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# What do we know about the effects of Citizen Science on Participants' Knowledge?

**Lena Finger[a],* Vanessa van den Bogaert[a], Katrin Sommer[a] and Joachim Wirth[a]**

*a Ruhr-University Bochum,*
*Universitätsstr. 150, 44801 Bochum, Germany*

*E-mail:* lena.finger@rub.de

One of the central goals of Citizen Science (CS) is to provide individual benefits for participants, such as promoting interest as well as building knowledge (effects on personal characteristics). There is an increasing number of empirical studies that investigate how participants benefit from CS in terms of increased knowledge. Since the question of what benefits participants can derive from CS also relates to the motto of the Austrian Citizen Science Conference 2022, parts of this manuscript were presented in a talk. To enable generalizable conclusions about the effect of CS on the participants' knowledge, we summarize the results of those studies systematically and their results are reflected against the background of their research designs.

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## 1. Theoretical Background

CS is a modern means of science communication and pursues both scientific and educational goals [1]. Phillips and colleagues [2] developed a framework for evaluating the effect of CS projects on individual outcomes of the participants (educational goals). In this framework, individual outcomes likely to be influenced by participation in CS are divided into different categories. One of these categories is knowledge and includes both the knowledge of scientific processes and the knowledge of project content. An increase in knowledge is a meaningful basis to initiate behavior change in participants as it may not only lead to reflecting one's own behavior (cognitive level), but it highlights the relevance of the topic to the participants and increases personal significance (motivational level). Even though, an increase in knowledge is not a sufficient precondition for changed (e.g. ecological) behavior [3, 4].

## 2. Evidence for effects of Citizen Science on knowledge

So far, there are already some reviews that synthesize the empirical evidence regarding the effects of CS on knowledge from numerous individual studies [5, 6].

Peter and colleagues [5] found 608 studies on the effects of biodiversity CS projects on participants and analyzed 14 studies in more detail. All studies investigating knowledge of project content found an increase as a result of participation in CS, whereas studies investigating knowledge of scientific processes merely found an increase in knowledge. However, in most cases, the empirical studies lack a sound methodological approach. Aristeidou and Herodotou [6] analyzed 10 studies out of a total of 75 studies found on online CS programs. On the one hand, they analyzed the impact of citizens' participation in online CS programs on learning. On the other hand, they analyzed the methods and instruments used to capture learning from citizens' participation. Many studies reported an increase in topic-specific knowledge and overall, as well as a positive correlation between the level of engagement and the amount of knowledge gained. This correlation could not be shown with respect to scientific knowledge. However, the authors found that a large part of the studies (N=8) used self-reports to assess outcomes of participating in CS. Some studies used further measurement instruments like project questions (false/right) or surveys (e.g. Informal Learning in Citizen Science Scale). Only two studies used a pre/post design. In view of the existing studies, the authors recommend the inclusion of control and experimental groups in the future.

To sum up, many empirical studies suggest that there is empirical evidence to support the assumed potential of CS projects to increase knowledge. However, the methodological approaches of these studies do not justify this suggestion. For example, they used self-report measures instead of performance tests or they only implemented one measurement point after participation in CS.

Within a systematic literature search (papers with the term "citizen science" in their title published until April 2020 in German or English), n=38 studies could be identified from a total of N=1159 hits that investigated a possible increase in knowledge on scientific processes or on the project's topic through participation in a CS project.

N=29 studies reported a (significant) change in knowledge [e.g. 7]. This increase is determined in most cases by self-reported methods (questionnaire, interview). However, the use of self-reports to measure knowledge is problematic. An individual's self-assessment of his or her knowledge, which is assessed via a questionnaire, is a different construct than actual knowledge about project content or scientific processes [8]. Further, self-assessment is often inaccurate, i.e., a self-assessment of one's own knowledge cannot be used to infer actual knowledge, as overestimation often occurs [9].

To validly assess the knowledge of the participants, a knowledge test is to be used as a measuring instrument, in which an individual performance can be evaluated as more or less good [8]. For example, the study by Forrester and colleagues [10] used a quiz in which the participants receive points for the correct answer. It was found that the participants in the CS project eMammal (N=210) significantly increased their wildlife knowledge at the second measurement point, whereas the control group (N=263) did not show any significant increase in wildlife knowledge.

Similarly, Masters and colleagues [11] used a science knowledge quiz in five different CS projects to measure the knowledge of participants (N=1921) in a posttest. It was shown a relationship between the extent of participation in CS and project-specific science knowledge, but not with general science knowledge. However, a posttest-only-design does not allow to measure actual knowledge gain [12].

Among the N=35 studies analyzed, there were hardly any other examples of the use of a knowledge test. The fact that only few studies have used such a knowledge test makes it difficult to draw valid conclusions about the effect of CS on participants' knowledge.

### 3. Outlook

Even though there have been some promising study results regarding an increase in knowledge through participation in CS, no reliable statement can yet be made about the increase in knowledge resulting from participation in CS projects based on the studies conducted to date.

There is a need to measure the knowledge of participants in future studies by using adequate knowledge tests [13]. This raises not only the challenge of developing such knowledge tests, but also the general complexity of surveys in the CS context, in which participants should be recognized primarily as researchers rather than becoming research subjects themselves.

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