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Cell Spotting: educational and motivational outcomes of cell biology citizen science project in the classroom

Cândida G. Silva, António Monteiro, Caroline Manahl, Eduardo Lostal, Teresa Holocher-Ertl, Nazareno Andrade, Francisco Brasileiro, Paulo Gama Mota, Fermín Serrano Sanz, José A. Carrodeguas and Rui M. M. Brito

Abstract

Success stories of citizen science projects widely demonstrate the value of this open science paradigm and encourage organizations to shift towards new ways of doing research. While benefits for researchers are clear, outcomes for individuals participating in these projects are not easy to assess. The wide spectrum of volunteers collaborating in citizen science projects greatly contributes to the difficulty in the evaluation of the projects' outcomes. Given the strong links between many citizen science projects and education, in this work we present an experience with hundreds of students (aged 15–18) of two different countries who participate in a project on cell biology research — Cell Spotting — as part of their regular classroom activities. Apart from introducing the project and resources involved, we aim to provide an overview of the benefits of integrating citizen science in the context of formal science education and of what teachers and students may obtain from it. In this case, besides helping students to consolidate and apply theoretical concepts included in the school curriculum, some other types of informal learning have also been observed such as the feeling of playing a key role, which contributed to an increase of students' motivation.

Keywords

Citizen science, Informal learning, Science education

Introduction

In recent years, we have witnessed a growth of citizen science projects not only in number but also in scale and scope. Citizen science projects involve non-scientist citizens in scientific research projects by inviting them to collaborate in several different processes, steps, or activities of the scientific method, which may include choosing or defining questions for study, gathering information and resources, collecting and/or analysing data, interpreting data and drawing conclusions, disseminating conclusions, and discussing results and asking new questions [Bonney et al., 2009; Shirk et al., 2012]. Throughout the years, several reports have placed special attention on the understanding and assessment of the real impact of citizen science projects at the scientific, educational and motivational levels [Trumbull et al., 2000; Bonney et al., 2009; Kountoupes and Oberhauser, 2008;

Marshall and Kleine, 2012; Zoellick, Nelson and Schauffler, 2012; Raddick et al., 2013; Science Communication Unit, 2013; Edwards, 2014, and references therein]. The evaluation and assessment of the educational impact of citizen science projects raises particular interest because although many of these projects are envisioned and implemented in scenarios of informal science education, many times the young students are one of the preferential target groups with their engagement being promoted through schools [Zoellick, Nelson and Schauffler, 2012]. For teachers and students, the establishment of a school-scientist partnership is usually very attractive as it offers them the opportunity to be involved with an on-going scientific project and to work with real data [Falloon, 2013].

Socientize, acronym for "Society as e-Infrastructure through technology, innovation and creativity", was a project funded by the European Commission under the Seventh Framework Programme [Silva et al., 2014; Socientize, 2015]. The Socientize consortium has developed intensive activities along three major axes of action: (i) implementation of citizen science projects; (ii) dissemination activities with different target groups; and (iii) network activities with major stakeholders on citizen science worldwide, resulting in the publication of the White Paper on Citizen Science.[1]

Several web-based applications were developed to support scientific projects in the areas of molecular and cell biology and drug discovery (Cell Spotting[2]), linguistics and semantics (Mind Paths[3]), energy saving and sustainability (SavingEnergy@Home[4]) and astronomy (Sun4All[5]). In order to promote the engagement of society, Socientize developed many dissemination activities to specific target groups, such as students and teachers in school communities, citizens 50+ through universities for seniors and 50+ web platforms, patients associations, and other risk-of-exclusion groups such as prison inmates. To monitor the success of the activities developed and to assess their potential impact, a series of quantitative and qualitative evaluation activities were conducted to learn about the project impact and achievements.

Here, we focus on the evaluation of the educational and motivational outcomes of the Cell Spotting project reported by students and teachers from secondary schools in Portugal and Spain. The results shown are gathered from a combination of data collected from an online questionnaire about the Cell Spotting project available for all participants in the application (students, in this case), an online questionnaire directed to teachers, and a focus group discussion with teachers. Special emphasis is given to a better understanding of the drivers and barriers for teachers and students to contribute to citizen science projects as part of their regular classroom activities.

[1] http://socientize.eu/?q=eu/content/white-paper-citizen-science.
[2] http://cellspotting.socientize.eu.
[3] http://mindpaths.socientize.eu.
[4] http://savingenergy.socientize.eu.
[5] http://sun4all.socientize.eu.

The Cell Spotting project

Cell Spotting project has been developed in collaboration with the "Stem Cells and Apoptosis Group" from the Institute for Biocomputation and Physics of Complex Systems (BIFI) of the University of Zaragoza (Spain). Cell Spotting involves volunteers in the search of new treatments for cancer [Lostal et al., 2013a; Lostal et al., 2013b]. The main objective of the Cell Spotting project is to identify small chemical compounds capable of selectively inducing cancer cells' death. Volunteers are invited to participate by observing and analysing thousands of images of cancer cells under the treatment of potential drugs obtained by fluorescence microscopy over time. The analysis of the cancer cells images consists of the collection of several parameters such as cell status, cell content release, mitochondria distribution or nucleus' shape.

From the researchers' point of view, the development of the citizen science application Cell Spotting allows them to tackle two distinct problems. First, citizens' participation in the analysis of these large data sets provides an amount of analysed results that would otherwise be prohibitively expensive to obtain. Second, the results compiled will enable the creation of a large training set that can be used for machine learning techniques, enabling the automatic analysis of future cancer cells images [Lostal et al., 2013b; Lostal et al., 2013a].

For teachers and students (aged 15 to 18 years) in secondary schools, Cell Spotting provides an integrated view of several topics covered in Biology classes, thus favouring a strong curriculum interconnection. General topics covered include learning scientific research methodologies and analysing data sets, while more specific topics of the curriculum include understanding the importance of the apoptosis (type of cell death) in cellular growth and renovation, understanding the differences between the processes of apoptosis and necrosis (another type of cell death), and recognising and distinguishing the main morphological characteristics of these two types of cell death.

Cell Spotting (Figure 1) has been developed to integrate easy-to-use self-guided tools for the analysis of the cell culture images coupled with different educational resources which include a didactic unit (available in English, Portuguese and Spanish), and a virtual excursion room, where schools are able to remotely experience the work at the cell laboratory. This virtual excursion is made available via the GLOBAL Virtual Science Hub[6] — "ViSH", which contains a selection of e-Infrastructures and science-teaching related material accessible via a collaborative content repository for teachers and scientists to exchange and establish collaborations. Additional educational resources include a video[7] explaining the scientific process and research challenges addressed by Cell Spotting (also available in English, Portuguese and Spanish), and two teaching activity packages published by Casa das Ciências[8] [Monteiro et al., 2014] and Science in School[9] [Monteiro, Silva and Carrodeguas Villar, 2015] — two online platforms that aim to promote inspiring science teaching by encouraging communication and proposing joint activities between teachers and scientists.

[6] http://www.globalexcursion-project.eu.
[7] http://youtu.be/XXegth8CmM4.
[8] http://www.casadasciencias.org.
[9] http://www.scienceinschool.org.

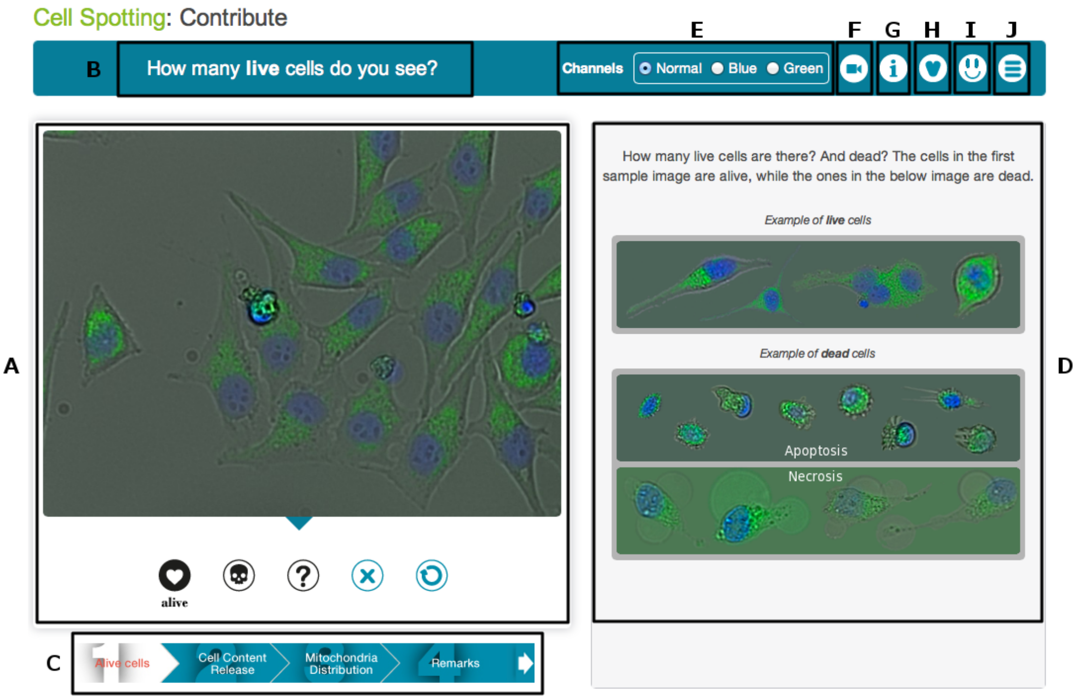

Figure 1. Screen shot of the Cell Spotting application. Volunteers are asked to classify large sets of images of cancer cells. In the search for new and effective drugs, these cells were treated with a drug sample. Via the Internet, citizens receive images of cell cultures being studied under a microscope (Box A) and help to determine the actual state of each cell based on the answer to simple questions (Boxes B and C). Guiding instructions on how to answer the questions are shown in Box D. Multiple tools (Boxes E and F), tutorials (Box G) and the didactic unit (Box J) are easily accessible to assist in the completion of the task, as well as the questionnaire to evaluate the application (Box I). The virtual excursion room is available via the symbol in Box H.

Promotion of teachers and students participation

In Spain, the Cell Spotting application was promoted among schools since its early deployment in March 2013. Given the calendar of academic year, schools' participation was significantly active between May and June 2013 and from September 2013 to May 2014. Most of the schools were contacted through the Education Office of the Aragoìn's Regional Government (a Spanish region), being invited to participate in the project. After a first contact by e-mail and phone, representative teachers from those schools were invited to the facilities of the Institute for Biocomputation and Physics of Complex Systems (BIFI) of the University of Zaragoza (Spain) for a workshop where the Cell Spotting project and application were presented in detail, which included background information and further explanations provided by Joseì A. Carrodeguas, the project's principal investigator. Teacher training workshops took place in January and September 2013. As a result, 18 secondary schools from Aragoìn joined the project in the 2012/2013 school year, while 36 schools joined in 2013/2014. Overall, nearly 50 teachers participated in the training workshops. In addition, groups of students from the different schools participating in the Cell Spotting project visited BIFI and the "Stem Cells and Apoptosis Group" facilities offering students the opportunity to interact with the project's researchers and get acquainted with the laboratories where the cell images under analysis in Cell Spotting were obtained.

In Portugal, the Cell Spotting project activities in schools took place between September 2013 and May 2014. Secondary schools were invited to have a first meeting with the Portuguese project partners in their schools. With a structured plan of activities developed, the team presented the project to science coordinators and Biology teachers, and discussed the main goals of citizen science projects and how schools could benefit from it. In each school, a teacher was appointed as contact point for the Socientize team. Activities in schools started with a training workshop specially designed for teachers providing them with the necessary tools and resources to explore and implement the project with their students in the future. Around 60 teachers attended the training workshops. Activities involving students occurred throughout the school year of 2013/2014 and were included in regular Biology classroom lesson periods of 90 to 135 minutes. During these lessons, students were introduced to the Cell Spotting project, the use of the Cell Spotting application and (when possible) a videoconference with José A. Carrodeguas was also organised. A total of 180 students attended the videoconferences organised in five different schools. In the videoconference, students had the opportunity to talk with Joseì and ask him about the life of a scientist, his research work, scientific volunteering and so on. After these sessions, students were invited to fill in the online questionnaire evaluating the Cell Spotting application and to continue collaborating with the Cell Spotting at home. In Portugal, students from the 10^{th} to the 12^{th} grade (aged 15 to 18) were involved in the Cell Spotting project. Classroom activities with students took place in six schools, with a total number of 30 classes attending, and involving 565 students.

Evaluation methods

In order to assess the success of the activities promoted around the Cell Spotting project and to understand the educational and motivational outcomes of the participation of teachers and students, the evaluation activities were conducted via a mix of quantitative and qualitative data collection instruments, which included an online questionnaire to collect volunteers' feedback, an online questionnaire to collect teachers' feedback, and a focus group with teachers who used the application in Biology classes.

Online questionnaire for volunteers of the Cell Spotting application

In the Cell Spotting application, after completing the analysis of a cell culture image, volunteers were asked to provide feedback on their experience with the application via an online questionnaire made available in English, Spanish and Portuguese. The questionnaire consisted of questions/statements regarding the following aspects: (i) perceived understandability of the instructions and ease of use of the application itself, (ii) motivation to participate in the project, and (iii) impact of the participation in the project at personal level. The last section of the questionnaire collected socio-demographic details of the volunteers.

The following five questions/statements measured the perceived ease of use of the application and the comprehensiveness of the provided instructions: "Do you believe that you understand the objectives of the Cell Spotting project?", "I thought the tasks from the Cell Spotting application were easy to do.", "The provided information and instructions were difficult to understand.", "I needed to learn a lot of things before I could participate in the project (e.g. instructions on how to classify cell images).", "The cell culture images provided for analysis were clear to me.".

Four statements measured students' motivation to participate in the project: "I am attracted by the idea to be involved in a research project.", "I wanted to provide some valuable contribution to this important research topic.", "I wanted to try it out of curiosity.", "I was requested to do so by somebody.".

The impact of the participation in the project at personal level was assessed by the following statements: "I learned more about cell biology through this project.", "I understand better now how researchers are working.", "I have the feeling that my participation in the project was a valuable contribution to research.", and "I intend to continue my active participation in research projects.".

An 11-point Likert scale was used to collect feedback to all the questions/statements presented above, where the value 0 corresponds to total disagreement ("Not at all") and the value 10 corresponds to strong agreement ("Very much").

The Spearman's rank correlation coefficient (r_s) [Spearman, 1904] was calculated to test for differences in students' responses to the questions/statements presented by age.

Online questionnaires for teachers

Teachers who collaborated with Socientize and participated in the Cell Spotting project with their students in class were asked to provide feedback on their experience by answering an online questionnaire. As before, the questionnaire was made available in English, Spanish and Portuguese.

The questionnaire consisted of questions regarding the school where the teacher implemented the Cell Spotting, the teachers' experience with the implementation of the project in the classroom, the impact at student level, and opportunities and barriers for Citizen Science at school.

The impact on the students was assessed based on the following questions: "Did the involvement increase the students' interest in citizen science?", "Did the involvement increase the students' knowledge and understanding of the research processes in general?", "Did the involvement increase the students' knowledge and understanding about drug research?", "Was the involvement in the project perceived as exciting or motivating for students?", and "Was it easy for you to include the project in your teaching curriculum?". Teachers were requested to provide feedback on these questions using an 11-point Likert, where the value 0 corresponds to total disagreement ("Not at all") and the value 10 corresponds to strong agreement ("Very much"). Associated with each of the above questions, the teachers were asked to explain their choice in open text question.

The identification of opportunities and barriers for implementing Citizen Science projects in schools was also promoted via direct open text questions.

Focus group with teachers

In Portugal, a focus group was hosted with six teachers participating. The teachers participating had implemented Cell Spotting in Biology classes. The objective of the focus group was to promote more detailed discussion on the questions already addressed in the teachers' online questionnaire, such as the Cell Spotting project and its applicability at schools and opportunities and barriers for Citizen Science in schools. The discussion was summarised by inviting participants to perform a SWOT analysis (Strengths — Weakness — Opportunities — Threats analysis) of the Cell Spotting project and citizen science in general.

Results

The results presented below are based on data collected from the online questionnaires between April 2013 and June 2014, and the focus group with teachers carried out in May 2014.

Students' feedback

Although, students were invited to fill in the online questionnaire evaluating the Cell Spotting after using the application in the classroom, by April 2014 only a small number of students had provided feedback. Thus, a reminder email was sent to all students. A total of 283 students provided feedback on all questions of the questionnaire. 63% of them were female and 37% male. 67% of the students resided in Spain compared to 32% in Portugal. 90% were aged between 15 and 17 years when answering the questionnaire. Table 1 provides a general overview of the students' answers to the online evaluation questionnaire of the Cell Spotting application.

Students gave very positive ratings to the statements related to the understandability and ease of use of the application (Table 1, S1 to S5). Most students rated the question "Do you believe that you understand the objectives of the Cell Spotting project?" with value 10 revealing that the scientific goals of the project were clearly understood. Still, and although a majority of students stated that they did not need to learn many new things before starting to collaborate with the projects (Table 1, S2, Mode=1), and that the provided information and instructions were easily understandable (Table 1, S3, Mode=0), it is possible to observe that the mean and standard deviation values for both statements are comparably greater than the mode values, which indicates that some groups of students felt the need for additional preparation before being able to participate in the project such as the one provided during the students' training workshops. After the initial training, the students considered the Cell Spotting tasks easy to perform (Table 1, S4: Mode=8; Mean=7.8) and the images of cell culture provided for analysis with a clear interpretation (Table 1, S5: Mode=0; Mean=7.2).

The Spearman's correlation coefficient revealed no statistically significant relationship between the age and students responses with regard to the question "Do you believe that you understand the objective of the Cell Spotting project?" (Table 2, S1: r_s=-.07; p-value=n/a). However, relationships between students' age and the responses given to the remaining statements (Table 2, S2 to S5) were significant. In general, older students tend to agree less with these statements than

Table 1. Students' online evaluation questionnaire of the Cell Spotting application. A total of 283 student provided feedback on the questionnaire. Statistical descriptors of the students' answers include the mode, mean and standard deviation (St. Dev.). Value 0 corresponds to total disagreement ("Not at all") and value 10 corresponds to strong agreement ("Very much").

Statement / Question	Mode	Mean	St. Dev.
Perceived ease of use of the application			
S1. "Do you believe that you understand the objectives of the Cell Spotting project?"	10	8.6	1.6
S2. "I needed to learn a lot of things before I could participate in the project (e.g. instructions on how to classify cell images)."	1	4.4	3.3
S3. "The provided information and instructions were difficult to understand."		2.3	3.0
S4. "I thought the tasks from the Cell Spotting application were easy to do."	8	7.8	2.0
S5. "The cell culture images provided for analysis were clear to me."	8	7.2	2.4
Motivation to participate in the Cell Spotting application			
S6. "I am attracted by the idea to be involved in a research project."	10	7.8	2.6
S7. "I wanted to provide some valuable contribution to this important research topic."	10	8.2	2.3
S8. "I wanted to try it out of curiosity."	8	6.9	2.8
S9. "I was requested to do so by somebody."	10	7.8	3.1
Impact of the participation at personal level			
S10. "I learned more about cell biology through this project."	10	7.8	2.2
S11. "I understand better now how researchers are working."	10	8.0	2.0
S12. "I have the feeling that my participation in the project was a valuable contribution to research."	8	7.3	2.4
S13. "I intend to continue my active participation in research projects."	10	8.2	2.0

their younger peers ($-0.14 \leq r_s \leq -0.24$, p-value<0.05). Squaring the correlation coefficients indicates that age seems to explain 4.4% and 5.8% of the variance in responses to statements "I needed to learn a lot of things before I could participate in the project." (Table 2, S2) and "The provided information and instructions were difficult to understand" (Table 2, S3). The higher agreement with these statements by younger students may be explained by the fact the concepts like cellular growth and renovation, and its relation to apoptosis are only introduced in the curriculum of older students.

The four statements measuring students' motivation to participate in the Cell Spotting project received very similar answers by the students (Table 1, S6 to S9). However, results presented must be interpreted considering that the students participated in the project at school as part of their regular Biology classes, so their participation was not entirely voluntary. Thus, it comes without surprise that the most frequent response to statement "I was requested to do so by someone" was the value 10 (Table 1, S9). Nevertheless, the students indicated that being "attracted by the idea to be involved in" (Table 1, S6) and "making a valuable contribution" (Table 1, S7) to the research project constituted strong motivators for participating in Cell Spotting (mean ratings of 7.8 and 8.2, respectively). Curiosity was considered the less important motivator (Table 1, S8). In an open text question, students were also invited to identify other reasons for their participation in the project. 35 students provided feedback to this question. About one third referred in their comments to the possibility to contribute to an important topic/project. About

Table 2. Analysis of differences in the responses to online evaluation questionnaire of the Cell Spotting application by students' age based on the Spearman's correlation coefficient (r_s).

Statement / Question	r_s	*p*-value
Perceived ease of use of the application		
S1. "Do you believe that you understand the objectives of the Cell Spotting project?"	−0.07	-
S2. "I needed to learn a lot of things before I could participate in the project (e.g. instructions on how to classify cell images)."	−0.21	< 0.01
S3. "The provided information and instructions were difficult to understand."	−0.24	< 0.01
S4. "I thought the tasks from the Cell Spotting application were easy to do."	−0.14	< 0.05
S5. "The cell culture images provided for analysis were clear to me."	−0.18	< 0.01
Motivation to participate in the Cell Spotting application		
S6. "I am attracted by the idea to be involved in a research project."	−0.03	-
S7. "I wanted to provide some valuable contribution to this important research topic."	−0.08	-
S8. "I wanted to try it out of curiosity."	−0.05	-
S9. "I was requested to do so by somebody."	−0.16	< 0.01
Impact of the participation at personal level		
S10. "I learned more about cell biology through this project."	−0.32	< 0.01
S11. "I understand better now how researchers are working."	−0.20	< 0.01
S12. "I have the feeling that my participation in the project was a valuable contribution to research."	−0.25	< 0.01
S13. "I intend to continue my active participation in research projects."	−0.15	< 0.05

20% stated their interest in learning something new as additional reason. About 20% described their experience with the project as very interesting. These results indicate that although students' participation was not completely voluntary (as the project was part of regular classes), there were other very relevant factors that motivated them to participate.

The analysis of the Spearman's correlation coefficients to test for differences in motivation by age (Table 2, S6 to S9) shows hardly any differences in motivation with regard to age. The only significant relationship between age and motivation could only be observed regarding the statement "I was requested to do so by somebody". Older students tend to agree less to this statement than their younger colleagues (Table 2, S9: $r_s = -0.16$, $p<0.01$). Still, by squaring the correlation coefficient we can observe that only 2.6% of the variance in responses to this statement can be explained by age.

The statements evaluating on the impact the participation in the project had at personal level received also strong agreement by students (Table 1, S10 to S13: Mode: 10 and 8, Mean values between 7.3 and 8.2, where 0="Not at all" and 10="Very much"). The students strongly agreed with the statement "I intend to continue my active participation in research projects" (Table 1, S13). Students seem to believe that the effect of their participation is greater at individual level (knowledge increase in cell biology research and about the work of a researcher; Table 1, S10 and S11) than on progress of the scientific project itself (Table 1, S12). In fact, when inquired about the feeling that their participation "was a valuable contribution to research", students show lower values of confidence in this regard (Mean=7.3; St. Dev.=2.4).

For this group of statements, a strong dependence is observed between students' responses and their age (Table 2, S10 to S13). The relationship between age and the statement "I learned more about cell biology through this project" is highly significant. Clearly, younger students expressed a stronger agreement with this statement (Table 2, S10: $r_s = -0.32$, $p<0.01$). In fact, squaring the correlation coefficient indicates that 10.2% of the variance found in the responses on this statement can be explained by the age of students. Younger students also acknowledged getting a better understanding of how researchers are working due to the project (Table 2, S11: $r_s = -0.20$, $p<0.01$). With regard to the value of their contribution for the progress of the Cell Spotting, older students were less convinced than younger students (Table 2, S12: $r_s = -0.25$, $p<0.01$). These results reveal the participation in the Cell Spotting project was stronger on younger students than on older students.

Students' were also asked if they intended to share their experience with family and friends, thus helping to disseminate the Cell Spotting project. 97% of the respondents stated they would recommend the participation in the project to family and friends. Only eight people (=3%) would not recommend the participation in the project. Four students explained their choice. Two students stated the project is not attractive. Another student explained that if any person can participate, the project could not be serious. Other student feared his friends and family lacked the necessary knowledge to participate.

Among the 275 students who would recommend the project to family and friends, 206 ($\sim$75%) explained their choice. A content analysis of the statements provided confirms the results of the previous analysis regarding students' motivation (Table 3). Most students explained their motivation to recommend the project with the possibility to contribute/to help. Very frequently "contributing" was named in relation to the importance of the topic. This underlines the importance students gave to the subject and purpose of the data collected in the Cell Spotting application. Another frequent reason to promote the participation among friends and family was the interestingness of the project. Comments also indicate that students appreciated the possibility to learn something new. Some students thereby explicitly referred to cell biology or science. Entertainment was often named in combination with other factors like "interesting project" or "contribute". Curiosity and learning about science in general seems to be of less importance. This feedback gives a very good overview about the motivation of the students to participate in the project.

Finally, students were asked which research areas would motivate them to participate in other citizen science projects (Table 4; multiple choices allowed). Results show a strong preference for Microbiology, Wildlife and Physics/Mathematics. Environmental issues, Geology and History are of less interest for students. In open comments, IT (5 students), Psychology (4 students), Chemistry (3 students) and Sports (3 students) were named as further fields of interest. A strong bias is observed towards citizen science projects in the areas of natural and exact sciences, which is probably influenced by the fact that students participating in the Cell Spotting project activities were attending mainly science courses such as Biology and Geology, Mathematics, Physics and Chemistry.

Table 3. Reasons identified by the students to recommend the participation in the Cell Spotting project among friends and family. From the 275 students recommending the participation in the project, 206 justified their recommendation. Some students presented multiple reasons.

Topic	Frequency	Percentage
Contribute / Help	67	23.3
Interesting project	58	20.2
Important topic	48	11.5
Learn something new	33	11.5
Learn about (cell) biology	31	10.8
Contribute to science	29	10.1
Entertainment / Fun	12	4.2
Learn about science	7	2.4
Curiosity	2	0.7
Total	**287**	**100**

Table 4. Research areas the 283 students identified that would interest them to participate in citizen science projects. Multiple choices allowed.

Research Areas	Frequency
Microbiology	131
Wildlife	129
Physics / Mathematics	89
Social Sciences	53
Astronomy	43
Environment	32
Geology	31
History	17
Other: IT, Psychology, Chemistry, Sports	15
Total	**540**

Teachers

Although more than 100 teachers were involved in the activities around the Cell Spotting, only eight teachers started answering the questionnaire. However, only five of them completed it. The following analysis will not be restricted to the completed questionnaires but take into consideration all answers available.

In the first part of the questionnaire, teachers were asked to provide a short description on how the Cell Spotting application was used in the classroom indicating the time period spent around the project and how many students participated in the activities promoted by the teachers. The time of the engagement of the teachers varied between 2–3 hours, three months and the entire 2013/2014 school year. The teachers implemented the project in 11^{th} and 12^{th} grades Biology lessons. One teacher stated that she/he intended to use the application on regular basis in particular lessons dedicated to research projects and sporadically in other lessons as well. Teachers reported to have worked with between 10 and 40 students around the Cell Spotting project. The total number of involved students according to teachers' feedback is 112.

Table 5. Teachers reported impact of the participation in the Cell Spotting projects had on students. Data collected from the questionnaires of five teachers. Value 0 corresponds to total disagreement ("Not at all") and value 10 corresponds to strong agreement ("Very much").

Question	Mean	Median	St. Dev.
Did the involvement increase the students' interest in citizen science?	8.0	8.0	1.9
Did the involvement increase the students' knowledge and understanding of research processes in general?	8.2	8.0	1.5
Did the involvement increase the students' knowledge and understanding about drug research?	6.2	6.0	2.7
Was the involvement in the project perceived as exciting or motivating for students?	8.6	9.0	1.7
Was it easy for you to include the project in your teaching curriculum?	7.0	7.0	2.5

Table 5 describes the answers from the five teachers who provide feedback on the impact the participation in Cell Spotting had on the students in class. To a large extent, these results are very similar to the results obtained in the analysis of the students' feedback. Teachers reported that students appear very motivated and interested in citizen science projects. Same as students, teachers also got the impression that the participation in the project had stronger effects on students' knowledge about research processes in general (Mean=8.2) than about drug research (Mean=6.2) in particular. Answers to the question "Was it easy for you to include the project in your teaching curriculum?" varied between 4 and 10 and thus were very diverse.

In open comments teachers provided feedback on the required facilitation and potential benefits and barriers for the cooperation with schools in citizen science projects. Teachers considered training, continuous support and the collaboration with scientists as useful. It was also mentioned that researchers should make their results available for students and explain how students contributed to the achievement of those results. From teachers' point of view, the involvement of schools in citizen science offers several benefits such as the increase of the students' scientific literacy and interest in pursuing studies in the fields of science. Also, it creates awareness for the possibility to participate in research projects happening anywhere in the world and at any time. However, repeatedly teachers identified the lack of time, tight curricula and the need to prepare the students for exams at national level (which determine the ranking for accessing university degrees) as potential barriers for the involvement of schools in citizen science projects. In spite of these constraints, teachers would recommend the participation in citizen science projects to other colleagues.

The discussion during the focus group organised with six Portuguese teachers highlighted and detailed much of the feedback already collected in the questionnaire. Again, teachers explained the motivation to implement the Cell Spotting in class with the relevance of the subject and the possibility for students to participate in a research project. One teacher also asserted that the participation of the school in the Cell Spotting project was able to attract students usually unmotivated to science.

According to teachers' feedback, Cell Spotting could be too difficult for students in the 10^{th} grade (aged 15–16) since many of the concepts it addresses were not yet covered in classes. In contrast, Cell Spotting is perfectly adequate for the 11th and 12th grade (16 to 18 years old) as it fits very well to the curriculum. In this respect, the work with the Cell Spotting application helped students to consolidate concepts covered in Biology classes and learn new ones, and to understand them in an applied way. For example, concepts such as apoptosis and necrosis were better comprehended by applying them to the analysis of real cell culture images. In addition, the participation in Cell Spotting fostered students' understanding of scientific processes. Students gained a more realistic perspective of what is the reality of a scientist's work. They also realized the importance of cooperation and teamwork to succeed professionally.

Special emphasis was given to the videoconferences with José A. Carrodeguas. Teachers deemed the direct contact between students and scientists as important to attract and motivate students to collaborate in research projects.

Statements of two teachers during the focus group:

> *"This project allowed the contact with different realities and also opened students' horizons to the world. This is a singular opportunity to involve students with the reality of Research in Science."*

> *"This project allowed the contact with a reality that we, as teachers, can try to explain but have not lived."*

The instructions and teaching materials provided were considered as very useful during the implementation of the activities in the classroom and helped to motivate students. Interestingly, very often the project especially motivated students with a rather weak school performance. According to teachers, this underlines the need to diversify teaching methods in order to reach all students. Citizen science was deemed as a useful tool in this regard.

Teachers in the focus group were also asked to share their impressions of what students considered interesting and/or attractive about the participation in the project and the use of the application itself. As before, the comments collected resemble the answers provided by students in the open questions of the volunteers' questionnaire. First of all, students could relate to the subject (cancer research) of the project and felt they were offered the possibility to participate/collaborate in "something bigger" and with social utility, by carrying out tasks similar to those performed by an experienced researcher. The knowledge that the data under analysis is real and its treatment necessary for real scientific purposes constituted an additional motivator. The participation in the project brought science and scientists closer to students, which can open new perspectives to their future. The close contact with the researcher responsible for Cell Spotting also helped students to demystify what a scientist is and what he/she does. According to teachers, many students realised that to be a scientist requires a lot of effort and does not always bring the expected results, which contrasted with a general romanticised view that science and scientists can solve almost anything.

In what concerns the potential barriers for a more active engagement of schools in citizen science projects, teachers in the focus group reinforced the comments

Table 6. SWOT (Strengths — Weaknesses — Opportunities — Threats) analysis resulting from the teachers' focus group. Strengths and weaknesses refer mainly to the Cell Spotting project. Opportunities and threats refer to citizen science in general.

Strengths	**Weaknesses**
– Strong complementarity with the curriculum. – Brings students/schools and science closer. – Widens the school knowledge network. – Students' motivation. – Broadened students' horizon. – Use of technology.	– Technological requirements. An offline version could be available. – Images are very similar in different tasks. – Teachers cannot keep track of students' contributions to the project at home. – Lacks links to other institutions, which already cooperate with schools (like parents associations, etc.).
Opportunities	**Threats**
– Helps breaking the monotony in teaching. – Students learn things, which go beyond knowledge measurable in exams. – Training courses for teachers were suggested to support them in the implementation of Citizen Science projects at school. – Contacts already established with schools could be used for other Citizen Science projects.	– Lack of time to implement such activities in class. – Organisation of schools is rigid and leadership change could affect continuous participation. – Projects need to be complementary to curricula

collected in the questionnaires: tight schedule and exam preparations constitute a major threat for the implementation of these projects in schools. The lack of time caused by the tight schedule was also identified during the focus group as the reason preventing the development of activities around the Cell Spotting project in several sessions at schools. To overcome this problem, some teachers tried to promote continuous participation of students on their own at home throughout the academic year.

Statement of a teacher during the focus group:

> *"Secondary teaching is a run for the national exams. Although, curricula suggest the development and implementation of activities that foster discussion, research and knowledge application, there's a great pressure in having a good classification in national exams which constitutes a major barrier to develop more dynamic and enriching activities in the classroom."*

In the last part of the focus group, teachers were asked to summarise their views on the Cell Spotting project and on citizen science in general by completing a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis, which is presented in Table 6.

Discussion

The feedback from teachers and students concerning their involvement in the Cell Spotting project within the context of regular Biology classroom lessons revealed important insights.

Although the participation in the Cell Spotting project was "forced on students" as part of their Biology class curriculum, the motivation of students to participate in the project was very high. The opportunity to contribute to something important and relevant, to help and be part of something bigger, to have hands-on experiences with science by analysing real data and performing tasks usually reserved only to experts, and thus becoming a valuable part of a scientific project in a topic of interest were the most important motivational factors identified by the students which are in agreement with previously reported outcomes in other projects [Roy et al., 2012; Zoellick, Nelson and Schauffler, 2012; Edwards, 2014]. However, and although many argue that the participation in citizen science projects improves students' attitudes towards Science and understanding of scientific practice [Bonney et al., 2015], students' feedback revealed that the subject and the objectives of the research project were more important than the general aspect of helping research advancement *per se*.

Concerning the understandability and ease of use of the web-based application supporting the Cell Spotting project, both teachers and students provided very positive feedback. The task of distinguishing between two different processes of cell death, through the identification of the morphological characteristics of the cell (such as shape, mitochondria distribution and content release), was perceived as clear and motivating by the majority of the students. However, some groups of students recognised that some initial training and preparation was necessary to understand what to look at and take care of when analysing the cell images. For these groups of students, the face-to-face training workshops and the didactic unit were paramount. Simultaneously, the direct contact with the researcher (even if only in a videoconference) was one of the most interesting support activities for students and teachers. The need for citizen science projects to potentiate bi-directional contact with researchers [Gray, Nicosia and Jordan, 2012; Falloon, 2013] and to be accompanied by a set of communication and support activities, such as training sessions [Kountoupes and Oberhauser, 2008; Marshall and Kleine, 2012; Zoellick, Nelson and Schauffler, 2012] and didactic material [Bonney et al., 2015], also merged in other studies suggesting that these are important factors to exploit a maximum of benefits for students and teachers.

The intrinsic motivators associated with the Cell Spotting project and the variety of the support and communication activities developed highly contributed to the impact reported at the individual level by teachers and students. Self-reported evaluation results confirm the knowledge increase about scientific research in general, but more importantly in the content domain of the Cell Spotting project. Teachers argued that the participation in the project created a direct link between the concepts learned in regular Biology classes and their application to help solve a scientific problem, which helped students to better apprehend and consolidate concepts previously presented in a theoretical way. Clearly, aligning the scientific goals of the citizen science projects and the school curriculum is an important factor to have in consideration when developing a project for classroom education [Jordan, Ballard and Phillips, 2012; Zoellick, Nelson and Schauffler, 2012; Collins, 2014; Bonney et al., 2015] as it increases the chances of create a profitable relationship for both the researchers and the students. Furthermore, the fact that students continued with their contribution to the Cell Spotting project outside the classroom, thus showing an increased interest in scientific research, is of high relevance, which could be further exploited with the aim to attract young people to science. Another interesting observation made by teachers was that the participation in the Cell Spotting project seemed to motivate those students who were normally less engaged in class and therefore provided an opportunity for exploring new teaching methods.

The evaluation results also show that the impact of participation in the project was stronger on younger students than on older students (Table 2). For example, older students tended to disagree more with the statements expressing they learned something new about cell biology and acquired new insights into the work of researchers. The fact that older students had more knowledge in the field of biology, science and research than younger students poses as a possible explanation for these findings. Faced with this scenario, the question is now how to incorporate different levels of involvement with the Cell Spotting project, from starting exercises of classifying the cell images (for "beginners", e.g. younger students) to more complicated tasks, which provide and/or require more knowledge to those especially interested in the research topic addressed (for "advanced volunteers", e.g. older students).

The observation and interaction with the students during the training workshops also revealed that the participation in the Cell Spotting project confronted students with two new situations. First, after completing the task of analysing a cell culture image there was no "you did it right or wrong" at the end. Second, by chatting with the principal investigator of Cell Spotting, students discovered that being a researcher requires a lot of work, many times performing not so exciting tasks and pursuing many venues without guarantees of positive outcomes. These situations contrast with the every day experience in the classroom, where for each asked question there is always a wrong or right answer and practical protocols used in the laboratory usually conduct to the expected outcome, which made some students feel somehow uncomfortable.

Conclusions

The benefits of citizen science for researchers are continuously being confirmed. Furthermore, and although many citizen science projects have explicit educational goals, most of these projects are developed in informal educational settings. In this work, we investigated the possibility of implementing a citizen science project in the context of formal science education. Here, a citizen science project in the area of cell and molecular biology — Cell Spotting — was implemented with hundreds of students in high schools in Portugal and Spain as part of regular Biology class.

The results presented show that it is necessary to create an adequate environment so that science and education can mutually benefit from each other [Dickinson et al., 2012]. Considering the time constraints most teachers identified in the school schedule, the interconnection between the concepts addressed by citizen science projects and the school curriculum is a critical requirement that needs to be fulfilled [Dickinson et al., 2012; Mueller and Tippins, 2012]. This enables teachers to use the project as new teaching tool to help students achieve specific learning outcomes, thus avoiding burning them out with extra time consuming activities. For students, participating in such projects helps to consolidate and apply concepts learned as part of their school curriculum while improving their understanding of the scientific process through their direct participation. Therefore, students not only obtain a theoretical and practical background on the specific topic at hand, but also have the possibility to perform tasks of professional researchers by handling the same tools and data. Our results suggest that citizen science projects, acting as alternative teaching approaches, can increase especially the interest of the low performance students to science topics.

Other important aspects to take into consideration for the implementation of citizen science projects in schools are the development of easy-to-use and self-guided applications (if applicable), and the preparation of rich and attractive support activities and educational materials so that continuous participation and engagement can be triggered outside the classroom. Support infrastructures and regular contact with the researchers involved in the project to clarify doubts and report on the progress of the project and results accomplished with the collaboration of schools was also considered of the utmost importance to motivate both teachers and students.

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Authors

Cândida G. Silva is a researcher at the Coimbra Chemistry Centre, Department of Chemistry, and the Center for Neuroscience and Cell Biology, University of Coimbra, Portugal. Her research interests focus on machine learning, data mining, drug discovery, citizen science, e-science, volunteer computing and data warehousing. E-mail: candidasilva@qui.uc.pt.

António Monteiro is a biologist with an MSc in biology and geology teaching. He is actively involved in science communication and promotion. He has worked for the Science Museum of the University of Coimbra in Portugal as an exhibition guide and education developer of science activities, mainly for the Researchers Night. He currently holds a position at the National Museum of Natural History and Science, University of Lisbon, Portugal. E-mail: antoniobmonteiro@gmail.com.

Caroline Manahl is a researcher at the Centre for Social Innovation, Vienna, Austria. Her research interests focus on migration and inclusion, adult and youth education, and regional employment policy. E-mail: manahl@zsi.at.

Eduardo Lostal is an Informatics Engineer responsible for the software development line in Ibercivis Foundation tightly coupled to Institute for Biocomputation and Complex System Physics and University of Zaragoza. E-mail: eduardol@bifi.es.

Teresa Holocher-Ertl is a researcher and project leader at the Centre for Social Innovation, Vienna, Austria. Her current research interests focus on user-centred development and evaluation of socio-technical innovations, participatory design and participation in research. E-mail: holocher@zsi.at.

Nazareno Andrade is a researcher at the Systems and Computation Department, Federal University of Campina Grande, Campina Grande, Brazil. His current interests focus on large-scale distributed systems — particularly in peer-to-peer and grid computing systems — and in all sorts of cooperative systems such as volunteer computing/thinking, collaborative tagging, media-sharing, Q-and-A sites, among others. E-mail: nazareno@dsc.ufcg.edu.br.

Francisco Brasileiro is a researcher at the Systems and Computation Department, Federal University of Campina Grande, Campina Grande, Brazil. His main research areas are in fault tolerance, distributed systems and protocols, with special interest in cloud computing and peer-to-peer systems.
E-mail: fubica@computacao.ufcg.edu.br.

Paulo G. Mota is the director of the Science Museum of the University of Coimbra and an associate professor at the University of Coimbra. His has been actively involved in the development of many activities and projects related to science dissemination and communication. E-mail: pgmota@ci.uc.pt.

Fermín Serrano Sanz is a researcher at the Institute for Biocomputation and Complex System Physics, University of Zaragoza, Spain and the Director of Ibercivis Foundation. His research is oriented to leverage citizen science, including deployments on volunteer computing, volunteer thinking, volunteer sensing, experimental data gathering, advanced learning and collective creativity.
E-mail: fserrano@unizar.es.

José A. Carrodeguas is a researcher at the Institute for Biocomputation and Physics of Complex Systems (BIFI) at the University of Zaragoza in Spain. He leads a research group focused on the study of apoptosis in cancer, the immune system, nervous system and other systems. He is also the principal researcher of the Cell Spotting experiment and is actively involved with citizen science projects and activities at Socientize and Ibercivis. E-mail: carrode@unizar.es.

Rui M. M. Brito is a researcher and associate professor at the Coimbra Chemistry Centre, Department of Chemistry, and the Center for Neuroscience and Cell Biology, University of Coimbra, Portugal. His research interests in protein-ligand interactions and rational drug design triggered his participation of the development of different volunteer computing and citizen science projects.
E-mail: rbrito@ci.uc.pt.

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