (or citizen cyberscience) projects, since volunteers are not involved in active data collection, data analysis or project definition. In this paper we present our research, which was conducted in 2013-2014 with the BOINC Community “Alliance Francophone”, and demonstrate that some of the volunteers in Distributed Computing research projects are not at all passive. We show that the dynamism of BOINC greatly relies on community-led gamification and that participation may lead to important learning outcomes. These include extending one’s scientific interests and network of people who share similar interests, and progressing within the fields of communication, computing and Internet literacy. Also, as demonstrated by our recent ILICS survey research (2015), these latest learning outcomes are experienced by all categories of participants according to their level of engagement irrespective of their level of formal education, which is an interesting finding for lifelong education policies. Altogether, VC projects engage volunteers emotionally, far beyond the simple use of their computer time and power, and may have a personal and educational value. For a minority of very active volunteers, these projects become real “Windows of Opportunity” for making friends, gaining skills and benefiting from new experiences, which would not easily happen otherwise in their normal everyday environment.

1. INTRODUCTION

This paper focuses on an unexplored dimension of Citizen Science: the potential of Volunteer Computing (VC) for informal learning. VC has been one of the most popular forms of Citizen

Science since its beginnings in 1997, when the idea of using personal computers as a parallel supercomputer emerged. The idea came to life within several projects, including GIMPS, which searched for large prime numbers and Distributed.net, which was created to decipher encrypted messages. In 1999 the idea got a boost with the SETI@home¹ project which was aimed at detecting radio signals emitted by intelligent civilizations outside the Earth, and Folding@home², which works on protein folding simulation, both of which attracted hundreds of thousands of participants. BOINC (Berkeley Open Infrastructure for Network Computing) was then created to host a range of scientific projects based on the same infrastructure for distributed computing. According to one of its creators, David Anderson, “the implications of this “public computing” paradigm are social as well as scientific. It provides a basis for global communities centered on common interests and goals. It creates incentives for the public to learn about current scientific research. Ultimately, it will give the public more direct control over the directions of science progress” (Anderson, 2003). However, as participation in VC is based on volunteers donating their idle computer resources to contribute to large scale scientific research, VC has mostly been seen as a passive form of participation, compared to other online Citizen Science projects. Volunteers are supposed to download and run a free program that analyzes scientific data, and are not involved themselves in active data analysis or project definition. However, the issue has not been extensively analyzed to date.

In our research, we investigated the following questions: What are the participation patterns of volunteers in Volunteer Computing? What do they do and what do they get out of it? Is learning possible through participation? What kind of learning happens and how?

We begin by summarizing the current knowledge about engagement and learning in Citizen Science and Volunteer Computing in the scientific literature. We then present our qualitative and quantitative research conducted in 2013-2014 within the BOINC Community “Alliance Francophone.” We demonstrate that at least some of the volunteers in Volunteer Computing projects are not passive at all. We show that:

- (a) the dynamism of BOINC hugely relies on community-led gamification,
- (b) that participation may lead to important learning outcomes, and
- (c) (c) that engagement and learning are linked: the greater the number of responsibilities volunteers take on in the community, the more they get out of it in terms of informal learning.

These outputs include extending one’s scientific interests and network of people who share similar interests, and progressing within the fields of communication, computing and Internet literacy. In a third section, we compare the data collected within a specific community with a larger sample from our recent ILICS survey research (2015), and compare Volunteer Computing with other types of Citizen Science projects. We show that learning is not significantly different between Volunteer Computing and Volunteer Thinking (VT) projects. We also show that this is

¹ <http://setiathome.ssl.berkeley.edu>

² <https://folding.stanford.edu>

the case for all kinds of participants and that it is even more so for people who have a lower level of education, which is an interesting finding for lifelong education policies. We conclude that altogether, Volunteer Computing projects engage volunteers emotionally, far beyond the simple use of their computers time, may have educational value, and for a minority of very active volunteers, become real “Windows of Opportunities” for making new friends, gaining new skills and benefiting from new experiences, which would not easily happen otherwise in their normal everyday environment.

2. LEARNING IN CITIZEN SCIENCE AND VOLUNTEER COMPUTING: LITERATURE REVIEW

2.1 Learning in Citizen Science

Research on learning in citizen science is still in its early stages. While the contribution of volunteers to scientific data collection and analysis has been well documented, research on participation patterns in citizen science projects and how they may be connected to learning is emerging. However, as public policies begin to explore the potential of citizen science in science education and social innovation, the topic is quickly gaining importance. Although most citizen science projects are usually firstly designed with science in mind, educational goals become more and more important as (a) learning is shown to be an efficient way to encourage sustained participation of engaged volunteers (Jennett et al., forthcoming), (b) science education and promotion are considered a challenge and asset for future democracy in both the US and Europe, and (c) project teams may face requests from funding agencies to analyze the educational potential and outcomes of their citizen science projects. Citizen science researchers also highlight that “the growth in citizen science programs over the past two decades suggests that we need to evaluate their effectiveness in meeting educational goals” (Crall et al., 2012).

To date, research on learning in citizen science has largely focused on scientific literacy and attitudes toward science (Bonney et al., 2009; Cronje et al., 2011; Crall et al., 2012; Price & Lee, 2013; Trumbull et al., 2000) and content-knowledge (Jordan et al., 2011); some projects also advocate changes in everyday behaviour (Jordan et al., 2011). Gains in scientific content knowledge may be easier to detect in this context (Brossard et al., 2005). For example, Jordan et al. (2011) showed a 24% increase in the knowledge of invasive plants after participating in training for a citizen science project, with participants reporting an increased ability to recognize invasive plants, and increased awareness of the effects of invasive plants on the environment, even though this translates into little behavioural change regarding invasive plants. As illustrated above, most studies so far, with a few notable exceptions (Price & Lee, 2013; Holohan, 2013; Nov et al., 2011a, 2011b, 2014; Raddick et al., 2010, 2013; Reed et al., 2014; Kloetzer et al., 2013) focus on natural science and conservation projects, i.e. traditional citizen science as opposed to CCS.

A look at their results shows that the effects of participation on scientific literacy are difficult to assess: “In our study, participant knowledge of the nature of science and science-process skills did not change, despite explicit instruction” (Jordan et al., 2011). Trumbull et al. (2000) found no effect on scientific literacy with quantitative measures; however, qualitative analyses of 750 letters revealed that 80% showed evidence of some scientific inquiry among participants. Crall et al. (2012) also found no changes in science literacy or overall attitudes between tests administered just before and after a one-day training program, matching results from other studies. However, they found improvements in science literacy and knowledge using context-specific measures and in self-reported intentions to engage in pro-environmental activities. Cronje et al. (2011) also assessed the effect of invasive species monitoring training on the scientific literacy of citizen volunteers thanks to contextual multi-item instruments, and were able to demonstrate significant increases in the scientific literacy of citizen scientists. The authors conclude that “there remains little published evidence that citizen science experiences can improve the scientific literacy of participants”, maybe due to the lack of specific evaluation tools, which would be able to detect the very specific learning process involved (p.136).

However, despite these nuanced conclusions, a strong trend remains in most studies, that is the role of social involvement and learning within Citizen Science communities. Price and Lee (2013), who conducted research on an online astronomy citizen science project³, report how the volunteers' attitudes towards science and their epistemological beliefs about the nature of science changed after six months of participation. Analysis of pre- and post-test data of 333 volunteers reveals a positive change in scientific attitudes. Correlating these data with the participation paths of the subjects in the project, the researchers conclude that improvement in scientific literacy is related to participation in the social components of the program but not to the amount of contributed data. This conclusion is strongly supported by our own data as well, as will become clear later in this paper and as already described in our other publications (Kloetzer et al., 2013; Jennett et al., 2016).

Another strong trend is the relationship between learning and sustained participation in citizen science projects. Project teams are just beginning to take full advantage of this positive effect of learning on the initial and, most importantly, long-term participation in their projects. As projects struggle to find, train and retain efficient volunteers, any dimension supporting the strong and long-term engagement of volunteers should be encouraged. According to our recent research (see Jennett et al., 2016), learning is one of these important dimensions: although learning is expressed as a reason to participate for a minority of participants (between 20% and 1/3 of the volunteers, depending on the projects), it becomes, with experience and engagement within a community of volunteers, a driver of continuous participation.

³ Citizen Sky, <http://www.citizensky.org>

2.2 Participation patterns in Volunteer Computing

In Volunteer Computing (VC), very few studies have explored participation patterns of volunteers in such projects in general. As early as 2003, Anderson described how the SETI@home design features and social dynamics interact to support productive contribution: “Our poll indicates that 92% of SETI@home users are male, and that most of them are motivated primarily by their interest in the underlying science: they want to know if intelligent life exists outside earth. Another major motivational factor is public acknowledgement. SETI@home keeps track of the contributions of each user (i.e. the amount of computation performed) and provides numerous web-site “leader boards” where users are listed in order of their contributions. Users can also form “teams”, which have their own leader boards. The team mechanism turned out to be very effective for recruiting new participants.” Science (or at least interest for extraterrestrial life and collaboration with scientists), public recognition (soon to be turned into competition by volunteers themselves, as will be reported in this paper), and community in the form of teams, were the three main motivations highlighted by Anderson. Anderson recognized the richness of the contributions made by BOINC volunteers to the projects: “SETI@home participants have contributed more than CPU time. Volunteers have translated the SETI@home web site into 30 languages, and have developed many kinds of add-on software and ancillary web sites. We believe that it is important to provide channels for this sort of contribution.” (Anderson, 2003). These various roles allow for multiple social engagements within the community of volunteers and BOINC researchers. Finally, Anderson also noticed the emergence of BOINC-related communities: “Various “communities” have formed around SETI@home. There is a single worldwide community, which interacts through the SETI@home web site. There are also national or language-specific communities, with their own web sites and message boards. The SETI@home user group in Germany has had conventions for several years. At least three couples have met and married through SETI@home communities.” (that was back in 2003 – there have no doubt been many more since then).

The three main components identified by Anderson in his early paper are consistently reported in Holohan’s recent book: “The motivations of the individuals involved can be summarized as: science, community and competition. But for many volunteers, they are inextricably intertwined. To be able to participate in a community, play the game of competitive crunching and at the same time contribute to a worthy scientific project is a powerful combination made possible by the Internet.” (Holohan, 2013, p.115). Holohan highlights a critical point according to us: the “powerful combination” of “intertwined” motivations for volunteers, whose initial individual interests for science find in the BOINC technical and social infrastructure multiple opportunities of expression and development. Holohan highlights the efficiency of a project community for the performance of volunteers and integration of newcomers. As will become clear in the second section of this paper, we can only agree with her claim that: “Communal ties typically increase individual productivity compared with those volunteers who are not part of a project community and play an essential role in welcoming newcomers and getting them successfully started.

Projects with a very active and committed community based on teams and forums increase their likelihood of longevity and inspire a very loyal, committed core group which keeps projects going through the ebbs and flows of the wider public interest.” (Holohan, 2013, p.117).

However, so far, no studies have been conducted on the learning outcomes and processes linked to participation in Volunteer Computing. In section 3, we will report on our qualitative and quantitative research conducted within the French-speaking BOINC community – “Alliance Francophone.” In section 4, we will compare the findings on volunteer computing with other types of online citizen science projects, thanks to a larger survey called Informal Learning in Citizen Science (ILICS, Schneider, DaCosta et Kloetzer, unpublished data).

3. BOINC COMMUNITY STUDY: “ALLIANCE FRANCOPHONE”

3.1 French-speaking “Alliance Francophone” and our case study

Alliance Francophone (AF) is a BOINC community gathering French-speaking “crunchers” from around 100 different countries (France, Belgium, Canada, USA, Morocco, Australia, China, etc.). They describe it as “une communauté pour la science par le calcul distribué sur la plateforme BOINC” – “a community for science through Volunteer Computing on the BOINC platform.” It was created in 2005, and now consists of more than 18000 registered members. It is structured around a website and a forum. The website⁴ introduces VC philosophy, the BOINC concept, and the AF as a community. It features a guide to VC, as well as news and summaries of scientific projects to which members might want to contribute, as it appears in Figures 1 and 2:



Figure 1: Alliance Francophone website

⁴ <http://www.boinc-af.org/>

The AF forum comprises 3500+ members, among whom around 300 are regular contributors. BOINC events (seasonal international competitions in teams called “raids”) are regularly organized, as well as coordinated “actions”: these are weekly suggestions of projects to crunch on, selected by a vote in the forum.

The screenshot shows the homepage of the Alliance Francophone forum. At the top, there is a navigation bar with the forum's logo and a search bar. Below this, there are several main sections:

- L'Alliance Francophone:** A list of categories with their respective message counts and last activity.

Généralités Présentation de l'AF, ses sites, ses ressources techniques, ses membres, les questions générales au sujet de notre équipe BOINC, les échanges avec les autres équipes mondiales etc. ...	8434 Messages 499 Sujets	Dernier message par UCCTET_SaDiNe dans Re: Charity Event 2015 le Aujourd'hui à 21:18
Les mini-teams Rassemblements des Mini-Teams de l'AF	4728 Messages 138 Sujets	Dernier message par [AF]Amis de la Mer / ConzOron dans Re: [AF]Amis de la mer... le Aujourd'hui à 22:01
L'AFabric Section réservée à toutes les initiatives techniques pour promouvoir le calcul distribué et encourager nos membres à cruncher!	2163 Messages 47 Sujets	Dernier message par dxi dans Re: [AF] Condamna e... le Aujourd'hui à 09:37
- BOINC et les projets distribués:** A list of BOINC projects with their message counts and last activity.

Annonces sur Boinc et les projets Modérateurs: Thymyri, Sasho	17493 Messages 271 Sujets	Dernier message par Thymyri dans Re: [BOINC] [BOINC]... le Aujourd'hui à 10:12
Astronomie	14569 Messages 95 Sujets	Dernier message par JermineC dans Re: [BOINC] [BOINC]... le Hier à 22:28
Biologie	1412 Messages 76 Sujets	Dernier message par jrtf200 dans Re: [BOINC] [BOINC]... le 17 janvier 2016 à 19:18
Ecologie	7643 Messages 63 Sujets	Dernier message par rortulou dans Re: [BOINC] [BOINC]... le Aujourd'hui à 06:15
Mathématiques	11064 Messages 65 Sujets	Dernier message par jrtf200 dans Re: [BOINC] [BOINC]... le Aujourd'hui à 11:59
Physique-Chimie	4165 Messages 38 Sujets	Dernier message par JermineC dans Re: [BOINC] [BOINC]... le 17 janvier 2016 à 12:48
Multi-catégories Section regroupant les projets dits à brins.	5984 Messages 76 Sujets	Dernier message par jrtf200 dans Re: [BOINC] [BOINC]... le 18 janvier 2016 à 05:42
Traductions Traductions concernant BOINC et les projets modérateurs: ventral	407 Messages 13 Sujets	Dernier message par Maurice Goulet dans Re: [BOINC] [BOINC]... le Aujourd'hui à 10:39
- FAQ Technique:** A list of technical questions with their message counts and last activity.

BOINC Des soucis avec Boinc? Venez en discuter!	17122 Messages 564 Sujets	Dernier message par [AF]Amis des Lapons / JermineC dans Re: [BOINC] [BOINC]... le Aujourd'hui à 13:35
Projets Des soucis avec un projet? Venez en discuter!	3916 Messages 258 Sujets	Dernier message par rortulou dans Re: [BOINC] [BOINC]... le 18 janvier 2016 à 11:17
Tutoriels La mise à jour de l'AF Modérateurs: rortulou, Duce Bob	3107 Messages 95 Sujets	Dernier message par jrtf200 dans Re: [BOINC] [BOINC]... le 17 janvier 2016 à 21:01
Problèmes techniques divers Vos problèmes techniques qui ne concernent ni Boinc, ni un projet	9326 Messages 287 Sujets	Dernier message par [AF]Lentilles dans Re: [BOINC] [BOINC]... le Hier à 01:05
- Tavernes:** A list of social or discussion topics with their message counts and last activity.

Tavernes @ Home Discussions diverses Modérateurs: Sasho, wess111	13030 Messages 962 Sujets	Dernier message par [AF]Amis des Lapons / JermineC dans Re: [BOINC] [BOINC]... le Aujourd'hui à 10:23
Le coin des personnalités Section destinée aux news "people" de la science, de l'informatique ou autres qui influencent ou ont influencé notre question	1109 Messages 21 Sujets	Dernier message par f0x00 dans Re: [BOINC] [BOINC]... le Hier à 15:10
Projets non-BOINC Cette section regroupe les sujets ayant trait aux systèmes de calcul partagé utilisant d'autres plateformes Modérateurs: JermineC, Sasho	2187 Messages 48 Sujets	Dernier message par f0x00 dans [BOINC] [BOINC]... le 17 janvier 2016 à 11:33

Below these sections, there is a 'Messages récents' section listing recent posts with their titles, authors, and timestamps. At the bottom, there are sections for 'Prochains événements', 'Stats du forum', and 'Membres en ligne'.

Figure 2: Alliance Francophone forum

Some face-to-face meetings are also organized sporadically between community members, through interpersonal networks of friendship or collaboration. The existence of the AF requires the core members to engage with various responsibilities, which are organized in different working groups, some of which have hierarchical relations. For example, the AF is led by a group of founding members, called CD5 (“Club des Cinq”, or Famous Five), as well as by a group of appointed members managing the forum, who call themselves “la Chambre à Air” (“the Air Tube”). Subteams are identified and run in different ways by dedicated members. Interestingly, the complex structure of the BOINC AF community contrasts with the more homogenous and centralized organisation of another BOINC community, the Chinese Team called “Equn Team China.” This suggests that there are diverse community organizations within BOINC, although they share the same purposes (community-led gamification, project performance and VC promotion).

Thanks to the EU Citizen Cyberlab project, we were able to explore participation dynamics within the AF community from February 2013 to January 2014. We conducted 10 individual interviews with active members recruited through the forum. The interviews focused on four topics: motivation to volunteer, modes of participation in BOINC and AF community, learning, and creativity. Whenever possible, these were run as contextual interviews (i.e. at the home of the volunteer, in his/her usual VC environment). We also observed online community interactions, i.e. on the forum. With support of volunteer community managers, we designed and administered a survey on engagement and learning among all members of the AF through the forum in Oct and Nov 2013. The survey was completed by 147 members. The findings were analysed and a summary shared with the community in January 2014, and commented by members in the forum. Presented below are the main findings of this research regarding engagement and learning.

3.2 Participation patterns in a VC community: the case of Alliance Francophone

3.2.1 Overview of the VC population in Alliance Francophone

Our survey shows that gender distribution is principally male: 93% of the respondents are men. AF has a Gaussian distribution of age: 95% of the respondents are aged under 55, 2/3 of the population is between 26 and 45 years old, only 1% are aged under 18. From our comparative analysis of another BOINC team, Equn Team China⁵, we know that the age distribution could be very different (most Equn Team China participants are between 16 and 25 years old, most of them are students, and tend to “retire” from VC when they grow older and get a job, which is not the case for AF members). The question on occupation was left open (free text), and the analysis of the answers reveals the diversity of the professions among the respondents. Among

⁵ www.equn.com/forum

participants, 23% work in the field of computer science, but the rest of the answers provided a wide range of very diverse occupations. Another factor of heterogeneity of the community is the level of studies of the participants: 29% of the respondents stopped their studies at the baccalaureate level or earlier; 23% pursued studies for 2 years after the baccalaureate; 17% for 3-4 years after the baccalaureate; and 30% studied for 5 years or more after the baccalaureate. With exception of gender balance, this is an altogether highly heterogeneous community, confirming the spontaneous feeling of the participants whom we interviewed: *“Dans l’Alliance Francophone, on trouve de tout”* – “In Alliance Francophone, one finds all sorts of people” (AF community manager):

“A nice thing is that there are extremely different people who take part. people from all walks of life. There is this variety which makes a community interesting. There are really all sorts of people... There are young people, old people, bikers, cyclists, ecologists, people who are pro-nuclear... There are all sorts, it is very much alive.”
(BOINC AF Volunteer, Q1)⁶

“For me it was about sharing different things from what I am used to sharing with my usual group of people. It opens up other perspectives, and enables me to share the experience I have of BOINC and of BOINC technical problems.”
(BOINC AF Volunteer, Q2)

However, AF is very homogenous in terms of the level of interest expressed by respondents regarding the two dimensions that we investigated: interest in science (see figure 3 below, Estimated interest in science and competence level) and interest in computers (see figure 4 below, Estimated interest in computers and competence level), since both are high and are shared by participants.

Therefore, dialogue with others in the AF community seems to be facilitated by two strongly shared interests - computers, and science:

“Computing drove me into BOINC, and BOINC put me even more into computing.”
(BOINC AF Volunteer, Q3)

Another participant explains:

“It was my interest in computers which drove me to join, because I found out about SETI by chance, at the beginning. I discovered the original SETI project, which made it possible to make small calculations on your computer and to send them back, I thought it was great. For several years, I was not at all interested in communities, I did it really in a passive way. I thought it was pleasant, I checked to see if it worked well, and that it did

⁶ For the long quotes, original quotes in French are presented in Appendix 1.

not prevent my computer from working, I experimented on my own, but it did not go beyond that. After that, I stopped for two three years, I can't remember exactly. When I wanted to go back to SETI, I saw that they had joined BOINC. I saw that there was a lot of other stuff and I thought it was even better.” (BOINC AF Volunteer, Q4)

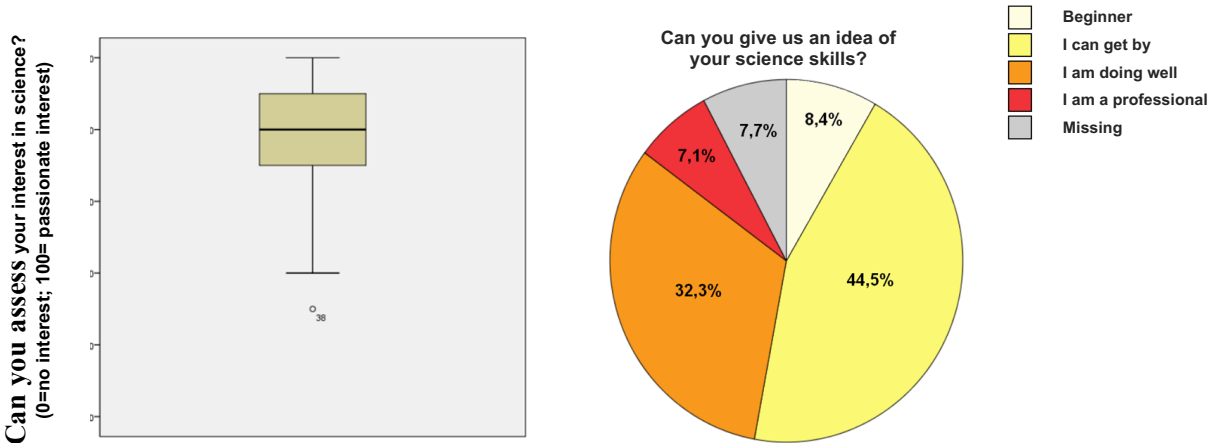


Figure 3: Estimated interest in science and competence level

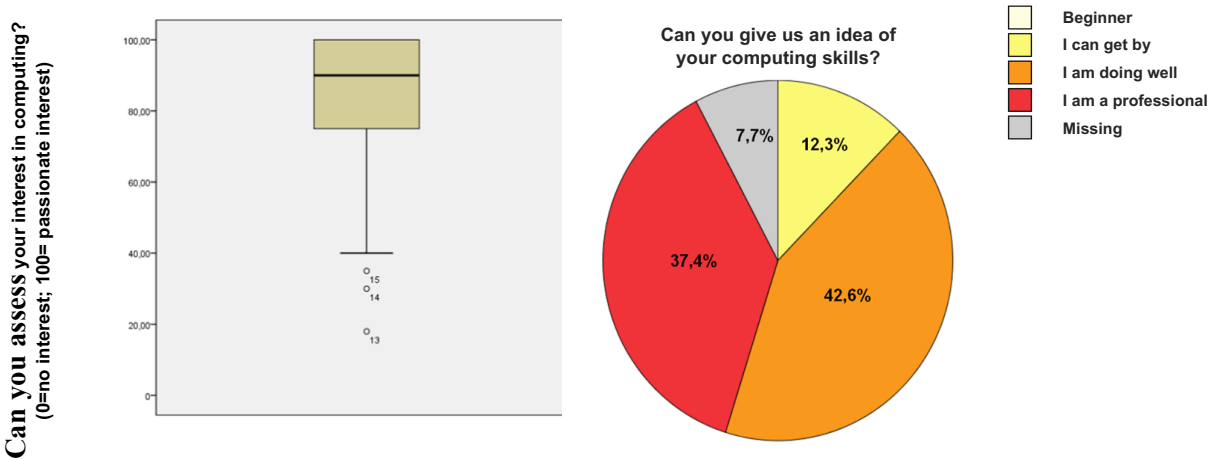


Figure 4: Estimated interest in computers and competence level

For some participants, BOINC seems to be a way of keeping in touch with a youthful passion for computing by deepening their understanding and practice of some of its aspects; for others, BOINC is a way of keeping up with fields of computing which are complementary to those

tackled in their professional lives. This is specific to VC, contrary to the strong interest in science expressed by volunteers, which is widespread in online Citizen Science. In VC, two passionate interests are combined: the passion for science and the passion for computing motivate volunteers to participate in VC projects (at least those volunteers who were present in the forum, in which the research was publicized, and decided to answer our survey or participate in our interviews), since it allows them to develop their knowledge of science as well as their knowledge of computers and the Internet.

3.2.2 *Engagement within a Volunteer Computing community*

Some surprises and remarkable results emerge from both our interviews and survey within the community. First of all, the volunteers who answered our questions say that they invest a lot of time in VC each week: almost 20% of respondents evaluate that their participation in AF and VC (which are usually identified as the same activity) involve more than 10 hours per week; 40% of respondents say that they invest between 3 and 10 hours per week in AF/VC. In total, 60 % of the survey participants report investing a significant amount of time every week in VC. In addition, 50% of the respondents report visiting the forum every day – and an additional 20% at least once a week. Among the respondents, only 30% of participants are occasional visitors, participating irregularly or only in specific events. Although these results are clearly the side-effects of the self-selection bias induced by the survey towards the most engaged participants, they remain impressive.

The next question therefore is: What do these participants do practically every day for approximately one hour, bearing in mind the fact that VC seems to offer few opportunities for action and interaction? Taking inspiration from a number of researchers studying engagement in digital gaming (see for example Calleja, 2007; Nardi, 2010; Iaconides 2014), we suggest a distinction between an engagement in the project at the micro level (i.e., running the VC software on one's computer to contribute to scientific research) and an engagement at the macro level (i.e., participating in the life of the community). We hypothesize that the most active BOINC participants engage simultaneously at both levels. At the micro level, active participants closely monitor what their computer is doing (its functioning, its performance and the credits gained). They also spend time selecting and prioritizing the projects they wish to contribute to. For them, BOINC is not an opaque software running mysterious calculus in the back box of their computers. They drive and monitor this dynamic process through various tools. However, as their computer is doing much of the work, this supervision process leaves them time to engage in more social activities at the community level. How BOINC is running on one's computer also triggers problems and technical questions, which can be solved with the help of the community. In the case of BOINC communities, the micro and macro levels are intertwined, especially due to the competition enabled by the system of credits, and this is proving to be a powerful design feature. Interestingly, the programmers and scientists have designed the reward system with points, and they display the competition results and rankings by scientific projects, but most competitions are

organized and run by the community. In the case of AF (and possibly other major national communities which take part in the same competitions), the most active volunteers are designing and advertising the seasonal competitions, internal competitions or international competitions with other teams. The volunteers also select the BOINC projects for which crunching points should be counted, discuss with their project teams to ensure that the project can absorb this load, engage the community in the competition, send updates and encouragements to the community members, check the results of the different teams, write updates and comments on how the competition is running, publish the results, etc. This is a fascinating case of community-led gamification.

As highlighted by Holohan, the social ecosystem of VC is complex, including volunteers, scientists, computer programmers, system administrators, and the volunteers themselves, who “*are not a monolithic body: an intermediate layer between the people who are paid to work on the project (the scientists and programmers) and the unpaid volunteers is the “specialist” core of volunteers: the moderators, the beta testers, and the language volunteers*” (Holohan, 2013, p.7). From our observations and interviews, we can expand the list of expert volunteers’ activities performed in BOINC communities. The following have been observed in AF: **software development**, where people design software that facilitates monitoring of volunteer’s computer activity, or that improves the game system (for example, counting points between teams in a different, more rational, and therefore more enjoyable way), and beta-testers; **community management**, where people design and run team competitions, create and communicate about events in the team, get involved in developing new services and interfaces for the team, or act as moderators; **management of thematic groups**, who gather around shared topics of interests with like-minded members, for example on Open Source Computing; **communication and promotion**, where people create and share material to promote VC in their local communities and among the general public, search for new projects, study project documentation, compare and report back to the community about the really interesting projects etc. The following quote is a good example of this collaborative communication and promotion effort: “*Three members created documents to present BOINC in schools and universities. They have been documenting all the criticism that we face concerning security risks, increased wearing of computers, etc. These topics are regularly discussed in the forum, and we begin to have a lot of material to answer them.*” Other actions include **facilitation and FAQ**, including people coaching newcomers and answering their basic questions, software programmers answering these basic questions automatically, and people answering complex questions; and obviously, as also reported by Holohan (2013), translation, including summaries of new projects and project news for the community. Most of these activities are taken on by highly committed volunteers, who use their own expertise of the project to contribute to the community and develop useful tools and/or organise events. In AF, these expert volunteers are usually not acting on an isolated basis, but in a coordinated way, thanks to organizational structures: a structure of internal teams, of sub-groups

appointed to certain tasks, and management groups who manage the whole process. This organizational structure is supported and renewed thanks to the appointment of experienced members to these key roles. They rely a great deal on a few leading volunteers who dedicate time and energy to the development of the community – which is always under the threat of losing them, since by definition the work is voluntary.

Although these roles are critical for the life of the community, we should bear in mind the fact that they concern only a minority of volunteers. Among a self-appointed population of committed participants, 84% of the respondents had no formal or informal responsibility within the community, as presented in figure 5, Responsibilities in the community:

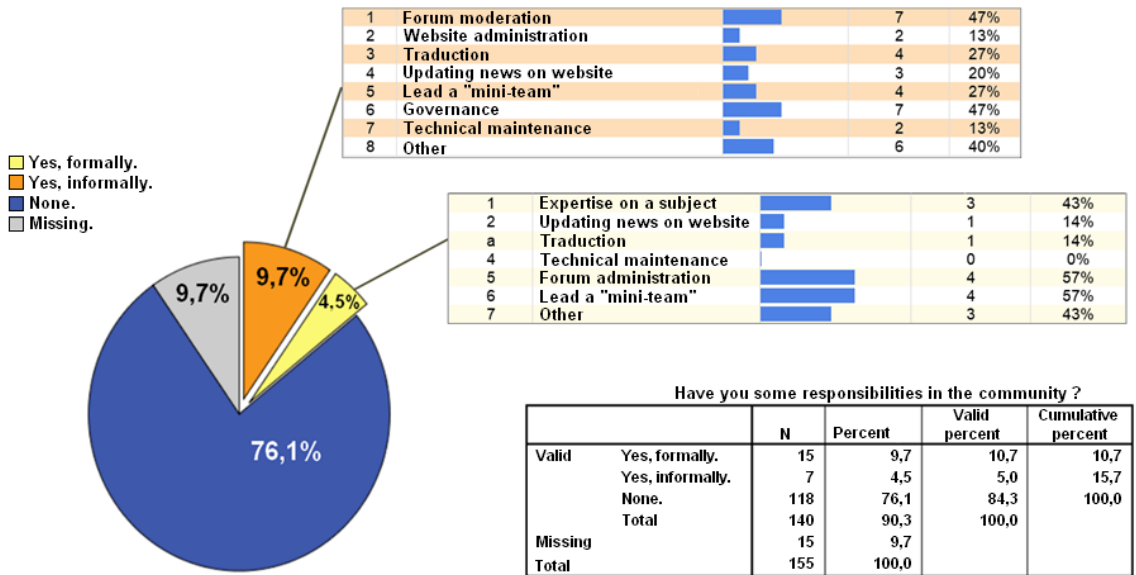


Figure 5: Responsibilities in the community

The responsibility of running the community is highly concentrated within the hands of a small group of volunteers, which is not unusual for online communities. The same result is reported in our larger ILICS survey (Schneider, DaCosta & Kloetzer, unpublished), which shows that less than 10% of the 900+ respondents were in charge of some community aspects in their various online citizen science projects. However, we hypothesize that engagement in a community plays a critical role in long-term participation in VC projects, via a transformation of the initial interests of the participants. The social dimension of participation in VC becomes a “good reason to continue to participate”, as reported in figure 6, what the AF community is bringing to its members:

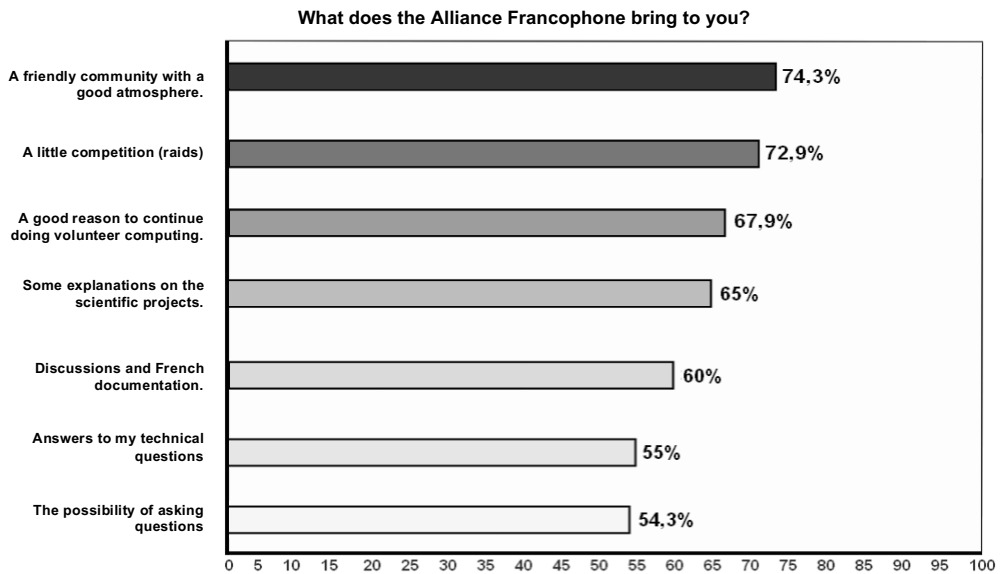


Figure 6: what the AF community is bringing to its members

As commented by one participant in an interview:

“When I started on SETI, I was not interested in the community dimension. It was really the subject itself, even though I kind of stopped. The community dimension, via the forum, also allows you to see other people, other approaches. It expands your group of “friends” somewhat. But I perceived it that way later, at the beginning you do this especially for the points, you see the piggy bank fill up, but at some point, when you get too rich, you don't know why you're rich, you can't see things any more... It requires looking at things differently and sharing, let's say that's my personal approach, to be more aware of people. Hence my involvement with the community, the forum etc.” (BOINC AF Volunteer, Q5)

3.3 Learning outcomes and processes in a VC community

“Learning refers to the act, process, or experience of gaining knowledge, skills, and attitudes, and as such, learning is inherent to all human life. People learn by doing, by exploring, by listening, by reading books, by studying examples, by being rewarded, by discovering, by making and testing predictions, by trial-and-error, by teaching, by abstracting away from concrete experiences, by observing others, by solving problems, by analysing information, by repetition, by questioning, by paraphrasing information, by discussing, by seeing analogies, by making notes, and so forth and so forth. Learning is an extremely broad concept and this makes it hard to answer the question of what the main factors influencing learning are.” (Van Merriënboer & Bruin, 2014). For all forms of volunteer activities, free choice and self-determined learning, as

well as informal and incidental learning occurring through participation in a project, are extremely difficult to document and study, as the outcomes of participation to these activities are difficult to disentangle from the various learning outcomes of the whole life activity of these volunteers, as suggested by the quote above. However, in the interviews conducted for the research and in the survey, volunteers attribute specific learning outcomes to their participation in VC activities. These learning outcomes are complex, since they occur for different people in different ways, are different for different people, and are often un-structured and social.

3.3.1 *General motivation to learn and impression of having learned something among VC volunteers*

As a general introductory comment, learning was reported as a motivation to join for only 1/3 of the volunteers in the AF survey. This is consistent with what we heard in the interviews. However, participants report observing learning outcomes for themselves and for their fellow members although they didn't initially consider learning as a goal. One participant says: *"Learning was not a priority for me. It happens but I don't do it for that purpose."* Another answers: *"I didn't realise what the opportunities would be when I joined. But it is something that has happened as a result of taking part."* Another one reports: *"In the beginning I don't think so. But it sure has become a learning experience."* (AF members)

Engaged participants (as the ones whom we interviewed or surveyed) consistently comment on their BOINC experience as being a learning experience. Almost 80% of participants in the BOINC survey report that they have learned "a few things or a lot of things" about science by doing VC. This percentage is 65% and 45% respectively for computing and social skills.

These findings from the survey are echoed in the interviews. Learning is reported, however, since learning happens over time and in a fragmented manner, it remains difficult to explain:

"It's not easy to express ... How to put it? You learn stuff, you develop computer skills that you may not have had before, you help others, whereas normally you would perhaps not have done so, you're going to talk easily with others whereas in real life you might not do that either... There are plenty of things... But since it has been for years ago now, it's very difficult to explain..."
(BOINC AF Volunteer, Q6)

So, whether or not participants expect it, learning occurs as a result of engagement in online citizen science projects. Is it possible to identify more precisely what is being learned in this context, and how?

3.3.2 Detailed accounts of learning experiences among VC volunteers

Our interviews investigated motivation to participate, participation modes, learning outcomes and processes, and creativity in online citizen science⁷. The questions on learning were formulated around two main subtopics: learning outcomes and learning processes, as experienced by the participant. In the analysis, regarding the BOINC Alliance Francophone volunteers, four main fields for learning were identified from our interviews: (a) computer and Internet literacy; (b) scientific knowledge and literacy; (c) communication: English and social learning; (d) personal development.

(a) Computer and Internet literacy

In the field of computing, BOINC may be a way for some participants to learn about and follow the latest IT developments (performance monitoring, virtual machines, graphics cards, etc.):

“I was already good with computers before. I have a good level in IT, I programme myself. So... It (BOINC) taught me a lot ... It is software, but it taught me how to resolve some issues... For example when the GPU arrived... It forces me to follow new developments in IT. I always liked it, ever since I was in secondary school, now there are times when one has other things to do, and one loses touch with the staggering evolution of IT, but it forces me to keep informed of the latest models, what is changing, now GPUs have taken over from CPUs, this obliges me to keep up with things. In programming too because I'm on Windows, everything is automatic. We can tinker, there are some special files that I enjoyed making myself, there is one that I made for a project to try to make more units at a time. In this case I tried and failed to do it on Einstein (the Einstein@home project). It allows me to keep up to date, to follow the technological evolution of computers.”
(BOINC AF Volunteer, Q7)

Many technical problems arise, versions of the software get regularly updated, volunteers try to monitor and optimize what is happening on their computers, and they may face security or computing power issues: all these issues result in participants progressing technically and seeking help in forums. Some participants say that they learned how to use their computer correctly and how to write in HTML thanks to BOINC:

“Lots of people are reluctant to install on their computer software that runs automatically. One is not very active at the beginning. At least this was my concern. I checked about what others experienced on the forums, if some had had problems with it

⁷ The complete interview guide, which was used for a number of online citizen science projects, is available in Appendix 2 and was developed by Charlene Jennett and Laure Kloetzer. However, the BOINC interviews were mostly conducted in everyday settings (homes of the participants or public places), covered these topics as well as topics introduced by the participants themselves, in order to gain the best possible understanding of their experience in volunteer computing.

afterwards. I was a real beginner in computers. I had to learn about computers... Thanks to this system, I learned how to use my computer correctly.”

(BOINC AF Volunteer, Q8)

Some participants report that the ways they use their computer changed as a result of their participation in BOINC as part of the AF community: for example, they took the steps of changing to an open operating system thanks to AF support. AF serves as a community of interest, of passionate interest even, where people help each other and are a technical resource to address problems posed by BOINC or other technical problems. Participants learn whatever their initial IT level may be.

Volunteers also appear to be gaining some very interesting knowledge and skills in the field of web literacy. Let us consider the Web Literacy Standards as defined by the open-source Mozilla community (see figure 7, Mozilla's Web Literacy Standards):

Web Literacy Standard Version: RFC (July 2013)

Exploring <small>Navigating the Web</small>	Building <small>Creating for the Web</small>	Connecting <small>Participating on the Web</small>
Navigation	Composing for the Web	Sharing and Collaborating
Web Mechanics	Remixing	Community Participation
Search	HTML	Privacy
Credibility	CSS	Open Practices
Security	Design & Accessibility	
	Coding / Scripting	
	Infrastructure	

mozilla
<http://mzl.la/weblitstd>

Figure 6: Mozilla's Web Literacy Standards (July, 2013 version)

Volunteers may learn at the *Exploring level: Navigating the Internet*, by intense Internet critical search practices (therefore improving their skills in the Search, Navigation and Credibility dimensions). The people in charge of updating project or community content on the web may also gain some *Building skills*, especially in Composing for the web, HTML programming, CSS (Cascading Style Sheets) and Design and Accessibility. People participating in online communities or collaborative content creation, or managing online communities, may finally

become more proficient at *Participating on the Web*, especially at sharing and collaborating and community participation.

These computer and Internet literacy skills are partly transferable. Therefore, such skills do not appear to be too “specialized” or “of no use.” One AF participant is considering changing job, from his former position to becoming an HTML developer, thanks to all the practical things he has been learning by facilitating the AF VC community for years:

“Step by step I learned how to post links and the whole HTML language, which I know quite well now, without taking courses. The other members helped me a lot. We help each other, sometimes we discover things together. We created a sandbox to practise, where we have been trying to design tabs. We have been learning the writing codes all together.”
(BOINC AF Volunteer, Q9)

(b) Scientific knowledge and literacy

In this additional Internet search process, participants learn a lot about topics which are directly related to the scientific focus of the project.

First of all, this scientific literacy is related to a general scientific culture: it is all about gaining a better understanding of what science does and how scientists work, which research questions they ask themselves and how they try to answer them. Talking about their experience in VC, participants say:

“If the researchers give feedback to the volunteers on what they do, try to explain what they do, I think all this can improve the general scientific culture. Show citizens that science is useful. When they watch TV, they constantly hear about scientific disasters. These projects enable us to go beyond this vision of catastrophic science.”

(BOINC AF Volunteer, Q10)

“It transforms the short term vision. Through experimenting with citizen science projects, people understand that science takes time and may have different goals. Science is not only a financial statement to be presented at the end of the quarter or the year. There is a long-term outlook.”
(BOINC AF Volunteer, Q11)

Direct experience with scientific projects and data may enable a large number of people to transform their views on science and better understand some of its specificities. The main things they learn are related to the scientific process and norms per se. The most important lesson learned, maybe, is that science takes time. This comment was repeated by a number of our participants. The scientific time of data collection and analysis, cross-checking, writing, and peer-review, is something new for most participants, and differs greatly from what they are used to in their professional life. Their initial expectations of obtaining quick results turn into a more

thorough understanding of the patience required to build scientific knowledge. The second lesson learned concerning scientific work is the fact that failure is normal and contributes to exploration. Participants contribute to exploring dead ends before sometimes finding interesting data and results. The third discovery is that science uses rigorous procedures and protocols, and relies, in particular, on independent and repeated measurements.

Besides reporting a better understanding of the process, when answering the question on what they thought they had learned thanks to the project, participants also reported they had expanded their scientific knowledge:

“Scientifically, it helped me discover new aspects of science, especially with space or medicine projects.”
(BOINC AF Volunteer)

“If you had told me about protein folding ten years ago, I would have told you: what is this silly thing?”
(BOINC AF Volunteer)

“When you are interested in a project for some reason, you find time to read about it”
(BOINC AF Volunteer)

These effects can be appreciated by, for example, looking at how access to popular scientific publications has changed for volunteers: *“I truly became much more open-minded. Today when I read a scientific magazine, it is very gratifying to understand all the text without having to check half of the words!”*

Knowledge is gained not just from participating at the micro level (crunching), but also at the macro level: participants are motivated to find out more about related topics through consulting external resources, such as the Internet, books, or the forum. The project provides not only the context and the motivation (e.g. for solving the task) to do so, but also basic tools such as keywords, concepts or references, which serve as points of entry to the topic. One participant observes: *“you can tell they have read the book because of their involvement in the project and not the other way around.”* Experience at the micro-level may provide the incentives for actively seeking more structured knowledge beyond the requirements of the project.

(c) Communication: English and social skills

One participant comments:

“On the human plane also, I think that it has been an experience, especially since I joined the forum, to open myself to other people, it also brought me things on the scientific plane, it forced me to look at other things. For example, on the forum, there is a medical section. Everything is published in English, but obviously on the forum everything must be translated into French, I am one of the translators, and I am learning things, because one has to check on Google for biology terms, check what the best

translation is. Looking for this information helps avoid translation errors. So it brought me all these things... via the forum, the fact of communicating with other people, of extending my circle of friends.”
(BOINC AF Volunteer, Q12)

The improvement in the English of volunteers is linked to the fact that most VC projects are presented in English. For non-English speakers, this is a major barrier, which prevents them from participating in most projects. However, for some participants who speak English well enough to be able to participate, the project provides opportunities for improvement both through reading documents in English and through interactions with the project community. Moreover, language barriers of their peers may even provide incentives for translating critical pieces of documentation on the project, tutorials, questions, or news. One participant explains that he got better thanks to this translation activity: *“Being able to help by translating texts makes it possible to understand better.”* Another one states: *“I have improved a lot in the last 5 years!”*

But even in French, volunteers learn communication skills by using the discussion tools provided by the community, especially the forum. Through peer-guidance, volunteers get a chance to learn the right way to ask questions, write answers, and initiate and contribute to discussions. In this regard the AF community provides structured ways to become familiar with communication tools which are widely available on the Internet. Some projects also offer Wikis, which might introduce people to using this kind of collaborative software, but we have not witnessed such cases in the interviews we have conducted so far.

Last, but not least, BOINC triggers volunteer-driven communities and therefore opportunities for engaged volunteers to obtain hands on experience in the management of a large, influential and diverse community that they would normally not have been able to create on their own. Such communities are involved in real-life scientific projects, with hundreds of participants, from very diverse professional backgrounds and age groups (from students to retired people). Community management activities observed in our data set involves, among others: keeping people engaged, organizing events, internal and external competitions, making decisions, operating technical platforms, creating and facilitating teams, dealing with inappropriate or rude comments, and organizing the life and sustainability of the community. Volunteers may be simple contributors, or assume different roles to support the community. As reported earlier, these roles provide opportunities for experimentation and learning.

(d) Personal development

As a result of their engagement, some VC participants report important outcomes at a personal level. These outcomes are related to identity changes for the participants. They concern only very engaged participants, and cover increasing one's self-confidence based on successful performance in the project, expanding one's interests, by discovering new topics of interests relating to science

or to community activities, extending one's social network, assuming new roles in a science-based community, and performing creative activities. In this paper we will develop the first three topics.

Improved self-confidence regarding one's contribution to science and interest for science

The main outcome of VC participation may be the positive experience that people, even without formal scientific training, may gain from contributing effectively to a real scientific project, if they experience their contribution as being valuable and valued. This contrasts with an understanding of science as a closed world, full of technical barriers. This is an important benefit, which might surpass other learning outcomes, and in which the support of the community plays a critical role. Volunteers may gain more confidence, for example, in their ability to translate short scientific texts from English into their mother tongue. Commenting on his current activity as a translator for the community in the BOINC AF community, a participant remembers his beginnings: *"I told myself I can't do it, I didn't dare try."* Learning also includes a meta dimension, which has to do with becoming competent in a field and realising this, something which often happens through the discovery that one is able to help others. This is another virtuous circle: the community helps people to become more competent, enabling them to help newcomers and at the same time to realise they are learning which in turn makes them more confident in the performance of their task and encourages them to assume new roles in the community. A participant in VC reports:

"I don't want to be too self-critical but we might suffer a bit from exclusion because of our passion... Science... It is not easy to share. Especially for novices. We are not experts. We are eager to understand, but we don't have the right training. These BOINC projects help us gain this knowledge(...) And then we try to make things understandable on the forum for a 10-year-old. I thought if my daughter visits this forum, she should get the essence of it without having to ask, "what does this mean Daddy?" or having to ask her teacher!"
(BOINC AF Volunteer, Q13)

"I have been passionate about science ever since I was a small boy. But I did not have the means to practise it."
(BOINC AF Volunteer)

Extending one's scientific interests

Participation is reported to be a way to "open one's mind":

"It opens up your world and your mind. It allows you to be able to get different perspectives on something you may not have understood or known about before, or even things in your everyday life, it can help you see things differently. It takes you on different

paths, it encourages you to engage in new experiences in your everyday life that otherwise you wouldn't have considered." (BOINC AF Volunteer, Q14)

On a scientific level, engagement in a citizen science project seems to be driven by interest in a specific topic, but it offers opportunities for expanding these initial interests: *"It has given me a new interest, something I wouldn't have gained otherwise."*

Extending one's social network

To the question, "Would you say that some people on the forum are friends?" the most engaged volunteers generally answered yes: *"Almost. They are in the process of becoming friends. I have been here for only two years, but there are people here I would like to meet, and I am sure we would become friends. In the forum, in the admin zone, I talk like I would talk to friends, and they do the same."* Friendship is a by-product of active involvement at the macro level, of shared responsibilities in community activities. Volunteers with close links come to communicate not only publicly or semi-publicly via the project communication tools (forum), but also in private via a variety of one-to-one media: phone, Skype, chat, Instant Messaging, email, face-to-face.

Sometimes, groups of people who are active online decide to meet in real life, usually for special, public or private, events. A large scientific society meeting may serve as a meeting point: volunteers will join and held a parallel social track, for example meet in a pub to socialize around the project. A subgroup may also organize a private meeting on a specific topic (for example, Open Source Development). The most common experience in such cases is a feeling of excitement and relief: excitement (and sometimes a bit of fear) at the prospect of meeting these online friends at last; and relief, when they experience the same familiarity and the same easy-going relationship in a face-to-face meeting as they do in their online interactions. Online pseudonyms are used equally with real names at such meetings.

3.3.3 Quantitative analyses of learning outcomes and processes in a Volunteer Computing community

For our AF survey, we received 140 full answers. We cannot give a precise response rate, as the exact number of visitors of the forum is unknown, but we can estimate that around 5% of the 3000 regular visitors answered this survey. Of course, this creates a double self-selection bias: our promotion method means that only the volunteers linked to AF community could answer (therefore, we call it an AF survey and not a BOINC survey); and among those AF members, the most engaged volunteers would probably be more motivated to invest time in answering the rather long survey. The following results should be read with this double bias in mind.

In the survey, the participants' perceptions of the principal learning outcomes were measured by nine questions. A Principal Component Analysis was conducted on this set of questions. The results confirm our qualitative analysis.

Variables measuring participants' perceptions of what they learn most can be reduced to three dimensions of learning, explaining over 68% of the variance (see Appendix 3, tab 1a and 1b):

- Factor 1 describes **learning about social aspects and communication tools** (learning how to use forums, interacting with people, and extending one's network).
- Factor 2 describes **learning about science and current trends in research**. Interestingly the same factor also includes "extend my interests."
- Factor 3 describes **learning how to use the computer** and being in touch with the latest developments.

In the survey, the participants' perceptions of the main learning processes were measured by nine questions. A Principal Component Analysis was also conducted on this set of questions.

Variables measuring participants' perception of how they learn most can be reduced to four dimensions explaining 61% of the variance (see Appendix 3, tab 2a and 2b):

- Factor 1 defines a **social dimension of learning: exchanging with members and researchers**. Perception that one learns most is strongly correlated with various forms of active contributions in discussions.
- Factor 2 defines a **self-exploratory dimension of learning: searching for information and reading mostly on the Internet**.
- Factor 3 defines a **learning-by-doing dimension** (experimenting with BOINC is the main learning process).
- Factor 4 defines a **"lurker" dimension of learning**, defined by using the information provided by the community and reading the forum, but with limited contributions.

Thanks to a hierarchical cluster analysis using squared Euclidian distance, we identified five types of participants that we label (in order of numerical importance): "silent readers", "actives", "conversation folks", "sharers/producers" and "experts." Not surprisingly, most participants (3/4) fall in the category "silent readers." However, that does not mean that those participants never ask questions. It only means that they claim to learn most from reading in the forum, i.e. a social practice that is described in legitimate peripheral participation model (Lave & Wenger, 1991).

3.3.4 *Summary on learning outcomes and processes in a Volunteer Computing community*

We use the ILICS (Informal Learning in Citizen Science) model (Kloetzer et al., 2013, see figure 8 below) to structure learning outcomes and processes in VC as reported in our interviews and survey within AF.

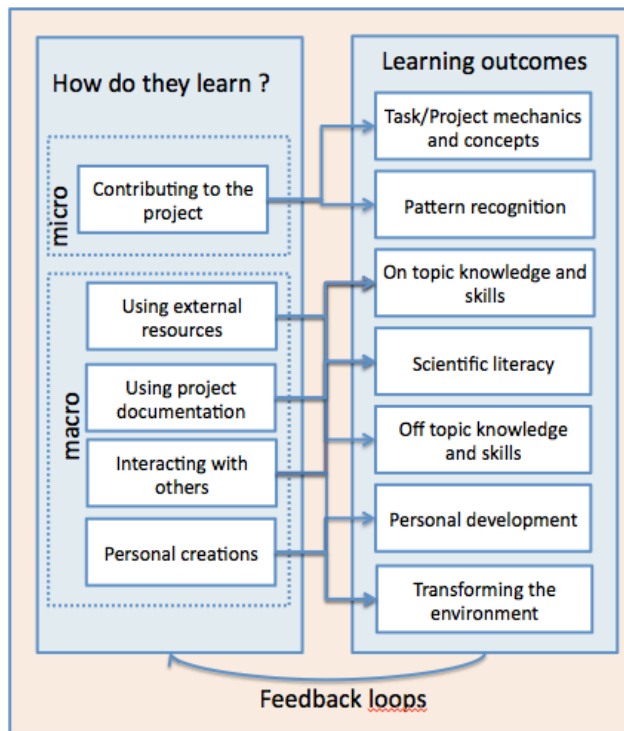


Figure 7: ILICS model: learning processes and learning outcomes in online Citizen Science (Kloetzer et al., 2013).

This model, which has been developed thanks to extensive empirical research within the Citizen Cyberlab project, suggests a range of potential learning outcomes that may be observed for some participants at least in online citizen science projects, and connects these learning outcomes with learning processes at the micro and macro levels. The learning outcomes reveal a large and somehow unexpected set of knowledge and skills: volunteers can, of course, learn about project and task mechanisms and concepts; but also about various additional skills acquired which may be divided into five categories: learning about the scientific domain of the project (on-topic knowledge and skills), learning about how science and research are conducted (scientific literacy), learning about various domains not related to the specific topic of the project (off-topic knowledge and skills) as well as personal development and political action. How people learn refers to the learning processes experienced by the volunteers in online citizen science projects: learning-by-doing (contributing to the task/project), interacting with others, using documentation (external or internal to the project), contributing through personal initiatives.

Crossing the dimensions of “what” and “how” they learn, we obtain this table for engaged VC volunteers:

How What	Contributing to the task/project	Interacting with others	Using external resources	Using project documentation	Personal creations
Task/project mechanics	Learn BOINC software, installation steps, practical concepts (crunching) and credit points	Overcome technical problems, improve performance	Overcome some technical problems	Overcome some technical problems	Add extra features, e.g. community-led gamification, create applications to monitor performance and calculate rewards. Create BOINC and AF tutorials and presentations...
On topic knowledge and skills	Apparently non relevant here	Share information on the scientific project, summaries, project news, and external links	Search the Internet via keywords from the project, watch talks by scientists, go to conferences and meetings	Read blogs, abstracts and scientific papers, watch talks by scientists from the project, understand main findings, trends and keywords of the field	Create glossaries and presentations of projects,
Scientific literacy	Understand the concept of distributed computing.	Understand that science takes time, understand the background of the project and the publication process	Understand the background of the project	Few opportunities for learning provided here	Co-authoring if available
Off topic knowledge and skills	Gain unexpected skills (for example, communication in English).	Take roles and engage in collective projects (software development, presentations, community management)	Read books and search Internet information to contribute to these collective projects	Few opportunities for learning provided here	Engage in collective projects (software development, presentations of the project or community management)
Personal development	Achieve high scores, be on the leaderboard. Make one's skill useful for a scientific project.	Become a community manager, moderator, leader. Get an identity as a super contributor or expert in the project.	Extend one's interests, gain new knowledge	Extend one's interests, gain new knowledge	Design for the project (software, algorithms, graphics, logos...). Can apply to other situations, e.g. a new job
Transforming the environment	Contribute to scientific progress and social change	Participate in local action groups	Few opportunities here	Few opportunities for learning provided here	Promote VC, or the project or the project topic.

Table 1: . Crossing learning outcomes types and learning processes types in VC.

Regarding VC, the first line on task and game mechanics is related to involvement in BOINC only at the micro-level (participating in the project). All the other outcomes require involvement at the macro level, especially by interacting with the additional resources provided by the researchers and participating in a BOINC community. Therefore, these communities, organized

and run by volunteers, play a critical role in providing opportunities for learning through participation in VC. For many reasons, communities play a vital role in the life of VC projects. If they disappeared, VC would be at risk of becoming exactly what it is still largely thought to be: a rather passive way of contributing to scientific research. With VC, participating in a community, and to an even greater extent, “being in charge” of certain aspects, appears to be a good way of increasing one's knowledge: performing additional work for the benefit of the whole community, discussing ideas with others, collectively looking for solutions, there are many opportunities for volunteers to learn.

4. COMPARING VOLUNTEER COMPUTING WITH VOLUNTEER THINKING PROJECTS: SOME PRELIMINARY FINDINGS FROM THE ILICS SURVEY

Our qualitative and quantitative research in a specific VC community, AF, has shown that participants may learn a lot through VC, mostly thanks to the technical and community aspects of this activity. How does VC compare however to other types of online citizen science projects? We can bring a preliminary analysis of this question thanks to our data from the ILICS (“Informal Learning in Citizen Science”) survey, conducted from August to October 2015. This long survey explored participation patterns and learning in online citizen science. It was sent to different online Citizen Science communities, including two VC projects and two VT projects (two Zooniverse projects, Planet Four and Plankton Portal). However, as Citizen Science volunteers usually participate in more than one project, the answers reflect their experience more largely through more than 60 distinct Citizen Science projects. Out of over 2500 respondents, 927 completed the full questionnaire. The global number of participants to which the survey was sent cannot be estimated reliably, as the survey was promoted openly in different communities. Therefore, we should assume a strong self-selection bias in the answers. Participants who are heavily engaged in online citizen science can be expected to be highly over-represented among the respondents. However, this is not a problem if we do not expect ILICS findings to represent learning in citizen science in general, but learning among highly engaged citizen scientists, who are key participants anyway in most citizen science projects, as well as if we consider internal comparisons between different participants. Following this latest line, and building on the now classical distinction between Volunteer Computing and Volunteer Thinking projects, we would like now to briefly conduct a comparison which is useful for putting our findings about VC so far in perspective: within the ILICS panel, we would like to compare VC and VT data regarding self-reported learning outcomes and processes.

For the analysis, we excluded all participants with a mixed profile (N=81), who had participated in other kinds of projects (N=14) and non-respondents on the projects they participated to (N=203). Of the remaining total of 606 participants, 256 were categorized as “VC” and 350 as “VT.”

If we look at the two direct questions that measure the impression of having learned something and the impression of having learned transferrable knowledge, we observe a weak relationship. VT participants have a slightly greater impression of having learned something than VC participants ($\text{Eta}=0.17$) and of having learned transferrable knowledge ($\text{Eta}=0.11$).

		How much do you feel you have learned from participating in a citizen science project?					
		1 Nothing at All	2 Very Little	3 Something	4 Quite a Bit	5 A lot	Total
(Project type)	1,00 Virtual Computing	7 3.0%	35 14.9%	108 46.0%	67 28.5%	18 7.7%	235 100.0%
	2,00 Virtual Thinking	1 0.3%	40 11.8%	118 34.7%	133 39.1%	48 14.1%	340 100.0%
Total		8 1.4%	75 13.0%	226 39.3%	200 34.8%	66 11.5%	575 100.0%

		Would you say that some of the things that you have learned could be useful in another context?					
		1 Not at all	2 Very little	3 Something	4 Quite a bit	5 A lot	Total
(Project type)	1,00 Virtual Computing	16 6.8%	108 45.8%	60 25.4%	43 18.2%	9 3.8%	236 100.0%
	2,00 Virtual Thinking	15 4.4%	126 37.0%	108 31.7%	63 18.5%	29 8.5%	341 100.0%
Total		31 5.4%	234 40.6%	168 29.1%	106 18.4%	38 6.6%	577 100.0%

Table 2: Types of citizen science projects and impression of having learned, impression of having learned transferable knowledge.

However, there is no difference between VC and VT with respect to stimulating new interests. If we analyze the responses to the question, “Could you say that a citizen science project helped you discover a new field of interest?”, Cramer’s V and the contingency coefficient are not significant.

Finally, we built a confidence scale from six questions regarding information literacy, use of technology and willingness to learn more, independent research, collaboration with other participants and with scientists:

```
COMPUTE ConfidenceGainScale = MEAN(confidence_AssessInformationQuality,
                                   confidence_TechnologyUse,
                                   confidence_MoreAboutComputerLearning,
                                   confidence_IndependantResearch,
                                   confidence_ParticipantCollaboration,
                                   confidence_ScientistCollaboration)
```

- 71 - Because of my participation in CS
[I feel more able to find relevant literature and assess the quality of information sources]
- 72 - Because of my participation in CS
[I am more confident in using technology]
- 73 - Because of my participation in CS
[I am willing to learn more about Computers]
- 74 - Because of my participation in CS
[I have improved my self-confidence and ability to do independent research]
- 75 - Because of my participation in CS
[I am collaborating with other participants on scientific matters]
- 76 - Because of my participation in CS
[I feel able to collaborate with scientists]

If we compare means of this confidence scale, we also can observe a very weak relation (Eta=0.115, Eta2=0.24, p=0.000)

Report

Gained confidence scale			
(Project type)	Mean	N	Std. Deviation
1,00 Virtual Computing	3.0757	235	.83468
2,00 Virtual Thinking	2.7825	340	.97763
Total	2.9024	575	.93236

Table 3: Comparisons of means for confidence scale.

These results corroborate results from the qualitative analysis. We cannot observe an interesting difference between VC and VT participants with respect to their perception of learning. We obtain similar results when we look at learning processes. With respect to “learning how” types computed with a cluster analysis, we cannot observe large differences between VC and VT participants (Cramer’s $V=0.154$, $p=0.037$). A large VT group (47.5%) favours learning through product documentation, whereas this group is smaller in VC (36.3%).

Project type * Learning-how types (rankings on learning-how items)

		Learning-how types (rankings on learning-how items)						Total
		1	2	3	4	5	6	
		Learns mostly by contributing to external resources	Learns by discussion and some other means	Learns by practising and some external documentation	Learns through other means	Learns mostly by practising and project documentation	Learns mostly through product documentation	
(Project type)	1,00 Virtual Computing	15 7.8%	25 13.0%	39 20.2%	11 5.7%	33 17.1%	70 36.3%	193 100.0%
	2,00 Virtual Thinking	13 4.3%	21 6.9%	52 17.2%	14 4.6%	59 19.5%	144 47.5%	303 100.0%
Total		28 5.6%	46 9.3%	91 18.3%	25 5.0%	92 18.5%	214 43.1%	496 100.0%

Table 4: Cross tabulation of Project type with a “learning how” typology.

Finally, and surprisingly, a larger part of VC participants in the survey population show higher engagement than VT participants (Cramer’s $V = 0.282$, $p=0.000$). The composite engagement scale was computed from the level of participation in projects, time spent per week, feeling part of a community and taking responsibilities, participation in events, and creation of products for the community. Again, these results confirm that VC participants are not less active than VT participants - and may even be more so.

Project type * Engagement in CS projects - Composite Index

		Engagement in CS projects - Composite Index			Total
		1.00 no or little engagement	2.00 normal engagement	3.00 high engagement	
(Project type)	1.00 Virtual Computing	42 16;4%	122 47.7%	92 35.9%	256 100.0%
	2.00 Virtual Thinking	112 32.1%	190 54.4%	47 13.5%	349 100.0%
Total		154 25.5%	312 51.6%	139 23.0%	605 100.0%

Table 5: Cross tabulation of Project type with Engagement in CS projects.

5. DISCUSSION

Our qualitative and quantitative analysis in the VC AF community, as well as the preliminary comparison of VC and VT in the larger ILICS survey, show that active participation may lead to various important learning outcomes. However, we estimate that these important learning outcomes occur for an active minority of the millions of participants who donate computer time to many Volunteer Computing projects worldwide. Our AF and ILICS surveys did not allow us to quantify which volunteers benefit from participating in these projects, since the respondents selected for the surveys were engaged volunteers. By definition, these surveys, which were shared in various BOINC forums, were not easily accessible for passive participants and we cannot assume that these passive participants would have been motivated enough to fill in the long questionnaires about their practices and what they had learned. All that we can say is that among the subset of participants who were engaged in these forums and who decided to answer our survey, these learning outcomes were widespread.

A 4-circle model might express the different participation engagements and related learning outcomes observed in the world of Volunteer Computing, as presented in figure 9 - a 4-circle model of engagement and learning for Volunteer Computing volunteers:

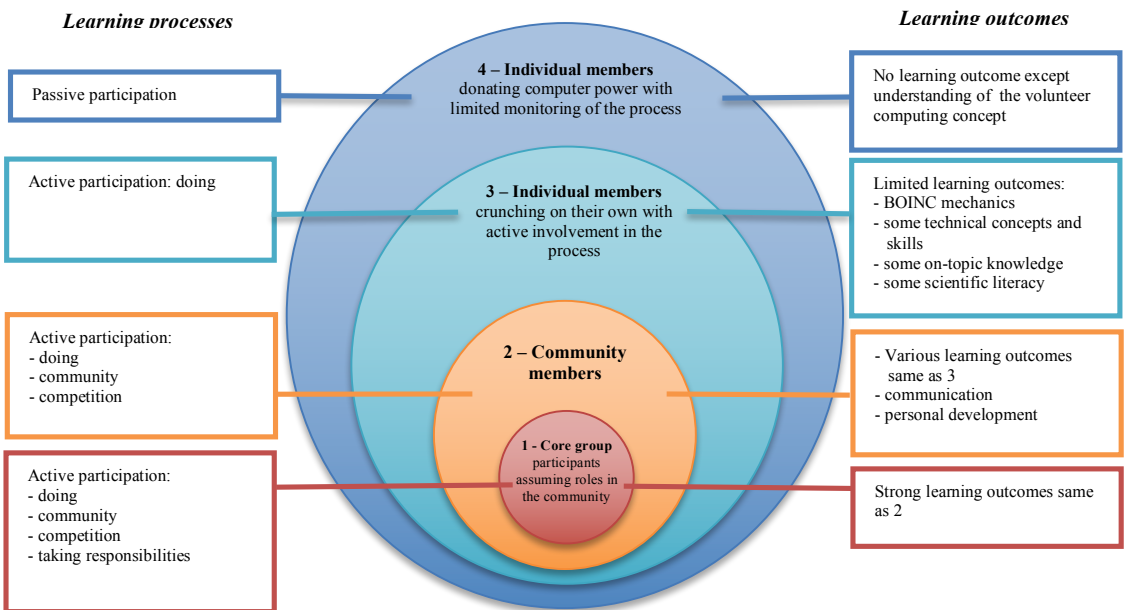


Figure 8: a 4-circles model of engagement and learning for Volunteer Computing volunteers.

Regarding circle 4, people may donate computer power because they wish to support science or a specific project without engaging personally, for example, by asking a friend or family member to install, run and control the software on their computer. In that case, Volunteer Computing is indeed passive, with few potential learning outcomes beyond the actual VC concept.

Regarding circle 3, people may participate in BOINC projects for the same reasons as those mentioned above, without engaging (and sometimes even without noticing) the existence of related communities; however, as they monitor actively the Volunteer Computing process on their computer(s), they will also learn about BOINC mechanics and key concepts, as well as some scientific content and processes related to different research projects. Some participants carefully select projects that they want to support and therefore look at their documentation in some depth. Technical problems may trigger learning by prompting additional searches on the Internet for example, but they might also discourage further participation as the volunteers lack the advice of others to overcome them. We might hypothesize that at this level, individual learning remains limited, as there are not echoed by the community.

Regarding circle 2, people remain active in the monitoring of their BOINC projects on their computers, and at the same time join a community of active participants. They may get answers to their technical questions, but also enter the dynamics of competition by community-led raids and challenges, and therefore their motivation for sustained participation is renewed. For them, the meaning of their activity might change from contributing firstly to support scientific projects to contributing because they enjoy participating in the life of the community. In addition, they enjoy a new learning experience as well as a change of identity. Potential learning outcomes here include scientific, computer and communication knowledge and skills, but also gains at the personal development level: increased confidence in one's own skills, larger network of contacts and friends who share the same passion, new interests, etc. Circle 2 distinguishes further between members of the community / members visiting the forum / members contributing to the forum (the later type representing only 2% of all registered members).

The strongest learning gains occur for circle 1, or "the core group". Circle 1 members are selected from participants in circle 2, whose engagement for the community becomes noticed after some time. Interestingly, participation in the core group is open to all highly engaged members, without any prior requests, except for participation: doing the crunching and participating in the community are the main selection criteria. Circle 1 participants take charge of various roles supporting the community life (organizing competitions, running mini-teams, moderating the forum, translating scientific texts and project presentations, etc.).

Participation in a citizen science project, including Volunteer Computing, is a dynamic process, in which volunteers may move from one circle to the other, and back, depending as much and even more on their professional and personal circumstances than on the life of the projects. Quantifying which group of volunteers belong to one circle or to another remains difficult. It

might be possible to evaluate this based on the figures from the BOINC project and the Alliance Francophone community (we estimate that fewer than 2% of all BOINC participants become active participants in a forum, and that fewer than 10% of these active participants ultimately become people in charge of managing the community, but this remains a very rough estimate). In our ILICS survey, half the volunteers reported learning something through Volunteer Computing, but active CS volunteers are overrepresented in our population. In our AF survey, more than 80% of the volunteers reported learning something, but the respondents are regular visitors of the AF forum (i.e., circle 2 volunteers).

6. CONCLUSION

The qualitative and quantitative research on VC, conducted with the help of the AF community, has demonstrated unexpected learning outcomes among engaged volunteers. These outcomes include increasing one's knowledge and skills in the fields of computer and Internet literacy, scientific knowledge and literacy, and communication, English language and social skills, as well as more personal outcomes, like extending one's interests and social network and increasing one's self-confidence in contributing to science or to a community. Most of the things learned are social skills, in the sense that they are not only learned through contributing to the project but through the social interactions involved. In this paper, we also highlighted the critical role that communities of volunteers play in making BOINC dynamic, and which is hugely based on community-led gamification. In the discussion, we estimated that learning outcomes through Volunteer Computing occur for a minority of volunteers, according to a 4-circle model of engagement. However, whether or not a participant experiences learning outcomes by participating in a Volunteer Computer project seems to be unpredictable based on demographics or level of education, and seems to be related mostly to the individual's active engagement in the project. This engagement is linked as much (and possibly even more so) to the personal and professional life circumstances of the participant at a given time as to the design of the project. The combination of community and competition aspects offered by BOINC projects seems to retain at least male participants who develop a lasting interest in science and computers, irrespective of their initial level of education. As demonstrated by our recent ILICS survey research (2015), all categories of participants undergo a learning experience, especially people with a lower level of education, which is an interesting finding for lifelong education policies. Altogether, VC projects engage volunteers emotionally, far beyond the simple use of their computer time and power, and may trigger informal learning. For a minority of very active volunteers, these projects become real "Windows of Opportunity", for making friends, gaining skills and benefiting from new experiences, which could not easily happen otherwise in their normal everyday environment.

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9. APPENDIX

9.1 Appendix 1. Original quotes in French

Q1. "Ce qui est sympa c'est que ce sont des gens extrêmement différents qui rentrent là-dedans. Tu as des gens de tous bords. Tu as cette variété qui rend une communauté intéressante. Il y a vraiment de tout : il y a des jeunes, il y a des vieux, il y a des motards, il y a des cyclistes, il y a des écolos, il y a des pro du nucléaire... Il y a de tout, c'est très vivant." (BOINC AF Volunteer)

Q2. "Pour moi il s'agissait de partager d'autres choses que ce que j'avais l'habitude de partager avec les personnes habituelles. C'est un peu une ouverture sur le monde, et partager l'expérience que j'ai de BOINC et des problèmes techniques". (BOINC AF Volunteer)

Q3. "C'est l'informatique qui m'a amené à BOINC, et BOINC qui m'a mis encore plus la tête dans l'informatique". (BOINC AF Volunteer)

Q4. "C'est vraiment l'affinité avec l'ordinateur qui m'a fait rentrer là-dedans, parce que j'ai découvert ça par pur hasard, c'était SETI au début. J'ai trouvé l'existence du projet SETI classique, qui permettait de faire des petits calculs sur ton ordinateur et de les renvoyer, j'ai trouvé ça super. Pendant plusieurs années je n'étais pas dans les communautés du tout, je faisais vraiment ça de manière passive. Je trouvais ça sympa de faire ça, je vérifiais que ça marchait bien, que ça n'empêchait pas mon ordi de bosser, j'expérimentais de mon côté mais ça n'allait pas au-delà. Après j'ai un peu arrêté, deux trois ans je sais plus. Puis j'ai voulu retourner dans SETI et je me suis rendu compte qu'ils étaient rentrés dans BOINC. J'ai vu qu'il y avait plein d'autres trucs et j'ai trouvé ça encore mieux." (BOINC AF Volunteer)

Q5. "Quand j'ai commencé sur SETI ce n'était pas l'aspect communauté qui m'intéressait le plus, c'était vraiment le sujet en lui-même, même si j'ai un peu arrêté. L'aspect communauté, via le forum, permet aussi de voir d'autres personnes, d'autres approches. Ça élargit un peu le groupe d'amis entre guillemets. Mais je l'ai vu comme ça un peu plus tardivement, au début on fait ça surtout pour les crédits, si on compare les crédits à des euros ou des dollars ou des francs suisses, donc on voit la tirelire monter, mais à un moment, quand on devient trop riche, on ne sait plus pourquoi on est riche, on ne voit plus les choses... Ça oblige à regarder un autre aspect des choses et plutôt à partager, disons que c'est mon approche personnelle, à regarder un peu plus les gens. D'où mon implication un peu plus dans la communauté, avec le forum etc." (BOINC AF Volunteer)

Q6. "C'est pas facile à exprimer... Comment dire ? T'apprends plein de trucs, t'acquières des compétences informatiques que tu n'avais peut-être pas, tu vas aider d'autres personnes alors qu'en temps normal tu ne le ferais peut-être pas, tu vas parler facilement avec d'autres personnes alors que dans la vie réelle tu ne le ferais pas non plus... Il y a plein plein de choses... En plus vu que ça fait des années maintenant c'est très difficile à expliquer..." (BOINC AF Volunteer)

Q7. « J'étais déjà pas trop mauvais avant. J'ai un bon niveau d'informatique, je fais des programmes moi-même. Donc... Ca m'a appris beaucoup... C'est un logiciel mais ça m'a appris à résoudre certains

problèmes.... Par exemple quand les GPU sont arrivées... Ca me force un petit peu on va dire à suivre toujours l'évolution de l'informatique. J'ai toujours aimé ça depuis que je suis au lycée, bon après il y a un moment dans la vie où on a autre chose à faire, on ne suit plus vraiment l'évolution faramineuse de l'informatique, et ça ça m'oblige à suivre quels sont les derniers modèles, quelle est l'évolution des GPU maintenant plutôt que des CPU, ça m'oblige un peu. En programmation pas trop parce que je suis sous Windows, tout est automatique. On peut bricoler, il y a des fichiers un peu spéciaux, ça je me suis amusé à les faire moi-même, il y en a un que j'ai fait pour un projet pour essayer de faire plus d'unités à la fois. Là j'ai essayé et échoué sur Einstein à le faire. Ca me permet de rester à peu près à jour, de suivre l'évolution technologique de l'informatique." (BOINC AF Volunteer)

Q8. "Encore aujourd'hui beaucoup de gens sont réfractaires, en tous cas inquiets, de mettre un logiciel sur leur ordinateur qui agit presque entièrement en automatique. On ne fait pas grand chose au départ. En tous cas c'était mon inquiétude. J'ai regardé les expériences, s'il y en avait qui avait des problèmes après avec. Et comme j'étais au tout début de mes connaissances informatiques, je ne savais pas encore qu'il n'y aurait pas de virus dessus, etc. Il fallait vraiment que je me lance dans le domaine de l'informatique. C'est grâce à ce système là que j'ai appris à bien utiliser mon ordinateur". (BOINC AF Volunteer)

Q9. "C'est surtout grâce au fait que je suis devenu administrateur du site, modérateur puis administrateur, où j'ai appris par exemple tous les raccourcis clavier que je n'utilisais pas, j'étais vraiment un noob en informatique, le débutant qui ne comprend rien ! Au fil du temps, j'ai appris à poster des liens, copier des URL, le langage de HTML que je connais super bien maintenant, sans avoir eu besoin de prendre des cours. Heureusement qu'il y avait les autres membres, on s'entraide, parfois on découvre des choses ensemble, c'est encore plus rigolo. On s'est fait un bac à sable d'ailleurs, invisible pour les membres mais visible pour les administrateurs et modérateurs." (BOINC AF Volunteer)

Q10. « Je défends la science citoyenne parce que je pense que c'est important au niveau global pour la société qu'elle se cultive pour pouvoir réagir quand on lui raconte n'importe quoi. (...) Je pense que tout ça peut améliorer leur culture scientifique et leur donner le goût de la science : ne pas voir que la bombe atomique qui détruit, le pétrole qui pollue les plages, voilà. Si on leur dit vous allez travailler par exemple pour l'énergie du futur, ils se diront "pourquoi pas ?". Je pense que les gens ne sont pas opposés à ce genre de choses. (...) Alors que quand ils regardent la télé ou les journaux, on leur montre plutôt les aspects de la science catastrophe. Que finalement le progrès scientifique ne donne que des catastrophes. C'est pour aller au delà de cette science catastrophe". (BOINC AF Volunteer)

Q11. "Et puis il y a la vision à court terme. Avec des projets CS, les gens peuvent comprendre que la science prend plus de temps et peut avoir d'autres finalités. Ce n'est pas simplement un bilan financier, au bout du trimestre ou de l'année. Il y a une vision à long terme". (BOINC AF Volunteer)

Q12. « Humainement aussi, je trouve que ça a été une expérience, surtout depuis que je suis sur le forum, de m'ouvrir à d'autres personnes, donc ça m'a apporté je dirais à la fois sur le plan scientifique, ça m'a obligé à aller voir un petit peu autre chose. Par exemple, sur le forum, il y a une section médecine. Tout est en anglais mais évidemment sur le forum ça doit être mis en français, je suis un des traducteurs, et là j'apprends des choses parce que ça peut être en biologie, là il faut aller voir sur Google un petit peu se renseigner pour voir quelle est la traduction la plus adaptée. Aller chercher ces informations aide à éviter de faire des non sens dans la traduction. Donc voilà ça m'a apporté un peu tout ça via le forum, une

communication avec d'autres personnes, un élargissement du cercle de connaissances.» (BOINC AF Volunteer)

Q13. "Je ne sais pas comment exprimer ça... Je ne veux pas nous dénigrer, mais on avait peut-être un peu d'exclusion du fait de notre passion. Les sciences.... ce n'est pas toujours simple de trouver des gens avec qui parler de ça. Surtout qu'en comme nous on est novices. On n'est pas des experts. On a envie de savoir, mais on n'a pas le bagage qui va avec. C'est vrai que grâce aux projets scientifiques de Boinc ça nous permet d'acquérir ce bagage. (...) Pour moi, je ne parle pas pour tout le monde, mais je pense qu'il y en a une bonne partie aussi qui pensent comme ça, on essaie sur le forum de le rendre lisible même pour un enfant de 10 ans. En tous cas c'est l'idée que j'en ai eu en le découvrant. Je me suis dit, c'est bien, ça veut dire que si ma grande fille vient là et qu'elle veut lire l'article pour savoir de quoi on parle, elle va au moins pouvoir comprendre l'essentiel sans devoir toujours dire papa c'est quoi c'est quoi ou demander à sa maîtresse." (BOINC AF Volunteer)

9.2 Appendix 2. Volunteer Interview Script

Background

- *Can you tell me a bit about your background?*
- *What do you do?*
- *What are your interests?*
- *How did you hear about [project name]?*
- *Why did you decide to take part in [project name]?*

Usage

- *How long have you been taking part now?*
- *Are you participating only in [project name]? Or are there any others that you participating in at the same time?*
- *How does [project name] fit in with your day-to-day life?*
- *When are you most likely to do it?*
- *How much time do you spend doing it?*
- *What do you do within that time?*
- *How do you feel when you are doing it?*
- *At what point do you decide to stop and leave the rest for another day?*
- *How would you describe your level of contributions compared to other people? (e.g. do you think you contribute more or less?)*
- *Why do you think this is?*

Forums

- *Do you also contribute to the online forums?*
- *If yes, how often?*
- *Why do you take part in the online forums? Why do you find them useful/ not useful?*
- *Do you post content, read content or manage content? Why or why not?*
- *Are there particular topics you take part in more than others?*
- *Do you make suggestions in how to improve the site?*
- *If no, do you still look at them and feel you gain any benefits from them*
- *Do you find them easy to use?*
- *Have you made any friends through the forums?*
- *What do you think could be done to improve the online forums?*

Motivations

- *Do you feel motivated to take part regularly?*
- *Why do you feel motivated/not motivated?*
- *Why do you think most people volunteer to take part in [project name]?*
- *Why do you think some people take part for a long period of time (several months), and others only take part for a short period of time (several days)? What factors could be involved?*
- *Have you any ideas how [project name] could attract more volunteers? And maintain the interests of volunteers they initially attract?*

Gamification

- *There are some projects that use game mechanisms to try to incentivise people to participate more. For example, scoreboards to show volunteers that do the most work, badges where you are promoted to a higher 'status' if you do more work. Does [project name] use anything like this?*
- *What do you think is good / bad about using incentives like this? How can these incentives be improved?*

Community

- *There are some projects that have social aspects to encourage a community. For example, blogs and forums. Does [project name] use anything like this to promote a community?*
- *What are the characteristics of the [project name] community? Why do you think some people more active in the community than others?*
- *Have you made any friends through the [project] site? Have you ever met any of the other volunteers off-line (in person)?*
- *How do you think the social tools of [project name] can be improved?*

Working with Researchers

- *How do researchers' feedback the results and progress of the project to the volunteers?*
- *e.g. blog posts, videos, forums, papers, meetings, online meetings, training sessions..*
- *Which of these do you like best?*
- *How do you think collaboration between researchers and volunteers could be improved?*

Learning

- *Do you feel you are learning something (anything at all, to allow for incidental learning) through your participation in [project name]? What would you say that you are learning?*
- *How are you learning...?*
 - *thanks to communications of scientists*
 - *blogs,*
 - *videos*
 - *papers*
 - *training sessions*
 - *other ?*
 - *through exchanges with peers*
 - *in forums*
 - *in a team*
 - *other ?*
 - *through gaming*
 - *tutorial*
 - *feedback from the system: which kind of feedback ?*
 - *other ?*
 - *thanks to your own investigation*
 - *additional searches on the Internet*
 - *other ?*
 - *thanks to the project network*
 - *new opportunities of participation*
 - *interpersonal exchanges*
 - *other ?*
- *Can you tell us about examples of learning (if any) which you have been experiencing or witnessing in [project name]?*
- *Would you say that learning is an objective for you in this [project name]?*
- *Is there something that you did that you wouldn't have done without [project name]?*
- *In your view, how learning be improved in [project name]?*

Creativity

- *What opportunities do you think [project name] offers for volunteers to be creative?*
- *Can you think of any examples where you have been creative? Or other volunteers have been creative?*

- *Can you think of any examples where you or other volunteers suggested idea/new features, which were then taken up by the researchers in the [project name] team?*

Citizen Science in general

- *What do you think are the benefits of citizen science to yourself and society? And what are the limitations?*
- *Have you been involved in any other citizen science projects besides [project name]?*
- *Which projects? Can you describe what you did in these projects? How do you think they compare to [project name]?*

9.3 Appendix 3. AF Survey

Rotated Component Matrix

Que diriez-vous avoir appris ?-	Component		
	1	2	3
Q25_1 J'ai appris des choses sur le fonctionnement de mon ordinateur	.283	.023	.721
Q25_2 -J'ai changé ma façon d'utiliser mon ordinateur	.171	.098	.752
Q25_3 Je me tiens au courant des dernières évolutions informatiques	.141	.120	.640
Q25_4 J'ai élargi mes centres d'intérêts scientifiques	.019	.775	.128
Q25_5 Je comprends mieux les enjeux actuels dans mes disciplines préférées	.107	.908	.059
Q25_6 Je comprends mieux la démarche et les méthodes scientifiques	.169	.788	.072
Q25_7 J'ai appris à utiliser les forums	.870	.006	.236
Q25_8 J'ai appris à échanger avec toutes sortes de gens	.897	.086	.253
Q25_9 J'ai élargi mon réseau social	.766	.298	.222

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.518	39.089	39.089	2.318	25.753	25.753
2	1.745	19.387	58.476	2.167	24.082	49.835
3	.911	10.117	68.593	1.688	18.758	68.593

Rotated Component Matrix

Comment avez-vous le plus appris ?-	Component			
	1	2	3	4
Q26_1 En lisant le forum	.218	-.020	.087	.738
Q26_2 -En posant des questions dans le forum	.337	-.671	.151	.179
Q26_3 Par des échanges interpersonnels avec les membres de l'Alliance Francophone	.721	-.083	.024	.152
Q26_4 -En expérimentant par moi-même pour faire tourner BOINC	.031	.043	.881	-.025
Q26_5 En allant chercher par moi-même sur Internet	.005	.742	.381	.228
Q26_6 En lisant les informations données par les scientifiques	.499	.498	-.440	-.052
Q26_7 -En échangeant avec les scientifiques	.461	.112	.303	-.241
Q26_8 -En faisant des traductions de sites, de projets ou d'articles scientifiques	.685	-.166	-.062	-.079
Q26_9 -En écrivant des synthèses pour la communauté	.292	-.040	.129	-.718

Extraction Method: Principal Component Analysis;

Rotation Method: Varimax with Kaiser Normalization.

Total Variance Explained

Component	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.738	19.307	19.307	1.698	18.870	18.87
2	1.307	14.526	33.833	1.300	14.442	33.31
3	1.247	13.854	47.687	1.257	13.964	47.27
4	1.198	13.313	61.000	1.235	13.725	61.00

Extraction Method: Principal Component Analysis.

How did you learn most ?	CLU5_2 Comment ont-ils appris le plus (5)					
	1 Actives	2 Silent readers	3 Sharers/-producers	4 Conversation folks	5 Experts	Total
	Mean	Mean	Mean	Mean	Mean	Mean
Q26_1 -En lisant le forum	1.00	.85	.50	.75	.50	.84
Q26_2 -En posant des questions dans le forum	.93	.17	.00	1.00	.50	.31
Q26_3 Par des échanges interpersonnels avec les membres de l'Alliance Francophone	1.00	.06	1.00	.00	.00	.18
Q26_4 -En expérimentant par moi-même pour faire tourner BOINC	.86	.61	.00	.25	1.00	.59
Q26_5 -En allant chercher par moi-même sur Internet	.86	.81	.00	.00	.00	.71
Q26_6 -En lisant les informations données par les scientifiques	.57	.36	.50	.08	1.00	.37
Q26_7 -En échangeant avec les scientifiques	.07	.01	.00	.00	.50	.02
Q26_8 -En faisant des traductions de sites, de projets ou d'articles scientifiques	.36	.03	.75	.25	.00	.10
Q26_9 -En écrivant des synthèses pour la communauté	.07	.03	.25	.00	1.00	.05

CLU5_2 How did they learn most clusters (5)

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid 1 Actives	14	9.5	10.0	10.0
Valid 2 Silent readers	108	73.5	77.1	87.1
Valid 3 Sharers/producers	4	2.7	2.9	90.0
Valid 4 Conversation folks	12	8.2	8.6	98.6
Valid 5 Experts	2	1.4	1.4	100.0
Total	140	95.2	100.0	
Missing System	7	4.8		
Total	147	100.0		