Open Science 2.0: How Research and Education can benefit from Open Innovation and Web 2.0

Oliver Tacke

Technische Universität Braunschweig, Institut für Organisation und Führung,
Abt-Jerusalem-Str. 4, 38106 Braunschweig, Germany

Abstract. Both, Open Innovation and Web 2.0, are concepts used in commerce in order to support the collaboration of different people and the emergence of new ideas. The approaches can be adapted to science, thus offering new opportunities for research and education. If necessary requirements are satisfied, Open Science 2.0 facilitates e.g. the public development of scientific papers and the conduct of public seminars, both harnessing collective intelligence. This way, it is not only possible to improve the individual outcomes, but also to encourage the exchange between theory and practice.

1 Introduction

Solving problems can be highly inspiring and motivating, and even complicated puzzles can be solved on your own given enough time and ambition. As complexity rises, it becomes more and more difficult, though, and the modern world seems to be full of intricate issues. Finally, you cannot do it all on your own and you depend on additional resources. The traditional approach would be to get in contact with a sage expert to help you. However, several critics emphasize that one person can never possess enough knowledge in order to judge complex situations expediently, and that it may be more appropriate to use the collective wisdom of crowds [11, 31].

Taking a closer look at science reveals a similar situation: problems have become more complex and often require a joint effort in order to find a solution. Bozeman and Corley found that some of the most frequent reasons for collaborative research are access to expertise or unavailable equipment, aggregation of knowledge as well as productivity, or simply the pleasure of working with others [3]. In fact, within the last decades, collaboration in science has become more common in various disciplines and has been explored empirically. Hunter and Leahey examined trends in collaboration over a 70 year period, using a random sample of articles that were published in two top sociology journals [15].

They discovered that between 1935 and 1940 only 11% of the observed articles were coauthored, whereas between 2000 and 2005 this was true for almost 50%. This increase in collaborative research is consistent with previous findings from sociology [20], economics [19], political science [8], physics [4] and behavioral ecology [25]. Within the latter field, using Hirsch's h-index for quantifying scientific research output, Pike examined connections between collaboration and impact [25, 13]. Results show that authors with a high scientific impact are those who tend to collaborate widely with others, those who form strong bonds with collaborators, and those who are less likely to be part of a clique.

Besides the benefits for research, Bozeman and Corley also point out that collaborative efforts offer chances for enhancing education and training of students, e.g. lecturers can improve their courses continually by accessing the experience within personal networks, and students can team up for joint learning [3].

The objective of this article is to outline how science could benefit similarly from being open and how research and education can utilize Web 2.0 tools for collaboratively constructed knowledge. Consequently, the approach is called *Open Science 2.0.* Section 2 briefly depicts the theoretical foundation of Open Science, Open Innovation and Web 2.0. Section 3 specifies opportunities and applications for research and education and discusses prerequisites and possible problems. Section 4 provides examples how Web 2.0 tools can be used for joint knowledge construction, and finally, Sect. 5 summarizes the paper's findings and shows some future prospects.

2   Theoretical Foundation

Open Science 2.0 is not to be misunderstood as a whole new concept, but rather, constitutes a combination and concurrence of Open Science, Open Innovation and Web 2.0. The following three subsections will elaborate the definition of *Open Science 2.0* step by step.

2.1   Open Science

In the 19th century, popularization of science was seen as a means by which to provide national education and to overcome outmoded beliefs by rationality. Since then, popularization was put more and more on a level with vulgarization and scientists tended to see their audience in their own kind only but not in the general public; thus a gap developed between universities and society. The vast growth of available information and the ongoing specialization amplified this process [7]. As a consequence, the metaphor of 'research in an ivory tower' arose, proposing isolation from the common people. In addition, the principle of 'publish or perish' pushes scientists to keep their ideas secret until they are published; secrecy and taciturnity have become the primary directives.

Adopting this behaviour wastes much potential for innovation, especially in a society that depends on creation, sharing and usage of knowledge. Hence, new and more intensive structures of communication have to be created to support

a wide-ranging transfer of ideas between science and public: science should be opened. This does not only mean sharing prefabricated knowledge with others but also developing a mutual comprehension of problems and to work jointly on subjects relevant to theory and practice [7].

So, on the one hand, Open Science intends to intensify the transfer of knowledge e.g. via public lectures or courses, scientific broadcasts on TV or activities in museums or science centres. It also strongly encourages Open Educational Resources which are understood to comprise content for teaching and learning, software-based tools and services, and licenses that allow for open development and re-use of content, tools and services [9]. But although Open Science supports the concept of Open Access – publishing scientific literature publicly on the internet, free of charge and free of most copyright and licensing restrictions [30] – it does not necessarily comprise it. On the other hand, open scientists give insights to their whole research progress, ranging from idea collection to publication of finished articles. They inform about their scientific activity and reflect their problems openly, inviting others to be part of the problem-solving process. Thus, Open Science explicitly advocates participation of other professionals, students and amateurs, leading to an intertwined construction of knowledge. One may argue that the general public lacks the ability to make a valuable scientific contribution but this point of view ignores the fact that science often explores real-life problems. Thus, scholars can at least benefit from discussing their ideas openly, as they not only ensure relevance in practice, but possibly also see problems from a different perspective. Furthermore, there are even some fields of research that depend on the efforts of amateurs, e.g. astronomy [2].

2.2   Open Innovation

In recent years, the concept of Open Innovation has become known to companies as a new paradigm for developing products and services more efficiently. Instead of relying solely on their own internal research, some firms foster intensive exchange with external sources. The integration of customers or users into the entire development process, in particular, can be significant for the creation of value [27].

Substantially, there are three possible core processes [6]:

Outside-In Process Valuable ideas cannot only stem from inside the company but also from outside as well. It is intended, therefore, to integrate the distributed knowledge of customers, suppliers, other firms or research institutes throughout the whole process of innovation [5]. In 2007, Cisco Systems used an external innovation competition to find a new business. In the end, more than 2,500 people from 104 countries submitted about 1,200 distinct proposals, leading to the idea for a sensor-enabled smart-electricity grid [16].

Inside-Out Process Companies use external paths to market by launching spin-offs or start-ups in business areas that do not yet belong to corporate strategy. Furthermore, they can license some of their technology actively to others. Finally, companies can profit by letting spillovers happen on purpose

(so-called free revealing), thereby giving up on appropriating future rents from this knowledge through patents or secrecy, which may bring numerous advantages to a corporation [1].

Coupled Process Merging the Outside-In perspective with the Inside-Out perspective leads to the Coupled-Process. It ranges from jointly finding ideas to commercializing new products and is characterized by give-and-take. IBM, for example, used the Open Source approach for their programming environment called Eclipse. Several companies and individuals collaborated on the complex basic platform, thus saving time to market and increasing the rate of standards adoption. Still, they competed on individual products or services that can be offered in addition [23].

Comparing Open Innovation to Open Science reveals that they build on the same fundamental idea: making the boundaries between you and your environment more permeable can lead to a better outcome, since solutions that nobody could possibly predict might emerge. Although both concepts are applied to different domains, they show various analogies (e.g. solving complex problems, intense urgency for innovation, etc.), and therefore, are assumed to follow very similar principles. Hence, findings about Open Innovation will be carefully adopted for Open Science and vice versa while still taking account of possible differences.

2.3   Web 2.0

The term *Web 2.0* is not defined consistently but it is commonly associated with web-based applications enabling the socialization of content. Those tools facilitate communication and the collaborative creation and usage of information spread on the Internet, harnessing openness and collective intelligence. They are easy to use and thus remove the distinction between producer and consumer – in Web 2.0, by using a standard web browser, virtually everyone can participate in the construction of knowledge [24, 34]. Typical generic classes of applications are blogs, wikis, online community websites and media-sharing platforms but often functions and characteristics are blended, making it difficult to distinguish between them.

Using Web 2.0 for implementing Open Science and Open Innovation seems to be a natural approach, as they share the same properties such as openness and participation of a wide range of people. In conclusion, the term *Open Science 2.0* does not mean a new version of Open Science but the application of Web 2.0 services and principles of Open Innovation to the domain of research and education.

3   Application and Prerequisites

In research and education alike, Open Science 2.0 can be used throughout the entire process of problem-solving, which focuses ideas. It can be separated roughly

into three main phases with specific tasks [33]: Phase number one comprises the generation of ideas that describe your problems, finding new ideas and proposing your own ideas to others. The next phase covers the exploration and evaluation of ideas. The aim is to meld them into a plan that can probably solve the problem. The final phase is concerned with the implementation of particular ideas, their transmission to the recipient and eventually the examination of acceptance and feedback.

There is a large variety of ways how Web 2.0 applications can be used during these phases to utilize collective intelligence: reflections about one's own work, reviews about conferences visited or new ideas can be presented in blogs and discussed publicly in the commentary section. Thus, it is possible to gather supplementary input from different people, reducing the risk of ignoring important facts. Collaborative elaboration can take place in wikis, which offer a flexible and easy-to-use working environment. Members of social networks can be asked to undertake peer reviewing in order to assure quality and to provide important feedback for further improvement. The circle is complete when commenting on articles starts, e.g. in blogs.

For utilizing collective intelligence in research and education, certain requirements have to be satisfied. In general, these have been investigated by Tapscott and Williams [32] and Surowiecki [31] and can be combined for Open Science 2.0:

Being Open Openness is the fundamental requirement in order to benefit from using Web 2.0 applications in research and education. Certainly, some circumstances can be obstructive such as legal or monetary issues. In science, the motto 'publish or perish' has led to a self-serving system in which people are reluctant to share their thoughts publicly before they have been publicized – someone might steal their 'intellectual property', come up with a paper first and harvest all the fame and glory. On the one hand, this point of view neglects the fact that only few things that can be read in scientific literature actually originate from the author, as they have only been possible by building upon the work of others [18]. On the other hand, if you openly spread your ideas on the Internet, you can prove easily that you were the first one who had the idea. In consequence, the 'pirate' would not only have to fear legal measures but also punishment by the scientific community.

Some individuals might also be afraid of publicly admitting or making mistakes and hence losing prestige in their community. This applies to students participating actively in lectures or projects, to teachers having particular problems in class and to researchers as well. This fear can be hearkened back to the idea that making mistakes is always bad, although they could also be understood as chances to learn. Open Science in general, therefore, requires an attitude towards life that admits that one may be wrong, others may be right and that one perhaps could approximate the truth jointly, as Popper described his philosophy of critical rationalism [26].

One more reason for openness being a fundamental requirement can be derived from the properties of a community that is based on mutuality. If you want others to share their ideas with you and offer help, you have to act

alike. Taking an exclusively Outside-In Perspective, e.g. browsing blogs or borrowing the homework from others, may result in some additional input, but will not allow the full potential to unfold. It is crucial to contribute something to social networks if you want to benefit from them.

Finally, being open also means being open-minded. Bringing many stakeholders together can result in the emergence of conflicting ideas. They should be discussed without prejudice and without a precise goal in mind beforehand. Giving up some control and abandoning a devised plan can be more beneficial than sticking to it. This means a higher level of uncertainty but something completely new and unexpected can emerge.

Endorsing Diversity A wide range of different perspectives can help to find better solutions to a problem, and so by making research and education public, you can gain access to many thoughts, ideas and opinions that you would miss otherwise. The more people that offer support, the better the outcome may become, so it is important to maintain a large network and activate it in due time. Web 2.0 applications seem to be particularly suitable for this intention because they even allow people with little technical skills to contribute their opinions. Those would possibly be missing otherwise. To ensure diversity, it is also necessary for people to specialize and to draw on local knowledge. This means that they have to act in a decentralized way so as to prevent the emergence of groupthink [10]: if you always discuss problems with the same fellow students, it is likely that you will not consider all possible alternatives to a solution, as the desire for unanimity exceeds the desire for quality decisions.

Another aspect related to the independence of opinions is hierarchy. Within the present system of research and education, there is a vast gap between professors, scientific assistants and students. Knowledge that is presented from a 'higher authority' is seldom questioned or contributed to, even though Humboldt demanded an exchange of ideas between lecturers and listeners 200 years ago [14]. To support innovative ideas, it is crucial to create a non-hierarchical environment and it can be necessary to restrain one's own personal ambitions. For example, lecturers should not think of themselves as superior to the students but as a *primus inter pares*, as part of a network. This way they can establish an atmosphere where ideas can emerge unhindered because the supposedly inferiors do not remain silent.

Merging Opinions Finally, all the ideas have to be aggregated and individual thoughts have to be melded into a collective decision. This process is particularly difficult and adequate methods for this process yet have to be found. Nonetheless, Web 2.0 applications offer several platforms for letting many people cooperate.

In addition to these requirements for harnessing collective intelligence, according to Martin [21], persons solving problems in groups have to possess a sensitivity for networks. They have to be able to grasp the interdependencies occurring cognitively and emotionally. Web 2.0 applications, such as online community platforms for social networking, can support this sensitivity by unearthing

the structure of links between persons and groups.

Most of the requirements described above can be satisfied by acting upon the neuron metaphor [22], which interprets humans as neurons of a brain obeying certain rules. They do not hold back their knowledge but 'fire' new impulses as soon as a certain action potential has been exceeded. That does not imply spreading any thought crossing one's mind, but rather, conceptualizing a proper statement and then feeding it to the non-hierarchical neural network without being afraid of embarrassing oneself. In addition, humans seen as neurons should react quickly and should also try continuously to connect to other neurons. This can be achieved by providing much information about oneself and offering motivating projects, thus giving others chances to find common ground for cooperation. Finally, neurons accept uncertainty and bear it.

4   Examples

Subsequently, I will present two examples illustrating how Web 2.0 applications are already used in research and education. The first example reflects my personal experience of writing scientific papers according to the methods mentioned above, and can be connected with action research [12]. The second example describes the experiences of Spannagel and Schimpf [29] and Wiley [35] with public seminars or open teaching, giving students the opportunity to learn in a context-sensitive environment.

4.1   Writing Scientific Papers

Scientific literature is a well-established medium for spreading information and can be considered a resource for learning. However, opening the entire process of scientific construction of knowledge can be even more valuable – being able to participate is not only more motivating for others, but also enables them to learn firsthand, instead of just reading finished compositions.

In order to gather ideas for new projects, I read several scientific and non-scientific blogs and discussed the articles with the authors. I also read the latest papers to keep up with progress, but I observed that discussions on the Internet are by far more up to date and offer a broader perspective. In presenting my premature ideas, I use a public wiki at Wikiversity, which serves as my lab notebook[1];it also contains the first idea collection to this very paper. Usually, I begin with a brief description of the initial point and then I sketch out the contemplated course of the study, followed by a short list of sources that might be useful. The bottom of the page contains a discussion area where anyone can comment or add suggestions.

Of course, in most cases, it does not suffice to make your ideas public; you have to encourage people actively to team up with you. Firstly, I advertise my

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[1] My public lab notebook can be found at http://de.wikiversity.org/wiki/Benutzer:O.tacke.

sketches in several social networks of which I am a member. Secondly, I feed information into Twitter[2] [28], requesting comments. If the worst comes to the worst, there is no reply at all; in comparison to the ordinary process of writing scientific papers, this situation is neither better nor worse. However, at best, those who read my message forward it to others, thereby spreading my information even further. Usually that is already enough to stir up enough interest to gain some valuable input.

In this particular case, in the early phase of idea generation I received three hints from two persons, both professors of pedagogy. In the wiki, they recommended several resources related to the subject, some of which I actually used in the end. Besides the page connected with this very article, there is also a section where I openly collect ideas for projects or papers. One of them deals with publishing students' papers and received feedback from three different people, among them one of the professors mentioned above, one student of business information systems and one scientific assistant which I did not know before. They made four suggestions which I will have to further evaluate when I eventually tackle the project. There are also some pages with ideas that have not received feedback so far, but I have not asked for either.

While progressing, I 'tweet' brief status reports, findings or difficulties. This way, on the one hand, others can learn about results before the paper is finished and published. On the other hand, I can receive further input or assistance in return continually. For example, when I publicly stated that writing papers in English was hard for a non-native-speaker, I received an offer for help[3] within a few minutes. Apparently, this approach mimics the Coupled Process from Open Innovation in commerce.

After preliminarily finishing this article, I posted it to a special social networking platform[4], which fosters the open exchange and feedback between people interested in science - not necessarily scientists. I also announced the availability via Twitter, asking for an open peer review. This way, I intended to assure quality once more before submitting the paper, and in fact I received valuable comments from two people, among them one student and one researcher in the field of media education. The suggestions from the latter were particularly useful as they pointed out weaknesses which I would not have noticed otherwise.[5]

This approach could also be applied to term papers or theses. In fact, few days ago, a student of mine announced that he was going to use a wiki to elaborate a term paper completely in public. One might argue that it will not be clear whether he really wrote it himself but that is quite normal and ignores possible advantages: firstly, my student can benefit from the same effects that I described

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[2] Twitter is a popular microblogging service facilitating a swift spreading of information, sending messages means 'to tweet', see http://twitter.com.

[3] see   http://twitter.com/otacke/status/6017200536   and http://twitter.com/mons7/status/6017385208

[4] see http://wissenschaftler20.mixxt.de

[5] Additionally, I would be glad to receive public feedback from as many readers or participants of the conference as possible in order to learn.

above. Furthermore, I cannot only examine the final result of his efforts but I can also monitor the development progress, giving me more information about problems about which I should possibly take care: I can learn about particular difficulties in which students engage. Last but not least, the 'scientific literacy' of the public can be fostered this way.

4.2   Public Courses

Independently, Spannagel[6] and Wiley[7] opened some of their academic courses that had been held traditionally so far. Students were encouraged to post their homework on their personal, publicly accessible blogs and to discuss their ideas in a wiki open to the public. Both lecturers then invited others to join via blogs, Twitter and personal invitations. As a result, several people joined in and debated with the students.

In the particular case of Spannagel, his seminar's subject was a special method of teaching (LdL)[8] which was intended to be adopted for didactics of computer science. The students had to find out the theoretical foundations of the method for themselves and discussed their findings in an open wiki. Spannagel reported about the seminar in his blog and and via twitter and did not foresee what would happen: external individuals joined the discussions about LdL, among them even its inventor, Jean-Pol Martin. This experience was highly motivating for the students and they suddenly discussed issues with Martin's pupils in nineth grade. Additionally, a trainee teacher learned about the special method from the students' wiki and tried it in one of his courses. Finally, he and Spannagel's students worked together: while he reported about his experience from practice, they developed teaching modules he could use. The results are still available[9] and can be used freely.

The added richness of broader perspectives from the outside led to higher motivation for the students and the informal participants of the course could hugely benefit as well. All this innovation could not have happened in that way if the teaching had not been opened to public discussion via Web 2.0 applications, allowing for the use of diverse knowledge from outside.

The approaches of Spannagel and Wiley reflect ideas of Personal Learning Environments (PLEs) that are a quite new approach to using technologies for learning. Whereas dominant Learning Management Systems, such as Moodle or Sakai, focus on the provision of prefabricated information and tools within a course context, PLEs are concerned with enabling a wide range of individual contexts to be adapted to the users' needs. Furthermore, they soften the distinction between the capabilities of learners and teachers by allowing any user

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[6] Christian Spannagel is a professor of mathematics, computer science and teacher training at the University of Education in Heidelberg.

[7] David Wiley is an associate professor of instructional psychology and technology at Brigham Young University.

[8] LdL is the abbreviation of 'Lernen durch Lehren' (learning by teaching).

[9] see http://de.wikiversity.org/wiki/Kurs:Fachdidaktik_Informatik

to both consume and publish content – just as Spannagel's students did in their wiki. Additionally, PLEs are concerned with sharing resources, not protecting them [36, 17]. These characteristics resemble to the attributes of Web 2.0 services described in section 2.3.

5   Conclusion

In this paper, possible benefits of applying Open Innovation and Web 2.0 to research and education were outlined. Open Science 2.0 embraces collaborative construction of knowledge and can lead to more diverse input for solving problems and also to more motivation for the participants. However, in order to yield the best results, several requirements have to be satisfied. The stakeholders need to be open-minded, willing and able to share their ideas unreservedly without fear of embarrassment or 'intellectual theft'. In addition, diversity has to be endorsed, and so, a wide range of different perspectives has to be appreciated, regardless of the hierarchical position of the contributors. Furthermore, there have to be adequate mechanisms for aggregating the different ideas and merging them into a solution.

Web 2.0 applications facilitate communication and the collaborative creation and usage of information. The Web 2.0 community is just as much based on openness and mutuality and constitutes an ideal environment for the approach of Open Science if the participants can develop a sensitivity for networks. Acting upon the neuron metaphor by Martin is a possible way to gain this competency.

One of the difficulties with Open Science 2.0 is that it contradicts the prevailing notion of research and education in some respects. It is sometimes even regarded as second-class science. Although the two examples presented in this paper show that it is already applied occasionally and that it leads to good results, more convincing research is necessary and critical issues have to be clarified, such as dealing with plagiarism or coping with the dominant 'publish or perish' system mentioned in section 3. Another problem could be seen in the amount of time which has to be spent for networking with others, sharing ideas etc. in order to benefit from collaboration, but then again, there is no such thing as free lunch.

As future work, it is planned to integrate open microblogs in educational events in order to research how knowledge of students and informal participants from the outside can be combined and complex problems can be solved using collaborative intelligence.

Acknowledgements

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