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Translating Scientific Articles to the Non-scientific Public Using the Wikipedia Encyclopedia

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The multilingual, web-based Wikipedia free Encyclopedia is used worldwide by people from different audience. It is openly editable, allowing quick updates. We used these properties as an educational tool in University classrooms, where students' assignment was to rephrase scientific articles for the public. We share here our teaching experience with an Earth Sciences class, based on class assessments and students evaluations. During the 2017 Fall semester, a 1 ECTS MSc level reading seminar on the broad topic of *Heat and Mass Transfers in Magmatology* was taught for 6 weeks at ETH Zürich. Three first semester and six third semester M.Sc. students have attended the course. All students had a B.Sc. degree in Earth Sciences, among which seven had their main specialisation in Mineralogy and Geochemistry and two had their major in Geophysics. By groups of two, students have read a scientific article, presented it orally to classmates and answered questions from their peers. During the last two classes, students have edited and created Wikipedia Encyclopedia pages in relation to their article's topic. Students really enjoyed creating a Wikipedia page, even if they didn't use it before or didn't trust the Wikipedia content. They had little experience with communication to a non-scientific audience and considered this exercise was challenging. Evaluations show that writing about a scientific paper in a Wikipedia page is a less efficient learning technique than reading a scientific article, presenting it orally or listening to such a presentation. However, it certainly contributes to better memorise important information, it is an efficient way to practice writing and public and scientific communication skills and it encourages students to work collaboratively on real-time projects. The teachers can use those combined effects as a multi-channel learning technique. It is also highly motivating for the students and the teacher to have a class exercise using modern media techniques with the potential to reach a wide international community. With this article, we wish to encourage colleagues to teach students how to communicate science, to scientific peers and to the non-scientific public. This promotes high-quality education and helps reducing inequality, two sustainable development global goals.

Keywords: Wikipedia Encyclopedia, communication skills, reading seminar, science teaching and learning, non-scientific audience, learning and teaching enjoyment

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INTRODUCTION

Communication is very important in academia. Presenting and confronting ideas allows transferring and improving knowledge within the community. Scientific publications and participation in scientific meetings are keys in an academic career. The importance of communication to non-scientific public is frequently underestimated in academia, or delegated to communication specialists (e.g., museum). Brownell et al. (2013) wrote: "Communication of science to the general public is increasingly recognized as a responsibility of scientists. This is a difficult skill that many practicing scientists lack, likely due to the combination of increased specialization over time and the absence of formal training in science communication. The public must be able to understand the basics of science to make informed decisions." Brownell et al. (2013) insisted on the importance of providing "communication skills to research scientists to enable them to better convey the details and impact of their work to the general public." Academic research grant money directly comes from the non-scientist tax-payers and it is therefore almost an obligation to communicate the public about the research results: open source publications are more and more requested by funding agencies. Also the great majority of students wishing to work outside academia have to learn how to communicate with colleagues in governmental and non-governmental agencies, industry and customers.

Today, in our society, it has become a habit sharing information with close and distant friends and family using the Internet and social media. Using Wikis and in particular Wikipedia is very similar. The multilingual, web-based, free-content Wikipedia Encyclopedia, founded in 2001, is openly editable and widely used by people from everywhere around the world (some 8,000 people view the site every second; Neal, 2016). Wikipedia is steadily ranked among the Internet's Top 10 most popular websites (Konieczny, 2012) and recently reached the sixth rank (Di Lauro and Johinke, 2017). Everyone (from a hobbyist to an accredited expert) can be a volunteer editor and edit or create a page, drawing a large number of editors. Also reviewers are from diverse backgrounds. These approaches have their pros (e.g., no censor, more articles, quick updates) and cons [e.g., errors, risk of misinformation, poor readability; which are progressively corrected (Luyt et al., 2008)], which have forced Wikipedia to increase control and edit official guidelines and rules (Knight and Pryke, 2012). Thus, Knight and Pryke (2012) wrote "Wikipedia is not necessarily anti-academic but it is anti-elitist." A British survey has shown 64% people interviewed trust the Wikipedia Encyclopedia content (Cox, 2014). This is higher than for well-established newspapers (e.g., *Times* or the *Guardian*) and TV (e.g., *BBC News)* and nearly as good as for the *Encyclopedia Britannica*, trusted by 83% people interviewed. As a matter of fact, the frequency of errors in Wikipedia and the *Encyclopedia Britannica* are comparable (Giles, 2005). While the daily reach per Internet users of the *Encyclopedia Britannica* has been constant in the last decades, the use of the Wikipedia Encyclopedia has been exponential (Konieczny, 2007). The growing success of Wikipedia as a knowledge resource has forced other encyclopedias to offer freely available pages and allow limited online edition by users (e.g., *Encyclopedia Britannica*) (Knight and Pryke, 2012). Since Wikipedia evolved from a new concept in 2003–2010, rejected by formal higher education, to a web reference with legitimate information (Cummings and Di Lauro, 2017), Wikipedia has become a sharing information platform for scientists, students and the public.

Being trained to critical thinking, scientists can and should contribute towards an improvement of public knowledge by editing and creating Wikipedia pages to explain fundamental scientific concepts (without referring to their own research products) (Callis et al., 2009). This way, Wikipedia pages may be used as an open source article, reaching even a much larger public than common scientific journals. Since its first use as a teaching technique in 2003 (see Cummings and Di Lauro, 2017, for the history of the use of Wikipedia as a teaching tool), an increasing number of teachers have been using Wikipedia in their class, covering a wide range of social, natural and medical sciences (e.g., history, chemistry, anthropology, literacy, psychology) (e.g., Pollard, 2008; Moy et al., 2010; Knight and Pryke, 2012; Cummings and Di Lauro, 2017; Di Lauro and Johinke, 2017), gradually contributing to the improvement of Wikipedia. Several universities (more than 500 universities, according to Wikipedia, including prestigious UC Berkeley, Harvard, Duke and now ETH Zürich) have already started incorporating the edition and creation of Wikipedia pages in their curriculum (Neal, 2016), using the Wiki Education tools. However, to the best of our knowledge, after conducting surveys, Wikipedia page creation is very rarely used as an exercise in small Geosciences classes. Here, in comparison to former studies, we explore the edition and creation of Wikipedia pages by a small group of students (<10 students), based on scientific articles in Geosciences. We present, analyse and discuss our assessments during and after a reading seminar class taught to postgraduate students in Earth sciences. We also present our results on alternative formats, with a poster and a PowerPoint presentation (**Presentations 1**, **2** in the Supplementary Material).

TEACHING AND LEARNING METHODS

It is important for students to learn communication skills, both to scientists and non-scientists, and acquire confidence. Brownell et al. (2013) pointed out that only "few undergraduate or graduate science curricula offer coursework-based opportunities for students to practice this skill." During this Wikipedia exercise, we wished to test how students can rewrite scientific information for the general public and train their communication skills. Ploetzner et al. (1999) wrote *learning by teaching* promotes learning, but the amount of learning seems to be more related to the cognitive activities necessary for constructing and presenting explanations than to the teaching itself. We may then make the hypothesis that the student's amount of learning would be bigger while thinking how to rephrase a scientific article into a large public Wikipedia page than by reading that scientific article. Initially, we had no idea about their experience in science vulgarisation, which is really important in society but frequently given a too low value. With this teaching project, we wished to train the students reformulating complex scientific information to the public and publish them on the Wikipedia Encyclopedia worldwide network. We had four goals: (1) Practice

scientific communication; (2) Develop writing skills; (3) Develop communication skills for a non-scientific audience; and (4) Improve and extend the Wikipedia Encyclopedia within our field of competence. We reached these goals by assigning geology M.Sc. students to select one scientific paper among a list, read it, present it orally to the class and finally rephrase it for the public by editing existing Wikipedia Encyclopedia pages, creating a new page and reviewing classmates' pages.

In Fall semester 2017, the teacher taught MSc students a course on "*Heat and Mass Transfers in Magmatology*," worth 1 ECTS credit (30 h of lecture and personal work). This Geology course lasted for 7 weeks, with 2 contact hours per week. Nine students have taken the class, among which seven had their main specialisation in Mineralogy and Geochemistry and two had their major in Geophysics. Three students were on their first M.Sc. study semester and six students were on the third semester. Despite the class was also opened to Ph.D. students, none have taken it in 2017. The course was composed of three parts.

(1) On week 1, the teacher gave lectures with short oriented exercises (e.g., microscopy, calculations, problem solving), serving as general introduction to create a common basis for the second and third parts. A list of five scientific articles was provided to the students (see **Table 1** and **Table S1** in the Supplementary Material), who were asked to form pairs (one student worked alone) and select one. The scientific papers covered a wide range of topics, all in relation with the course main theme.

(2) On weeks 2–6, the class was designed as a reading seminar course. All students had to read the weekly paper and volunteering students had to perform an oral presentation to the class, by pair or individually. Articles were comprehensive (ca. 25–35 pages) and the two presenters had to spend ca. 6 h on reading the selected paper and preparing a 15 min long oral presentation. The other students had to spend ca. 2 h reading the paper's abstract, introduction, conclusions and looking at the figures. Presentations were exactly 15 min long, similar as what it would be in a scientific meeting. The other students had to prepare 2–3 questions about the paper and asked them to the presenters. If necessary, the lecturer helped answering the questions and gave additional information. Each week, we started the class with the oral presentation of one selected scientific paper, followed by questions from the classmates to the two presenters. The students and the lecturer gave anonymous feedbacks about the presentation and the presenters, which were compiled and shared by the lecturer. Afterwards, the teacher gave a short lecture or organised a written exercise, a computer exercise or a communication exercise.

(3) On week 6, the teacher initiated a communication exercise using the Wikipedia media. The students were explained how to edit a Wikipedia page in html and visual modes (add text, add link, add reference, add image), showing how to proceed on an existing page. He is an experienced Wikipedia user and editor. He then asked all participants to look at the Wikipedia tutorial (https://en.wikipedia.org/wiki/Wikipedia:Tutorial or https://dashboard.wikiedu.org/training/students), create an account and edit existing pages using their knowledge from the course. The teacher then demonstrated how to create a new page and start entering information. He asked the students (4 pairs and 1 single student) to create a new page on a selected topic (list of topics in **Table 2**) for the final week 7, as homework, using the scientific paper they had read and presented. The lecturer insisted on the importance to reformulate scientific information for a large public. Wikipedia pages on general magmatic processes are already written. In order to create new pages, the lecturer had to select other topics, for which only the initiated public would show interest[1]. On the last class day (week 7), the students were asked to revise, edit and complete pages written by their classmates, using the information they had from their own paper and the knowledge acquired during the class. Each group had to check all new entries, but had to pay special attention to one related topic, as listed in **Table 2**. This related topic was in relation to the article they had presented. This process is a small-scale edit-a-thon[2] event. After completion of the course, all new created pages were submitted for revision by the Wikipedia volunteers. Through this process, the students have been learning by teaching to scientists and non-scientists. Wikipedia users will later improve those pages. In this way, communication via the Internet is a live process and scientific information is being transferred from the scientists to the public among which we may find the next generations of student.

TABLE 1 | Selection of scientific papers offered to the students.

	Papers to read [Full references in Table S1 (Supplementary Material)]	Pairs of students
Week 2	Grove et al. (1992) AGU	Group week 2
Week 3	Nandedkar et al. (2014) CMP	Single person week 3
Week 4	Solano et al. (2012) JPet	Group week 4
Week 5	Leuthold et al. (2014) JPet	Group week 5
Week 6	Helz et al. (2014) USGS	Group week 6

During this course, the students went through *successive construction of explanations*: (1) They started with self-explanation while reading the scientific article, (2) then formed pairs and discussed and explained the content, (3) then share to peers in an oral presentation, and (4) finally reformulated to the non-scientific public, using the Wikipedia Encyclopedia media. This is a test to check whether they have really understood what they read in the scientific paper and could get the most important outcomes. The students have received no specific training in science communication for non-scientific audiences, but were supported by the lecturer during the class.

RESULTS

Assessment During the Class

Discussion between the students and teacher and direct assessment during the creation of Wikipedia pages are favoured in small classrooms, with limited number of students. After

[1] Ideas of pages to edit and create can be found here: https://en.wikipedia.org/wiki/Wikipedia:Pages_needing_attention or in WikiProject pages related to your field (e.g., https://en.wikipedia.org/wiki/Wikipedia:WikiProject_Geology).

[2] An edit-a-thon is an organized event where editors of online communities (such as Wikipedia) edit and improve a specific topic or type of content, typically including basic editing training for new editors.

TABLE 2 | Propositions of new Wikipedia pages.

Wikipedia page topic[a]	Written by	Reviewed by	Decision, Grades[b]	Date of decision	Average page visits/month since publication
Lower oceanic crust	Group week 2	Group week 6	Accepted: C	28.01.2018	147
Experimental petrology	Group week 3	Group week 2	Declined: Missing references	30.01.2018	
Deep Crustal Hot Zones	Group week 4	Group week 5	Accepted: Start	20.12.2017	21
Torres del Paine Sill complex	Group week 5	Group week 4	Accepted: C	10.02.2018	23
			Later deleted on	08.03.2018	
Kilauea Iki lava lake	Group week 6	Group week 3	Declined: Reads more like an essay	17.02.2018	

[a] *Pages not yet submitted, under review or rejected can be accessed searching for draft: name of the topic on Wikipedia.*
[b] *Wikipedia grades are given in **Table S2** (Supplementary Material) and can be found here.*

a short introduction to Wikipedia and its use as an editor, students have immediately started visiting existing pages related to their topic and commented them. After a few minutes, the first students were already starting to create their own page. This was earlier than initially planned, but fine. Indeed, page creation is relatively easy and user friendly. We interpreted this as showing excitement, which was confirmed by the end of the class, with students giving very enthusiastic and positive feedbacks (e.g., "it was fun!"). The student engagement and motivations were greater on the Wikipedia assignment than during class exercises or in the discussion about presented scientific papers.

Assessment Using the Form

The lecturer has also given each student a form with 15 questions (**Table S3** in the Supplementary Material) to quantitatively evaluate and comment the course with a special focus on the Wikipedia exercise. All 9 students have anonymously returned the printed form filled at the end of the Wikipedia exercise and consented the results to be used in the present study. With 100% answers, we avoid biases due to categories of sounded students who might not answer the questionnaire (Knight and Pryke, 2012, got an answer rate of 8% only, representing 2,318 students), but have to deal with only few persons' opinion. Questions 1–5 were about independent learning techniques; questions 5–13 were about Wikipedia and the exercise; questions 14 and 15 were about the skills and knowledge acquired during the course. The lecturer has collected the form and treated the answers, so that he could check the coherence of answers and comments. Selected questions are presented in the **Figures 1–4** and discussed below. All results are presented in **Image 1** (Supplementary Material). For statistics, average is shown together with one standard deviation, showing the homogeneity of answers.

In questions 1–5, students have quantified independent learning techniques. Reading a scientific paper (question 1) has equivalent teaching results as listening to an oral presentation (question 2) and group discussion about the paper (question 3). Presenting the paper orally also helps the student to acquire knowledge about the topic (question 4). Writing a Wikipedia page from a scientific paper does not provide the same amount of learning, but the great majority of the students thought it helped to better understand the topic (**Figure 1**, question 5). This is a major outcome that will be discussed below.

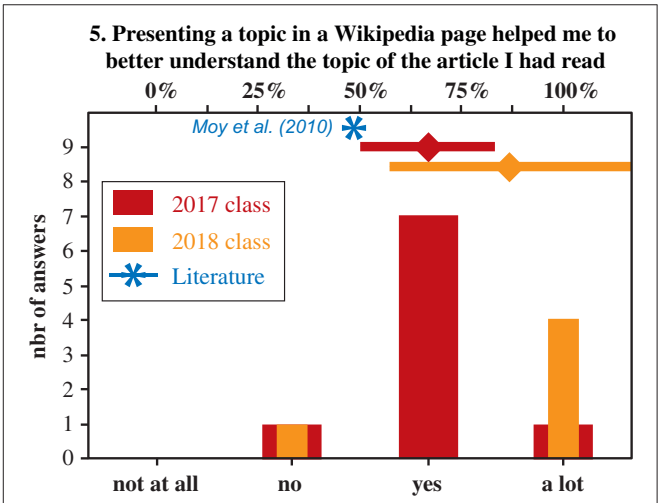

FIGURE 1 | Creation of a Wikipedia page, popularizing scientific data and information, generally helped the students to better understand the topic. However, the amount of learning is bigger while reading the paper, presenting it orally or discussing it in a group. Average (diamond) and one standard deviation (horizontal line) are shown.

Questions 6 and 7 were about the use of the Wikipedia Encyclopedia during their studies. We observe a wide range of answers, with some students using Wikipedia frequently, sometimes, rarely or never. Globally half of the students use Wikipedia sometimes or frequently during their studies, similarly to what was reported by Lim (2009) and Cummings and Di Lauro (2017). Students using Wikipedia find it easy and accessible. They would only use it to find early-stage information and useful references and would pursue their learning using scientific papers. Students who are not using or rarely using Wikipedia don't trust the content. Those students won't go on updating or creating Wikipedia pages (question 13), despite they all liked the exercise (**Figure 2**, question 12).

Most students had no or only little experience with communication to the non-scientific public (**Figure 3**, question 8). They thus found it was challenging to create a Wikipedia page and popularize scientific information (**Figure 4**, question 10). However, students who had some experience with non-scientific communication also found it challenging.

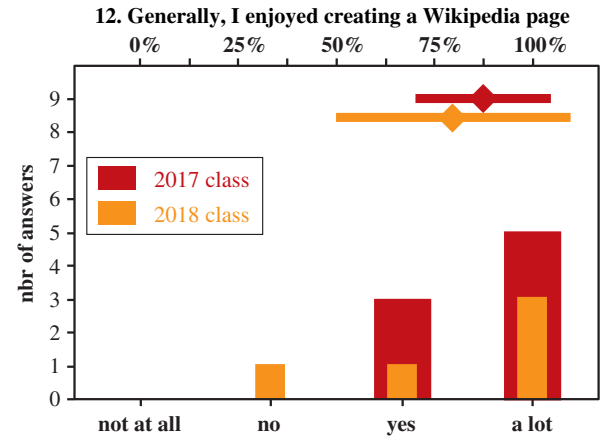

FIGURE 2 | Most students enjoyed creating a new Wikipedia page, even those not using this encyclopedia.

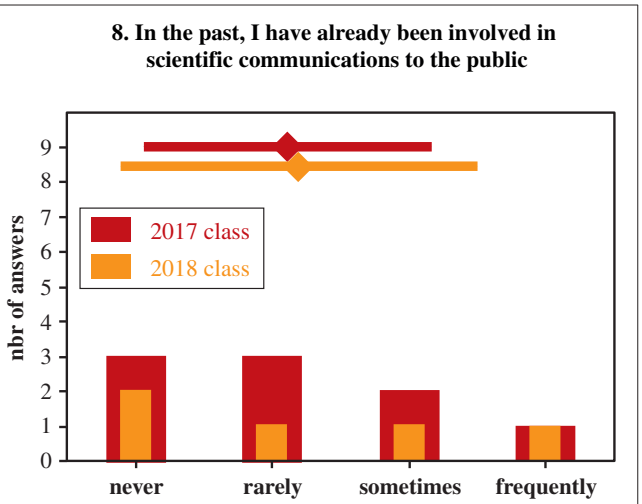

FIGURE 3 | Most M.Sc. students have no or only little experience in communication to a non-scientific public. This skill is very important in academia, governmental and non-governmental agencies and industry.

Assessment After the Class

We realised that students have very little communication skills, orally and to the non-scientific community. This is clearly visible on **Figure 4** (question 10), where most students found it challenging to popularize a scientific article. In our opinion, despite efforts had been made to popularize the scientific articles, we judge some pages are difficult to understand by non-specialists and need further work towards generalisation to a point where the initiated public can understand (the non-initiated public would have very little interest for the selected topics). The advantage of Wikipedia is its ease to link to other pages, so that technical words may not need explanation within each article, but this is not sufficient to make an article fully accessible to a non-specialist. Improvements are clearly possible but would require considerable more time. It would be reasonable for a course with communication as only objective.

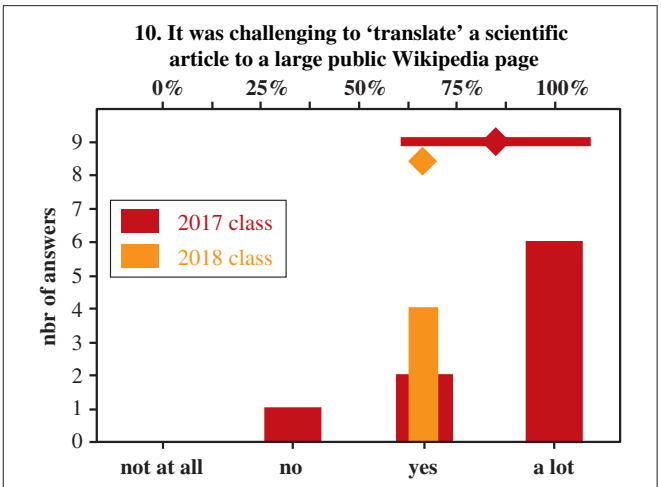

FIGURE 4 | Most students had difficulties to rephrase the scientific article so that the non-specialist community can understand it. It is thus important to offer more such exercises in the curriculum.

By mid-February 2018, all pages had been reviewed by Wikipedia volunteers (**Table 2**). Three pages had been published and two pages had been rejected. Wikipedia volunteers graded published pages [see grade table in **Table S2** (Supplementary Material)]. Grades are given in **Table 2**. One page was rejected because references were insufficient and one page was rejected because it looked more like an essay. One published page was reported as possibly being copied and pasted from a scientific article, which would be violating the Wikipedia's copyright policy, and has later been deleted. The lecturer contacted the students to encourage them to improve and, where appropriate, resubmit their page. He hoped students would go on improving their Wikipedia page after submission. In March 2018 (i.e., 3 months after the class) and December 2018 (i.e., 1 year after the class), we could check how students further updated their page and other pages, knowing their usernames (Wikipedia is transparent and any update made be someone logged-in is recorded). Students didn't pursue page edition, despite most students said they would go on editing and creating Wikipedia pages (question 13).

Additional Observations and Problems Encountered

The teacher asked the students to get their page ready for the week 7 and planned some time for the students to review pages of their peers during the last class. Unfortunately, students have been busy with end of semester exams preparation and used most of the last 2 h to finish their own page. Only few students have reviewed other pages (question 11). During a similar class in Fall 2018, 45 min were booked for revision of peers' text, resulting in more edits and improvement of the final product. However, two persons editing one page in parallel might result in one revision being lost.

Wikipedia does not allow new users to add figures, and this is a problem as images frequently give much better explanations than texts. Students were encouraged to edit other Wikipedia articles in order to be allowed adding figures on their own page. At the

end of the course, no figure had been uploaded on the draft pages. This situation did not change, when the pages were visited after the end of the course. Pages are visited by 19–145 persons[3] each month (**Figures 5**, **6**) and have been further modified by ca. 10 Wikipedia users (considering major edits only).

New entries have to be reviewed by Wikipedia volunteers before publication on the web. At the time of submission, mid-December 2017, there were ca. 2,500 recently created pages in the waiting list. At the time of submission, the exact time it will take and whether the new page will be accepted or rejected is unknown. For articles submitted to the Good Article review process, it is possible to invite reviewers on the Good Article Nominations talk page to look in priority to the newly submitted pages, when having short class deadlines (Konieczny, 2012). Wikipedia manages an online forum (Wikipedia help channel, available in several languages) where we were made aware that obtaining ECTS credits should not depend on the successful publication of a Wikipedia page. This was not the case for this course. Moy et al. (2010) assessed students' page based on completing assigned criteria such as the use of references, the creation of sections, the upload of figures, the use of hyperlinks and finally the quality of an in-class presentation of the newly created page.

DISCUSSION

With the article reading and oral presentation approaches, students have learned to read and understand a scientific paper in order to be able to explain it to their scientific colleagues (*interactive explanation*). With exercises incorporated in the lectures, the teacher made sure every student had correctly understood important processes in magmatology. With Wikipedia page creation, the students learned to communicate scientific wording and concepts for the public. The teacher was alternatively an authority, a coach and a facilitator, with clear delimitations in time. This encouraged the contact with the students, conserving the necessary authority when needed. Hawe and Dixon (2017) noticed it might be intimidating for students preferring to keep a relatively passive role to share ideas, review the work of peers and provide feedback. Such passiveness was observed during papers' discussion, where the lecturer indeed had to coach the students and sometimes use his authority. But working in small groups (i.e., by pairs in the present case) with clear specific goals promoted individual contribution during the Wikipedia assignment.

Students' Uses of Wikipedia

According to several authors using Wikipedia in classrooms (e.g., Cummings and Di Lauro, 2017), teachers often forbid students to consult or quote Wikipedia. Cummings and Di Lauro (2017) concluded "the initial rejection of Wikipedia by faculty in all formal education settings was understandable when Wikipedia was a relatively new concept in 2003–2010, but Wikipedia has become a part of the digital fabric of first-stop reference for almost everyone." At ETH Zürich, we had only rare negative reactions from the students and other lecturers showed interest in our results. Our assessments (questions 6 and 7 and during the class) show students commonly use Wikipedia, generally to search for definitions, simple explanations or references, before moving to scientific literature, confirming the observations by Lim (2009), Konieczny (2012), and Cummings and Di Lauro (2017). Globally half of the students use Wikipedia sometimes or frequently during their studies, similarly to what was reported by Lim (2009) and Cummings and Di Lauro (2017). Interestingly, this ratio doesn't seem to increase with time, despite Wikipedia efforts to evolve from a new concept in 2003–2010, rejected by formal higher education, to a web reference with legitimate information (Cummings and Di Lauro, 2017).

Learning Enjoyment

Students learned to popularize scientific information to the public by editing and creating Wikipedia pages. They were very positive and excited about this Wikipedia page creation exercise (**Figure 2**, question 12), from the beginning to the end of the exercise, putting more efforts than during classic exercises, confirming previous observations (e.g., Moy et al., 2010; Roth et al., 2013). They strongly encouraged the lecturer to do it again. Students and teacher motivations are multiple and diverse: It is well known that the students are more motivated to take part to activities when their contributions (both individual and collective) has a measurable impact and the potential audience of the sixth most visited website on the planet is enormous (Konieczny, 2012 and references therein; Di Lauro and Johinke, 2017). This is very rewarding also for the teacher, who sees the impact of his teaching far beyond the classroom. Secondly, discovery, exploration, mental stimulation, and excitement foster learning enjoyment (Packer, 2010) and, through its novelty and real–world usefulness, a Wikipedia assignment has the potential to be more enjoyable than most other traditional class assignments (Konieczny, 2012, and references therein). For a teacher, seeing his students learning with fun is gratifying. Thirdly, the "desire to learn" as well as altruism are two important motivators to develop the Wikipedia Encyclopedia (Baytiyeh and Pfaffman, 2010). Finally, getting a good academic grade also encourages students to work on a given Wikipedia assignment, but won't motivate them to become regular editors (Roth et al., 2013), while a good Wikipedia grade [e.g., Good Article GA (see **Table S2** in the Supplementary Material)] might.

Acquiring Knowledge and Skills

Based on the results of the assessment form, listening to lectures and oral presentation is the most efficient learning technique (97% of satisfaction), closely followed by literature reading (94% of satisfaction). This is similar to Moy et al. (2010) results, which however show lower learning from literature reading (62%). In the present study, the lecturer had selected comprehensive scientific articles, which might be more accessible than highly specialized articles. 75% of our students rated the creation of the Wikipedia page as helpful to understand the article topic (**Figure 1**, question 5). Interestingly, our results are distinctly higher than those reported in Moy et al. (2010)

[3]Check the number of visits on "page information," on the left list of links, and "Revision history statistics" at the bottom.

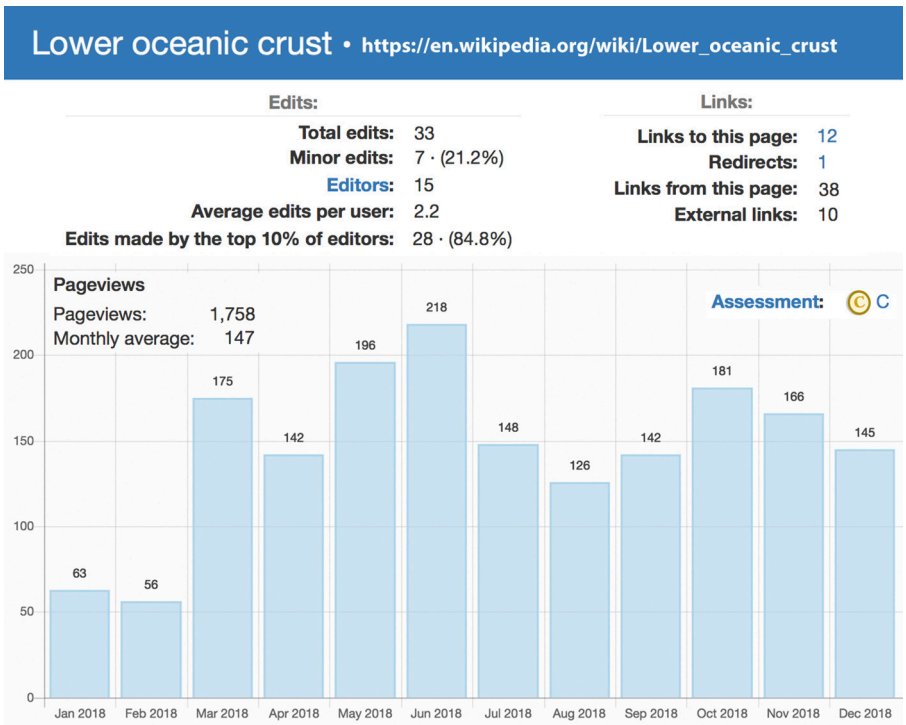

FIGURE 5 | Wikipedia statistics about the newly created page about the "Lower oceanic crust" (on 01.01.2019; 11 months after publication). https://en.wikipedia.org/wiki/Lower_oceanic_crust.

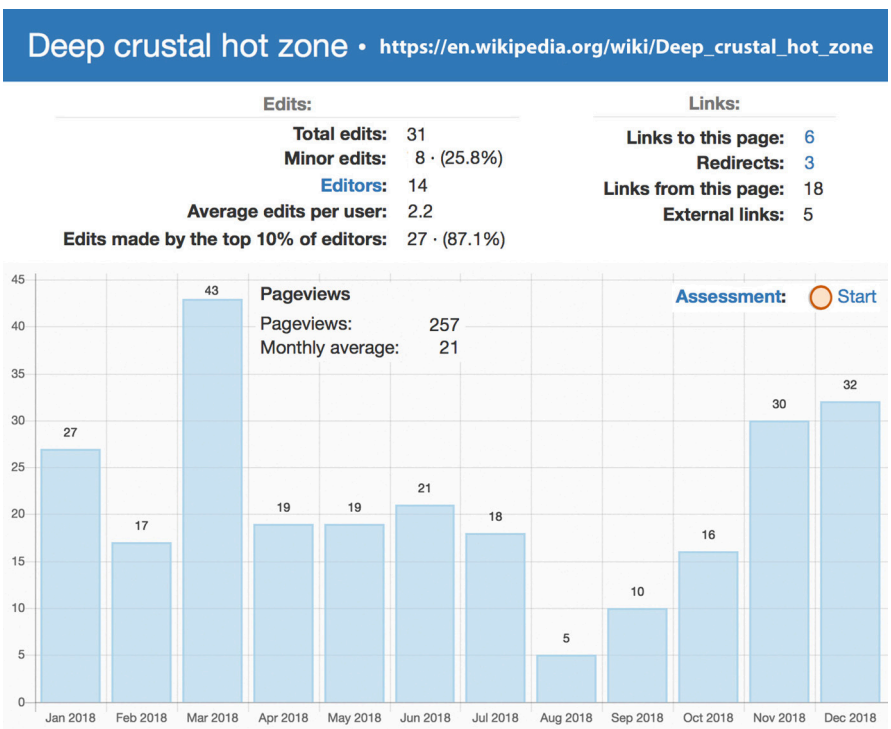

FIGURE 6 | Wikipedia statistics about the newly created page about the "Deep Crustal Hot Zone" (on 01.01.2019; 12 months after publication). https://en.wikipedia.org/wiki/Deep_crustal_hot_zone.

(48% of satisfaction), were students judged the creation of Wikipedia pages had no significant contribution in learning of advanced concepts. Thus, writing Wikipedia page should not be designed with the primary goal to increase student scientific knowledge, despite it can contribute to it. This seems to contradict with the idea of Ploetzner et al. (1999) that the amount of learning seems to be more related to the cognitive activities necessary for constructing and presenting explanations than to the teaching itself. But the fact that students could have made additional effort to popularize their Wikipedia page show the cognitive activities may be more exploited. Additionally, we don't have the necessary distance to say how much the students still remember from the class and how much they would still remember from their readings and oral presentations only, without this Wikipedia popularization exercise. But we can extrapolate that students may retain information over a longer period, thanks to repetition. Indeed, repetition helps sorting important and unimportant information and better recalling important information (Bromage and Mayer, 1986). It is to be noted the repetitions used in this class were calling different students skills, with new challenges at every stage, preventing the boring aspects of repetitions.

Wikipedia assignments have multiple other advantages than just learning scientific knowledge. In similar Wikipedia exercises, Pollard (2008) and Roth et al. (2013) reported students acquired (1) critical analysis skills (76% of sounded students) while insuring content validity, (2) writing skills (61%) and (3) editing skills (86%) and in that prospect might be equal to or better than a traditional research paper assignment. According to Moy et al. (2010), the creation of Wikipedia pages strongly helps identifying resources for building an argument (93%). Also (4) collaboration with others in our field of study is a skill trained during creation of Wikipedia pages (Pollard, 2008). In our case, collaboration was favoured in pairs more than with other classmates or the Wikipedia community (especially using the Wikipedia dedicated *Talk* page), because of a lack of time. Moy et al. (2010) students (6 panels of 5 students) evaluated the creation of Wikipedia page is the most efficient tool to learn working collaboratively (86%). However, in larger groups, some students may take a more passive role. Finally, (5) students are made aware of the importance of communication to non-scientific public and may later get involved in public websites edition or public events. To encourage this, science popularization, so important especially outside academia, should be taught as part of a class (e.g., short 5 min presentations, focused Wikipedia exercises) or even require one or more specific classes. According to Roth et al. (2013), "professors and students agree that their writing skills did not improve beyond what a traditional research paper would produce." Based on above discussion, we nuance this statement, as writing a scientific paper or writing a text for the public require different skills. It is challenging for scientists to "translate" technical text to a greater audience (**Figure 4**, question 10). We would have expected such an answer from people with more expertise, mostly trained speaking with and to peers but were surprised that M.Sc. students had difficulties explaining science to the public. Would results be similar with B.Sc. students? Di Lauro and Johinke (2017) distinguish between undergraduate students who may be asked to correct existing Wikipedia pages, and more experienced postgraduate students who may write about under-represented or unrepresented topics. However, Konieczny (2012) describes successful page creation by undergraduate students when students are progressively trained to Wikipedia edition.

We then qualitatively conclude rephrasing scientific articles in Wikipedia popular pages offers slightly lower amount of learning than reading an article or listening to a lecture, but offers additional valuable communication skills, and certainly better memorise. The teachers can use the combined effects as a multi-channel learning technique. How much have the students really learned about science communication and how many times or how frequently should this exercise be repeated to measure a significant skill improvement? The students will progressively gain experience and confidence presenting their knowledge to the public. However, this is a long-term task. We anticipate already one such single class exercise can motivate a student to pursue similar or different outreach activities (question 13).

Better Wikipedia Articles—More Advanced Learning

Several students were lacking time working on their Wikipedia page, which was given as homework, at the end of the semester. As consequence, only few of them reviewed and updated peers' pages. In the future, the lecturer will be stricter with homework or allow more time during the class. Unfortunately, no student further worked on his published or rejected page after submission or decision, despite the great majority said they would (question 13). Here, we were negatively surprised, as assessment and feedbacks were very positive. Hawe and Dixon (2017) showed that the process of peer review and feedback stimulated students' reflection on their own work. In our case, the students relied more on their peers' review to improve their work. We recommend planning more time for the students to work and develop their Wikipedia pages, to get a more resulted product and improve science generalization. However, two pages were graded C, which we consider already as a good mark, given the available time. In future classes, we may ask other students to work on those pages, to improve them by making them more accessible to the public, extend the content and create links from and to other pages. In Fall 2018, the teacher led another Wikipedia exercise at ETH Zürich, with a class of 5 students. Following 2017 students' suggestion, all students edited the same Wikipedia page about "Crystal mush"[4], individually writing one section. They were given 3 weeks, without homework, and were able to write their text and revise peers' sections. The product is distinctly more mature than with student pairs working on different pages, despite the teaching and learning efforts are similar. Collaboration between students was strongly enhanced, feeling they are all part of a group. However, only one page was created. With a fourth week, the students may have drawn and included figures.

[4]https://en.wikipedia.org/wiki/Crystal_mush

Comparatively, Moy et al. (2010) dedicated a 14 weeks semester to the selection of a topic, creation of a page, revisions, and feedbacks and final presentation to the peer students. The teachers gave specific minimal requirements, such as the number of sections, references, figures, or hyperlinks, which served as rubric for grading the students' work. Another teaching approach using Wikipedia is presented by Konieczny (2012). During a 7 weeks class to undergraduate students, he started with simple Wikipedia exercises and progressively increased complexity towards a major group project, with half pages achieving a GA grade[5] and the other half a B grade (see **Table S2** in the Supplementary Material). The selection of the topic by the students certainly helps to train their critical sense, identifying the strengths and weaknesses of current entries, but is time consuming and already requires advanced knowledge, especially since the number of Wikipedia entries continuously increases.

The Wikipedia Web Classroom

Statistics of the two newly published pages are given in **Figures 5**, **6** and **Table 2**. An average of 19–145 visitors each month is about 2–16 times bigger than the number of students attending the class. Thus, the Wikipedia publications reach many people from all around the World (it is not possible to know who visited the pages [e.g., which country, which background]). However, in the example described here, there is no interaction between the visitor and the teacher/author, which constitutes a major difference with normal classes. Wikipedia collaborates with teachers and created a special platform dedicated for teaching: Wikiedu. It is possible to create a page for a course, add and remove students, create classroom assignments, assign Wikipedia articles to students and communicate with them. There would even be no need for physical contact between the teacher and the students. The course can then be made accessible to worldwide students, and freely available to the community to encourage free and open access to knowledge.

Teachers are frequently researchers and thereby, may get additional benefits. The recent political decision to publish scientific articles as open source and give the public access to their content is very positive. But the real impact of these technically-written academic articles on the non-specialist public can be questioned as it is likely necessary to have them explained in simple words to be understood. The Wikipedia Encyclopedia could be an ideal platform to communicate science to the public. In addition, editing, and writing Wikipedia articles increases the social media article metrics of the referenced scientific articles, where the number of citations in Wikipedia being one criterion.

CONCLUSIONS

As conclusions, the teacher used a multi-channel learning technique, with (1) individual, pair and group works, (2) reading, thinking, talking, and witting about scientific results at (3) academic and public levels. Students have developed self-regulating learning, recognized as a "fundamental goal of education" (Bandura, 1997) and a valued outcome of higher education (Hawe and Dixon, 2017). The teacher and students all enjoy novel, community-based, live Wikipedia assignments more than classic exercises. Using the freely and worldwide accessible Wikipedia Encyclopedia as a tool to communicate science to a wide audience promotes "quality education" and "reduced inequalities," two global goals for sustainable development. The exact impact on students acquired knowledge is lower than with more traditional teaching techniques, but Wikipedia page creation offers valuable other skills such as writing, editing, critical thinking, negotiation which are valuable also outside academia. Following our successful experience, we thus strongly encourage universities and teachers to include classes and exercises about communication to the non-scientific audience in their curriculum.

[5]Best articles may get the community-awarded *Good Article* (GA grade, see **Table S2** in the Supplementary Material) status and may be elected for publication on the Wikipedia main page for few hours, being then visible by thousands of visitors.

ETHICS STATEMENT

All subjects gave written informed consent for their answers to written assessment, filled anonymously, to be used and published in this study.

AUTHOR CONTRIBUTIONS

JL has initiated the project, organized, and taught the class, assessed the Wikipedia exercise, written the manuscript, and prepared the figures and tables. AG has discussed the results with JL and helped writing the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2019.00015/full#supplementary-material

Presentation 1 | Poster presented at EGU (April 2018) and ETH Learning and Teaching Fair (November 2018).

Presentation 2 | PowerPoint presentation of our teaching experiment.

Table S1 | Articles used in this course.

Table S2 | The Wikipedia grading scheme (as on the 21st of December 2017).

Table S3 | The Wikipedia page creation assessment form.

Image 1 | Results of the Teaching method evaluation: Creation of a Wikipedia page form, filled by all nine students (except question n°15, which was answered by seven students). Results of 2018 five students are also shown. Questions 1–5 were about independent learning techniques; questions 5–13 were about Wikipedia and the exercise; question 15 (and 14, not shown here) was about the class. Average (diamond) and one standard deviation (horizontal line) are shown.

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