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Citizen science and geomorphology: the citizenMorph pilot system for observing and reporting data on landforms

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Abstract

Contributory citizen science projects face challenges regarding data quantity and quality. To counteract this, the projects must be centred around citizen needs and preferences, while considering aspects such as the data contribution process, including instructions, project promotion, information provision, feedback and recognition, and the design of the respective elements. Based on an understanding of the relevance of these issues affecting data contribution systems, we must determine which elements we can use to meet citizens’ needs and preferences and how to better tailor the system design to citizens’ requirements. The citizenMorph project, which aimed to create a pilot system for citizens to collect and report data on landforms, focused on the development of a citizen-centric system with elements that foster and encourage citizen engagement. We used a specifically conceived development workflow that combined participatory design with the prototyping model to involve citizen representatives in different ways and to different degrees in requirement specification, system design and implementation, and testing. This allowed citizens’ requirements to be specified and comprehensively considered in the citizenMorph system. Based on the input of citizens who were involved in the development process, the citizenMorph pilot system includes a data contribution application and a project-related website with several project-specific elements that focus on attracting and recruiting citizens to participate and increase their initial and ongoing engagement and willingness to report landform data. This includes traditional and web-based promotion elements, a specifically designed information strategy that considers information detail, depth and presentation media, project and task-tailored data contribution instructions and support, and the possibility for users to find and view the data they contributed on a web map.

1. Introduction

Citizen science has been used in many domains, including those concerned with environmental issues (Schaffer and Tham 2020, Peter et al 2021). Of the different forms of citizen science, i.e. contractual, contributory, collaborative, co-created, and collegial (Shirk et al 2012), contributory projects constitute the majority (Bonney et al 2009a, Kermish-Allen et al 2017, Fischer et al 2021, Land-Zandstra et al 2021). Contributory projects include passive sensing, crowdsourcing, environmental/ecological observations, and participatory sensing (Shirk et al 2012, Haklay 2021).

Advances in information and communication technologies have created new possibilities for contributory citizen science, i.e. to integrate the public, their knowledge, resources, and commitment to scientific research (Bonney et al 2009b, Fischer et al 2021, Peter et al 2021). This includes using geospatial technologies to allow citizens to generate and report spatial data (Haklay 2021, Skarlatidou and Haklay 2021). Such contributory projects are thus related to the concept of voluntary geographical information (Haworth et al 2018, Haklay 2021), which describes the use of online platforms to involve citizens in the voluntary creation, assembly, and dissemination of spatial data (Goodchild 2007, Brown and Kyttä 2014),
whereby data contribution is based on mapping activities or implicitly associating data with geographic locations through geotagged photographs or microblogs (Craglia et al 2012, Senaratne et al 2016).

Several benefits are associated with contributory citizen science: provision of data that are otherwise unavailable or difficult to obtain, such as people’s observations, their local spatial knowledge, and how they perceive, experience, value, and use infrastructure or resources (IFAD 2009, Brown and Kytta 2014, Herfort et al 2015). Data generated in the context of citizen science can cover a large geographic scale and a long period (i.e. to support monitoring), which is often challenging for traditional data collection approaches because of staff and budget constraints (Cohn 2008, Herfort et al 2015). Citizen participation promotes learning and acquisition of scientific and digital skills and knowledge related to the topic under consideration (Hecker et al 2019). However, contributory citizen science also faces challenges. The number of citizens willing to contribute to an initiative is often less than expected, citizens can be difficult to reach and engage with, or they close the application without contributing much or any data (Nielsen 2006, King and Brown 2007, Crowston and Fagnot 2008, Morais et al 2013). Another disputed topic is data quality, which covers, for instance, precision and accuracy, validity and reliability, completeness, consistency, timeliness, fitness for intended use, and bias (Balázs et al 2021, Downs et al 2021). Depending on the number of contributors, their level of domain-related knowledge, digital skills, and motivation, the quality of their contributed data can vary (Bonney et al 2009b, Haklay 2013).

To fully exploit the potential of contributory citizen science projects and to address the challenges of ensuring that data are collected and reported in sufficient quantity and quality, applications must be centred around the users (i.e. citizens) and their needs and preferences (Haltofová 2020, Hennig 2020, Silva 2020). Methods and tools are required to promote projects because people can only contribute to a project they know about (King and Brown 2007, Schaffer and Tham 2020). Relevant project-related information (Butt 2015), including support for data contribution activities (Schaffer and Tham 2020), must be adequately conveyed. Feedback and recognition also play a key role since their absence results in citizens dropping out of a project (Veeckman et al 2019, Fischer et al 2021). Applications must be designed to make them attractive, easy and comfortable to access, intuitive, and fun to use (Newman et al 2010, Mooney et al 2016, Fischer et al 2021). These aspects, which are also considered success factors for contributory initiatives, should be considered when developing systems that enable data contribution in the context of citizen science (Asingizwe et al 2020, Haltofová 2020, Hennig 2020, Schaffer and Tham 2020). A combination of different components, elements, and materials (i.e. building a system) is thus relevant for contribution to citizen science projects. The question is, which elements can we use to actually meet citizens’ needs and preferences and how can we better tailor the system design to their requirements? In the citizenMorph project (Observation and Reporting of Landscape Dynamics by Citizens; 2018–2020; https://citizenMorph.sbg.ac.at/), we aimed to address these issues for a geomorphology-related application. The focus was on the development of a citizen-centric system, in which the data (contributed by citizens) is used in further analysis steps.

2. Methods

2.1. The citizenMorph project

The citizenMorph project aimed to develop a pilot system that allows citizens to collect and contribute field data on landforms (location, landform type, geotagged photo for the overview of the landforms observed, and collection of images for multiview 3D reconstruction). The intention was to add a citizen science component to a larger research project (MORPH—Mapping, Monitoring and Modelling the Spatio-Temporal Dynamics of Land Surface Morphology; 2016–2020), which focused on studying natural hazards and geomorphological features using remote sensing and enrich and broaden its outcomes with citizens’ field data (figure 1).

Although novel methods for analysing the spatial-temporal dynamics of surface morphology by integrating various optical and radar remote sensing data have recently been developed (Dabiri et al 2020), there is still a high demand for data gathered directly in the field (e.g. for reporting and describing recent geomorphological events, landform characteristics, and landscape changes). Field data are of great importance for enriching and validating aerial and satellite remote sensing-based mapping results, as well as for increasing their detail and information content. Data collected in the field can aid spatial accuracy assessments, support change detection analyses, reveal unknown landscape information, and pinpoint details that are not visible in remote sensing imagery due to, for example, limited spatial resolution or the viewing angle. For example, small glacial features, such as hummocks, might not be detectable on remote sensing imagery but can be recognised in the field. Field photographs can also be used for multiview 3D reconstruction of the surface using structure from motion (SfM) and dense image matching methods (Remondino et al 2014, Brush et al 2019).

Thus, high-quality field data and remote sensing data are important for comprehensive analysis and broadening our knowledge about geomorphological landscape dynamics and the prevalence of landforms (Napieralski et al 2013). The integration of (multitemporal) data from different sources facilitates the creation of more detailed and up-to-date
2.2. Workflow and development approaches

The development of the citizenMorph system relied on the combined use of participatory design and the prototyping model. Participatory design involves users (referred to as ‘citizen representatives’ in the following) in all aspects of an application development process, such as requirement specification, design, implementation, and product testing (Baek et al 2007, Majid et al 2010, Wilkinson and De Angeli 2014). The close cooperation with the future users of a product gives us a better understanding of their requirements and skills and enables us to produce applications that allow users to achieve outcomes in a better way (Steen et al 2007, Muller and Druin 2012).

The prototyping model is an evolutionary software development process model. It is particularly suitable when the requirements of future users of a product are not well understood at the beginning of a development process or when developers are dealing with an unknown or new topic. The iterative nature of this model is crucial. Based on an initial specification, the product requirements are continuously developed and improved until the users are satisfied. This relies on an iterative loop of design, implementation, and discussion of prototypes. Then, the final requirements are specified and form the basis for the design, implementation, and testing of the final product (Agarwal et al 2010, Kumar 2021).

Combining participatory design and the prototyping model, the workflow for the development of the citizenMorph system comprised four steps (figure 2): (a) specification of citizens’ initial requirements, (b) development and discussion of prototypes by citizens, with further specification of citizens’ requirements, (c) system design and implementation, and (d) testing. Citizens were involved in these steps to varying degrees and in numerous ways.

Figure 1. The citizenMorph concept.

Figure 2. General workflow of the citizenMorph pilot system development.
### Table 1. Items covered by the online questionnaire for citizens.

| Groups                  | Items                                                                                     |
|-------------------------|-------------------------------------------------------------------------------------------|
| Socio-demography        | • age (open question)                                                                     |
|                         | • place of residence: country and zip code (two open questions)                           |
|                         | • civil status (closed question)                                                          |
|                         | • gender (closed question)                                                                |
|                         | • level of education (closed question)                                                    |
| Citizen science         | • knowledge of citizen science (closed question)                                          |
|                         | • liked best about citizen science (open question)                                        |
|                         | • examples of citizen science projects (open question)                                    |
|                         | • topics of interest (closed question, multiple choice)                                   |
|                         | • preferred form of participation: e.g. alone or with others (closed question)             |
| Elements/ components    | • amount of information (closed question)                                                 |
|                         | • media to provide information (closed question, multiple choice)                         |
|                         | • type of information provision (closed question, multiple choice)                        |
|                         | • desired functions, e.g. regarding communication and exchange (closed question, multiple choice) |
|                         | • experience with web maps (closed question, multiple choice)                            |
|                         | • joy of use when working with web maps or spatial data (closed question)                  |
|                         | • content of web maps (closed question)                                                   |
|                         | • additional comments (open question)                                                     |

#### 2.3. Work steps

##### 2.3.1. Step 1: specification of citizens' initial requirements

An online survey was conducted to gain insight into citizens’ needs and backgrounds. Created with SurveyMonkey, it contains open and closed questions covering different items in three groups (table 1; https://de.surveymonkey.com/r/citizenMorph). Cooperation with citizen representatives in its creation ensured that the questionnaire was tailored to citizens’ needs (e.g. avoidance of technical terms). The survey was conducted in German-speaking countries between August and December 2018 and promoted through e-mail, newsletters, social media, and word of mouth. The data provided by the questionnaire were statistically analysed. A quantitative content analysis was used to analyze open questions.

##### 2.3.2. Step 2: prototyping

Citizens’ contribution to prototyping took place between winter 2018 and summer 2019. After an introduction to methods and tools, citizens in small groups developed prototypes that corresponded to their needs and ideas for recording and reporting landforms. During four workshops and independent group work, the prototypes were implemented using ESRI’s Survey123 for ArcGIS Online. They were discussed by citizens and scientists, and additional citizen requirements were identified.

##### 2.3.3. Step 3: design and implementation

Taking the citizens’ needs (step 1, step 2) into account, the data contribution application and related materials were developed (e.g. information provision, instructions, giving feedback and recognition). The data contribution application was created by the scientists using ESRI’s Survey123. The related material was created in different ways, by the scientists, citizen representatives, or by scientists and citizen representatives together (summer 2018 and 2019). This relied on the use of the content management system (CMS) WordPress, ESRI products, and different multimedia tools. Ethical concerns (e.g. handling of personal data, intellectual property rights) were discussed and approved by the Legal Department and the Data Protection Coordinator of the University of Salzburg (Austria).

##### 2.3.4. Step 4: testing

Citizens tested the pilot system for acceptability, usability, and accessibility during excursions to (a) the German Berchtesgaden National Park and Austrian Weißbach Nature Park (11 July 2019) and (b) Hofn, Iceland (5 September 2019). After contributing landform data using the citizenMorph system during their field trips, participants reported on the citizenMorph system and its use in subsequent group discussions, see Downey (2007) for more information about group usability testing.

#### 2.4. Citizen involvement

Numerous citizen representatives from diverse backgrounds, including special needs users such as youth and the elderly (Kirakowski et al 2003), took part in the development process. This allows the creation of more useful and accessible solutions that benefit all users, which is particularly important for applications aimed at the general public a heterogeneous group of people with different backgrounds, knowledge, and requirements (Haklay and Tobón 2003, Steinmann et al 2004). Special needs users play a relevant role in application development since they are very demanding, critical, and sensitive to usability and accessibility issues (Brown and Hollier 2015, Gottwald et al 2016).
Table 2. Citizen representatives: recruitment strategies, background, and type of involvement in the development process.

| Steps/tasks | Citizen representatives (recruitment) |
|-------------|--------------------------------------|
| Requirements specification (citizen questionnaire) | Two high school students older than 16 years (employment contract, i.e. four-week internships) |
| Prototyping | Design | Eight older/ senior persons (project partnership/ cooperation with University 55-PLUS, Austria) |
| Prototyping | Discussion | Eight older/ senior persons (project partnership/ cooperation with University 55-PLUS, Austria) Fourteen young adults (project partnership cooperation with University of Salzburg, Austria) |
| Design and implementation | Data contribution application | No citizen involvement |
| Design and implementation | Additional elements/ material | Two high school students older than 16 years (employment contract, i.e. four-week internships) |
| Test | Eight senior persons (project partnership/ cooperation with University 55-PLUS, Austria) Three young adults (cooperation with University of Salzburg, Austria) Ten high school students older than 16 years (project partnership/ school cooperation: Framhaldsskólinn í Austur-Skaftafellssýslu, Iceland) Five adults (cooperation with Vatnajökull National Park, Iceland) |

Loranger and Nielsen 2013, W3C WAI 2016). Citizen representatives were recruited in different ways (table 2) based on cooperation (i.e. project partnership) with the University of Salzburg, including the University 55-PLUS (Austria), the high school Framhaldsskólinn í Austur-Skaftafellssýslu (Iceland), the Vatnajökull National Park (Iceland), and employment contracts (four-week internships) with high school students.

3. Results

3.1. Citizen requirements
3.1.1. Questionnaire results
Hundred and thirty eight people participated in the online questionnaire intended to specify citizen’s initial requirements. Selected results are shown in the appendix. Sociodemographic aspects of the questionnaire results are shown in figure 10. Most respondents had not heard the term ‘citizen science’ before (table A1), and only a few had previously participated in citizen science projects. The quantitative content analysis revealed that what the citizens liked best about the citizen science projects was that they could contribute, learn something new, and collaborate with others. None of the citizen science project examples provided related to geomorphology. Only a third of the participants declared interest in the topic of geomorphology for citizen science projects (table A1).

In terms of their preferences for a citizen science application (table A2), most respondents indicated that their preferred means for receiving information is text with pictures, and videos. Enough background on the project and clearly stated aims and objectives were considered important, and the option of face-to-face contact with others was also highlighted. Previous experience contributing to online maps was limited (20% contributed spatial data or performed map editing; table A3), but the majority were familiar with online maps for route planning, orientation, and address searches. Almost half of the respondents said they enjoy working with online maps and spatial data.

3.1.2. Prototyping
Three prototypes were jointly developed with citizen representatives (senior citizens). The discussion rounds focused on the main topics highlighted in section 1: (a) project promotion, (b) the type of information provided, including support and instructions, (c) the data contribution process and the design of the application, and (d) feedback and recognition (figure 3).

3.2. The citizenMorph system
Based on the citizen’s requirements (i.e. questionnaire findings, prototype discussions), the citizenMorph system consists of two interlinked web-based components (figure 4): a data contribution application and a project-related CMS website. Web-based methods and tools as well as traditional analogue methods and materials were used to inform and recruit citizens to participate in the project.

3.2.1. Data contribution application
The data contribution application was developed as a browser-based Survey123 smart form, which is an online questionnaire with information and instructions. The application allows users to contribute (spatial) data on landforms on-site or at home using different devices, such as mobile devices or desktop computers. The application can be used without registration or login. After a short welcome, the citizenMorph project is introduced, whereby participants can choose between written information,
Figure 3. Citizens' requirements collected during prototyping.

a video, or different audio files. All information is kept short and to the point, irrespective of the chosen media. Further information is available on the project website and can be accessed through links from the application.

The application provides different questions for participants to report on landforms (figure 5). This includes a map-based question to locate and map the landform and two image questions to upload photos of the landform (overview photo and photo series). The use of branch-logic (i.e. subsequent questions are only presented according to previous responses) supports citizens in categorizing landforms. While completing the survey, citizens can directly enter the type of landform (if known) or be guided. If guided, different landform categories are presented. Once the category is chosen, the associated landforms are displayed for selection. Only the 'consent of use' question is mandatory. No personal data is collected. Participants can optionally provide an e-mail address, used to send additional information about the project. To guarantee that no personal data is collected, participants are requested to add only e-mail addresses that do not include their first name and last name, and company name (i.e. first_name.last_name@company_name.com; EC 2022). The e-mail addresses are checked and deleted if they do not correspond to these requirements.

Although the application was created to be as self-explanatory as possible, instructions on landform categorization, mapping, and taking photos are available. Clear and easy to follow instructions were created with the support of the citizen representatives. Particular attention was paid to avoiding technical terms. Instructions are optionally available with varying degrees of detail and depth, both in written text and audio files (figure 6). The audio files (approximately one minute) were implemented in the form of a question-and-answer dialogue.

For landform identification and categorization (i.e. branch-logic), citizens are supported through specifically created landform factsheets that include a short and easy-to-understand description of the
landform with sketches and/or images showing the landform (figure 7).

Thus far, 28 factsheets have been created (figure 8), grouped into five landform categories: mass movement related, glacial, volcanic, and coastal features, and other landforms. The landform classification corresponds to approaches commonly used in geomorphology (Huggett 2011). Additional landform categories and landforms (including factsheets) can easily be added.

3.2.2. Project-related CMS website
The CMS website contains comprehensive information on different project-relevant aspects and complements the content of the data contribution application. It includes project information, i.e. aims, relevance of the topic (from the citizens’ point of view), domains behind the project (geomorphology, geoinformatics, remote sensing, and citizen science), and the project team, with contact information. The relevance of the field of geomorphology to the daily lives of citizens and the topicality of landscape dynamics regarding natural hazards and their connection to climate change are emphasised and explained. This also includes details about how the data is used. In addition to the data contribution instructions provided in the application, the project website contains information about safety measures when collecting data on-site and about data protection issues (e.g. data privacy, options to contact the project team in the case of questions, or to withdraw consent of use).

The citizenMorph website also contains information on project progress and results, displayed as a photo gallery, an event timeline, a list of publications, an embedded web map, and an external link to a dashboard that gives insights into the landforms reported by the citizens. The web map is the main element of the citizenMorph dashboard, which has several functionalities. For example, participants can search the map for the landform data they submitted (if a username was added). A pop-up appears with the
corresponding landform attributes when any landform feature on the map is clicked. The left panel of the dashboard displays the project logo, funding information, and the number of contributions. The right panel shows the locations and interactive 3D models of the reconstructed landforms generated
from the photo series using SfM techniques (figure 9). 3D models are generated only for those contributions where the photo series fulfilled basic requirements (several photos from different angles with a certain overlap). Before being included on the web map, citizens’ contributions go through an automatic and expert-based quality check (to ensure consent of use granted, correct location, landform assignment, photo content).

4. Discussion

The combined use of participatory design, a prototyping model, and traditional requirement analysis methods revealed several elements required to build a citizen-centric system. Considering users’ needs in project promotion, the design and implementation of instructions, information provision, feedback and recognition, and the design of the respective elements (figure 3; tables A1–A3), contributes to overcoming shortcomings in the quantity and quality of data reported by citizens.

Regarding project promotion, citizen representatives suggested various analogue and web-based techniques and tools. They highlighted the importance of in-person events, including the involvement of topic-related stakeholders to increase awareness of the project and the number of participants. The citizenMorph project took this into account through dedicated teaching activities and participation initiatives. These were carried out together with stakeholders, especially from the education sector. It must be highlighted that face-to-face contact is useful not only to increase interest, introduce the topic, explain the methods of data collection and reporting but also to build and maintain a project community as an important motivator for participants’ ongoing engagement (McCully et al 2011, Cooper et al 2021).
This is similar to other citizen science projects, such as Info Flora\(^1\) or Goldschakal\(^2\), which include in-person events as part of their promotion strategy.

Citizen representatives identified several key aspects related to data contribution activities (table A2), including instructions and tasks being clear, short, simple, and less work-intensive, which corresponds to findings in the literature (Rambaldi et al 2006, Newman et al 2010, Schaffer and Tham 2020). Considering citizens’ needs is key in this context, as participation and survey design influence participation rates and data quality, i.e. validity, reliability, and consistency (Fagerholm et al 2021).

Before citizens start contributing data, they must be on-boarded to the citizenMorph system. Since not everyone who enters a website or application engages with it, becomes a user, or contributes data, this deserves special attention (Agarwal et al 2010, Morais et al 2013). In the citizenMorph system, the user on-boarding process embraces various aspects that address the different needs of the citizen representatives: (a) no registration and login process, (b) a brief introduction to clarify the importance of contributing to the project (text, video), and (c) context-related, clear, and brief instructions (text, audio files) with the possibility of accessing further information if desired (external links from the application). These aspects are in line with the need for a smooth user on-boarding process, considering that low access barriers at first contact with an application contribute to a higher number of participants. With cumbersome and inconvenient access, poor design, and lack of support, people will likely close an application without participating (Renz et al 2014, Fischer et al 2021).

With regard to the user on-boarding process of the citizenMorph system, the topics of registration and login were discussed controversially during the test events. On the one hand, the possibility of contributing data without registration and anonymously was considered positive, simplifying and speeding up the contribution process and counteracting data privacy concerns. On the other hand, testers argued that having a registration option would encourage community building. Jay et al (2016) found that omitting the registration step increases contribution to citizen science projects by more than 60% but giving the option to create an account voluntarily raises contribution rates as well.

The use of a video to introduce the project (as part of the on-boarding process) was seen as a viable alternative to written text by the testers. This confirmed the questionnaire findings (table A2) and is also in line with other citizen science projects such as Picture Post\(^3\) and Coastwards\(^4\), which use videos to present the topic, the aim, and the contribution process.

Citizens emphasised the key function of information provision in citizen science projects (table A2). Apart from project information and data contribution instructions, the questionnaire results (table A1) and prototype discussions with citizen representatives (figure 3) stressed the need to raise public awareness of citizen science and geomorphology. This is underlined by literature: Goudie and Viles (2014), for instance, found that the public’s understanding and appreciation of geomorphology are lower than in other nature-related areas, like species and ecosystems. Thus, the question of how geomorphology can be made more relevant and engaging remains (Simms 2008), and as emphasized by Giusti (2010) the need for appropriate educational programs is clear.

The citizenMorph system addresses this in different ways, such as through in-person events and the use of different methods and media. Audio files (question-and-answer dialogue) to deliver data contribution instructions, branch-logic questions, and landform factsheets have been viewed positively by the testers in terms of inviting citizens to discover and discuss landforms together. Audio files are useful to foster collaboration (as preferred by the citizens; table A1) and increase the quality of the recorded landform data. While exploring landforms on-site, audio files are preferred, compared to texts, since intensive screen usage can be difficult outside, and users often dislike reading on the screen (Hennig and Vogler 2016). The information strategy used (figure 6) not only considers different needs to support differently skilled citizens, but also the fact that learning technology is usually related to a learning curve, so that after initial participation, citizens will need less support and, with more experience, contribute data related to a higher quality (Loiselle et al 2016, Cooper et al 2021).

The citizenMorph system considered different ways in which participants receive feedback and recognition (figure 2). As in other citizen science initiatives (e.g. CrowdWater\(^5\), Did you feel it\(^6\)) geospatial tools, such as web maps, were used in the citizenMorph system. Web maps are particularly useful for citizen science projects as they not only provide feedback and recognition but are also useful to promote a project and attract participants because the public has increased interest and enjoys working with spatial data and related products (Craglia et al 2012, Thielmann et al 2012, Veenendaal et al 2017; table A3).

Regarding the design, some of the testers, particularly younger ones, considered the citizenMorph design old-fashioned. They suggested considering

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\(^1\) www.infoflora.ch (Accessed 6 April 2022).
\(^2\) www.goldschakal.at/ (Accessed 6 April 2022).
\(^3\) https://picturepost.ou.edu/index.jsp (Accessed 6 April 2022).
\(^4\) http://coastwards.org/ (Accessed 6 April 2022).
\(^5\) https://crowdwater.ch/de/daten (Accessed 6 April 2022).
\(^6\) https://earthquake.usgs.gov/data/dyfi/ (Accessed 6 April 2022).
the design of social media tools. This corresponds with Hennig and Vogler (2016), who highlight the different preferences of younger and older users. In the design of the citizenMorph system, we considered the demands of citizen representatives (figure 3), which generally matched recommendations regarding the usability and accessibility of websites (e.g. Usability.gov 2022; W3C WAI, 2022) and met ethical requirements of participatory projects, such as attracting participants with different backgrounds and needs (Rambaldi et al 2006, Bonney et al 2009b).

Other ethical concerns were also considered in the citizenMorph system, including issues described in the literature (Chambers 2006, Rambaldi et al 2006) that also corresponded with needs highlighted by citizen representatives, such as (a) no collection of personal data, (b) the possibility of withdrawing consent of use, (c) the provision of information (i.e. purpose, related benefits, stimulating learning), (d) providing feedback and recognition in a suitable way, and (e) using a participation and survey approach that is in line with citizens’ reality (e.g. being considerate of people’s time, not exposing people to danger, using technologies that can be mastered, non-repetitive activities).

5. Conclusions

Contributory citizen science projects and systems must be centred around citizen needs to overcome the challenges of data quantity and quality. Although the importance of these aspects for contributory citizen science is known, the question is how to consider these aspects from the citizens’ point of view in the design and implementation of systems in ways that attract, inform, support, and motivate participation.

The results from the citizenMorph project, which informed the development of a pilot system to collect and report field data on landforms, emphasised the importance of in-person events for project promotion, suitable participation and survey design that is accompanied by a smooth user on-boarding process, increasing public knowledge on citizen science and the topic under consideration (i.e. geomorphology), giving feedback and recognition using elements that people enjoy using (e.g. geospatial tools), and a system design that is in line with usability and accessibility recommendations. Due to the different backgrounds of the citizens taking part in the development process, some features are controversial, such as whether to include a registration and login process as part of the citizens’ on-boarding to the system, to which citizens relate benefits but also problems, and the general design of the system, which is viewed differently by different user groups (e.g. depending on their age).

The use of participatory design and the prototyping model fostered a citizen-centric development process, design, and implementation of the citizenMorph pilot system. Based on our findings, we consider the applied approach to be an important step toward developing citizen science systems around citizen requirements because it allows in-depth identification and understanding of these aspects. However, even though the applied development approach helped reveal citizens’ (previously unknown) requirements and showed how to comprehensibly take them into account when creating the citizenMorph pilot system, it also became obvious that collaborating with citizens requires significant additional effort. This includes selecting methods and tools suitable to be used by citizens and providing appropriate support for citizens to complete the tasks, for which a specifically composed team of scientists, developers, mediators, and particularly motivated citizens is key. The additional time, effort, and resources must be considered in advance of involving citizens in development processes.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

Funding information

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Ethical statement

The data collection approach (including measures to address ethical issues, such as the consent of use declaration) was reviewed and approved by the legal department/data protection coordinator of Salzburg University. The workshops were conducted in the context of high school and university events. The high school students involved in the project were older than 16 years.

The participants consented to have their data contributions being used in the study in the context of the described scientific purposes.

Conflict of interest

The authors confirm that there is no conflict of interest.
Appendix

Questionnaire results

Figure 10. Socio-demographic characteristics of online questionnaire participants (N = 138). (a) age, (b) civil status, (c) country, (d) level of education, (e) gender.

Table A1. Knowledge and participation in citizen science projects: descriptive and quantitative content analysis results (N = 138).

| Question                                      | Options/Statements                | Count | Percentage |
|-----------------------------------------------|-----------------------------------|-------|------------|
| Knowledge of citizen science (closed question) | I am not familiar with the term | 72    | 52.2%      |
|                                               | I have heard the term before     | 45    | 32.6%      |
|                                               | I have already participated in citizen science projects | 11    | 8.0%       |
|                                               | I know exactly what it is        | 9     | 6.5%       |
|                                               | No answer/invalid                 | 1     | 0.7%       |
| Liked best about citizen science (open question) | Total number of statements, grouped below: | 13    | 9.4%       |
|                                               | ‘Contributing to a project’       | 6     | —          |
|                                               | ‘Learning something new’          | 5     | —          |
|                                               | ‘Contact with other participants’ | 3     | —          |
|                                               | ‘These projects open up new potentials’ | 1     | —          |
|                                               | ‘These projects are exciting’     | 1     | —          |
| Examples of citizen science projects (open question) | Respondents | 17    | 12.3%      |
|                                               | Number of projects mentioned      | 26    | —          |
|                                               | Projects related to zoology or botany | 13    | 50.0%      |
|                                               | Projects related to spatial planning | 10    | 38.5%      |
|                                               | Projects related to other topics (history, climatology) | 3     | 11.5%      |
|                                               | Number of unique projects mentioned | 20    | —          |
| Topics of interest (closed question, multiple choice) | Spatial planning | 84    | 60.9%      |
|                                               | Climatology                      | 70    | 50.7%      |
|                                               | History                          | 67    | 48.6%      |
|                                               | Botany                           | 49    | 35.5%      |
|                                               | Zoology                          | 46    | 33.3%      |
|                                               | Hydrology                        | 45    | 32.6%      |
|                                               | Geomorphology                    | 43    | 31.2%      |
|                                               | Economy                          | 41    | 29.7%      |
|                                               | Other                            | 14    | 10.1%      |
| Preferred form of participation (closed question) | Take part with others (family, friends, colleagues, in the context of school, university or other events) | 94    | 68.1%      |
|                                               | Take part alone                  | 37    | 26.8%      |
|                                               | Rather not take part             | 5     | 3.7%       |
|                                               | Other (e.g. depends on the situation) | 1     | 0.7%       |
|                                               | No answer/invalid                 | 1     | 0.7%       |
Table A2. Participants’ requirements regarding the amount, media, and type of information and required functions of a citizen science application (N = 138).

| Question Options | Count | Percentage |
|------------------|-------|------------|
| Amount of information (closed question) | | |
| Not too much information, but very topic-focused information | 84 | 60.9% |
| Very accurate and lots of information | 47 | 34.1% |
| Few information | 4 | 2.9% |
| Other | 1 | 0.7% |
| No answer/invalid | 2 | 1.4% |
| Media to provide information (closed question, multiple choice) | | |
| Text with many pictures | 104 | 75.4% |
| Videos | 85 | 61.6% |
| Only text | 34 | 24.6% |
| Audio files | 17 | 12.3% |
| Other (in person discussions) | 4 | 2.9% |
| Type of information (closed question, multiple choice) | | |
| Background and explanations to the project | 125 | 90.6% |
| Aim/Objective of the project | 109 | 79.0% |
| Importance/added value of the project | 78 | 56.5% |
| Use of the contributed data | 73 | 52.9% |
| Information on what to consider when collecting data (security aspects, etc) | 69 | 50.0% |
| Detailed description regarding data collection | 64 | 46.4% |
| Background information on the survey methods | 55 | 39.8% |
| Methods for data collection | 55 | 39.8% |
| Project team | 43 | 31.1% |
| Domains/disciplines involved | 39 | 28.2% |
| Desired functions (closed question, multiple choice) | | |
| Personal contact with others in the context of events, workshops, etc | 71 | 51.4% |
| Games/gamification | 63 | 45.7% |
| Online contact and exchange with others (e-mail, messenger) | 58 | 42.0% |
| Possibility to share content with others | 56 | 40.6% |
| Forum | 44 | 31.9% |
| Overview of participants | 38 | 27.5% |
| Other | 2 | 1.4% |

Table A3. Participants’ experience and joy of use of online maps and spatial data (N = 138).

| Question Options | Count | Percentage |
|------------------|-------|------------|
| Experience with web maps (closed question, multiple choice) | | |
| I am familiar with online maps and use them for route planning, orientation, address search | 126 | 91.3% |
| I have contributed to online maps by adding/editing data | 28 | 20.3% |
| I have never used online maps | 4 | 2.9% |
| Joy of use when working with web maps or spatial data (closed question) | | |
| I enjoy it a lot | 68 | 49.3% |
| I have some fun | 32 | 23.2% |
| I do not know | 24 | 17.4% |
| I do not enjoy it | 4 | 2.9% |
| No answer/invalid | 10 | 7.2% |

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References

Agarwal B R, Tayal S P and Gupta M 2010 Software Engineering and Testing (Sudbury, MA: Jones and Bartlett Publishers)
Asingizwe D, Poortvliet P M, Koenraadt C J M, van Vliet A J H, Ingabire C M, Mutesa L, Leeuwis C and Soundy A 2020 Why (not) participate in citizen science? Motivational factors and barriers to participate in a citizen science program for malaria control in Rwanda PLoS One 15 e0237396
Baek E-O, Cagiltay K, Boling E and Frick T 2007 User-centered design and development Handbook of Research on Educational Communications and Technology ed M Spector et al 3rd edn (Abingdon: Routledge) pp 660–8
Balázs B, Mooney P, Nováková E, Bastin L and Jokar Arsanjani J 2021 Data quality in citizen science The Science of Citizen Science ed K Vohland, A Land-Zandstra, L Eccaroni, R Lemmens, J Perelló, M Ponti, R Samson and K Wagenknecht (Cham: Springer) pp 139–57
Bonney R, Ballard H, Jordan R, McCalie E, Phillips T, Shirk J and Wildermer C C 2009a Public participation in scientific research: defining the field and assessing its potential for informal science education. A CAiSE inquiry group report (Washington, DC: Center for Advancement of Informal Science Education)
Bonney R, Cooper C B, Dickinson J, Kelling S, Phillips T, Rosenberg K V and Shirk J 2009b Citizen science: a
developing tool for expanding science knowledge and scientific literacy BioScience 59 977–84
Brown G and Kyttä M 2014 Key issues and research priorities for public participation GIS (PPGIS): a synthesis based on empirical research Appl. Geogr. 46 122–36
Brown J and Hollers S 2015 The challenges of web accessibility: the technical and social aspects of a truly universal web First Monday—Peer Rev. J. Internet 20 9
Brush J A, Pavlis T L, Hurtado J M, Mason K A, Knott J R and Williams K E 2019 Evaluation of field methods for 3D mapping and 3D visualization of complex metamorphic structure using multiview stereo terrain models from ground-based photography Geosphere 15 188–21
Butt M A and LI S 2015 Usability evaluation of collaborative PPGIS-GeoCWMI for supporting public participation during municipal planning and management services Appl. Geomat. 7 139–61
Chambers R 2006 Participatory mapping and geographic information systems: whose map? Who is empowered and who disempowered? Who gains and who loses? Electron. J. Inf. Syst. Dev. Countries 25 1–11
Cohn J P 2008 Citizen science: can volunteers do real research? BioScience 58 192–7
Cooper C M, Damane R and Swagten N 2021 The potential of citizen involvement in data collection for urban lake research in Denmark and J Buur and T Kaarsted Exploring Citizen Science—Nine Talent Student Projects (SDU) pp 11–18
Craglia M, Ostermann F and Spinsanti L 2012 Digital Earth from vision to practice: making sense of citizen-generated content Int. J. Digital Earth 5 398–416
Crowston K and Fagni N 2008 The motivational arc of massive virtual collaboration Proc. IFIP WG 9.5 Working Conf. on Virtuality and Society: Massive Virtual Communities (Lüneberg, Germany) pp 1–18
Dabiri Z, Höllbling D, Abd A L, Høgåsen J K, Saemundsson T and Tiede D 2020 Assessment of landslide-induced geomorphological changes in Hitardalur Valley, Iceland, Using Sentinel-1 and Sentinel-2 Data Appl. Sci. 10 5848
Downey J 2007 Group usability testing: evolution in usability techniques J. Usability Stud. 2 113–44
Downs R, Ramapriyan H K, Peng G and Wei Y 2021 Perspectives on citizen science data quality Front. Clin. 3 1–7
EC (European Commission) 2022 What is Personal Data? (available at: https://ec.europa.eu/info/law/law-topic/data-protection/reform/what-personal-data_de) (Accessed 11 April 2022)
Fagerholm N, Raymond C M, Olafsson A S, Brown G, Rinne T, Hasanazadeh K, Broberg A and Kyttä M 2021 A methodological framework for analysis of participatory mapping data in research, planning and management Int. J. Geogr. Inf. Sci. 35 1848–75
Fischer H, Cho H and Storksdieck M 2021 Going beyond hooked participants: the nibble-and-drop framework for classifying citizen science participation Citizen Sci.: Theory Pract. 6 1
Giusti C 2010 Introduction to the thematic issue: from Geosites to Geomorphologies: how to decode the landscape? Geodynamic processes, surficial features and landforms, past and present environments Geomorphology 6 123–30
Goodchild M F 2007 Citizens as sensors: the world of volunteered geographic GeoJournal 69 211–21
Gottwald S, Laatikainen T E and Kyttä M 2016 "Exploring the usability of PPGIS among older adults: challenges and opportunities" Int. J. Geogr. Inf. Sci. 30 2231–38
Goudie A and Viles H 2014 Landscapes and Landforms of Namibia (Dordrecht: Springer) pp 1–184
Haklay M 2021 Geographic citizen science: an overview Geographic Citizen Science Design: No One Left Behind ed A Skarlaticoudi and M Haklay (London: UCL Press) pp 15–37
Haklay M 2013 Citizen science and volunteered geographic information—overview and typology of participation Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice ed D Z. Sui, S Elwood and M Goodchild (Berlin: Springer) pp 105–22
Haklay M and Toblin C 2003 Usability evaluation and PPGIS: towards a user-centred design approach Int. J. Geogr. Inf. Sci. 17 577–92
Halfové B 2020 Critical success factors of geocrowdsourcing use in e-government: a case study from the Czech Republic Urban Rev. Pract. 13 438–51
Haworth B T, Tusker B E, Whittaker J and Read R 2018 The good, the bad, and the uncertain: contributions of volunteered geographic information to community disaster resilience Front. Earth Sci. 6 1–15
Hecker S, Wicke N, Haklay M and Bonn A 2019 How does policy conceptualise citizen science? A qualitative content analysis of international policy documents Citizen Sci.: Theory Pract. 4 32
Hennig S 2020 Motivation and its consideration in participatory spatial data contribution Prof. Geogr. 72 238–52
Hennig S and Vogler R 2016 User-centred map applications through participatory design: experiences gained during the ‘YouthMap 5020’ project Cartographi J. 53 213–29
Herfort B, Ecke M, de Albuerque J P and Zipf A 2015 Towards assessing the quality of volunteered geographic information from OpenStreetMap for identifying critical infrastructures Proc. ISCRAM 2015 Conf. (Norway: Kristiansand)
Huggett R J 2011 Fundamentals of Geomorphology (London: Routledge) (https://doi.org/10.4324/9780203860083)
IFAD International Fund for Agricultural Development 2009 Good Practices in Participatory Mapping. International Fund for Agricultural Development (Rome, Italy) (available at: www.ifad.org/documents/38714170/9144386e/PM_web.pdf/7c1eda69-8205-4c31-8912-3c25d69055) (Accessed 6 April 2022)
Jay C, Dunne R, Gelasporpe D and Vigo M 2016 To sign up, or not to sign up? Maximizing citizen science contribution rates through optional registration Proc. CHI ‘16 (San Jose, CA, USA) pp 1827–32
Kermish-Allen R, Sibuma B, Swisser A and MacPhee M 2017 Citizen Science. CIIR. Primer Series (available at: http://circenter.org/citizen-science) (Accessed 6 April 2022)
King S F and Brown P 2007 Fix my street or else: using the internet to voice local public service concerns ICEGOV ’07: Proc. 1st Int. Conf. on Theory and Practice of Electronic Governance (Macao, China) pp 72–80
Kirakowski J, Tischelgi M, Giller V and Frohlich P 2003 Usability support for EU projects—experiences and actions Human—Computer Interaction. Theory and Practice (Part I) ed J Jacko and C Stephanides (Mahwah, NJ: Lawrence Erlbaum Associates) pp 509–13
Kumar S 2021 What is Prototype model- advantages, disadvantages and when to use it? TRY QA (available at: http://tryqa.com/what-is-prototype-model-advantages-disadvantages-and-when-to-use-it/) (Accessed 6 April 2022)
Land-Zandstra A, Agnello G, Gültikyn Y 2021 Participants in citizen science The Science of Citizen Science ed K Vohland et al. (London: Palgrave) pp 243–59
Loiselle S, Thornhill I and Bailey N 2016 Citizen science: advantages of shallow versus deep participation Front. Environ. Sci. 4 1–2
Loranger H and Nielsen J 2013 Teenage usability: designing teentargeted websites (available at: www.mngroup.com/articles/usability-of-websites-for-teensgers/ (Accessed 6 April 2022)
Majid K, Noor N L M, Adnan W A W and Mansor S 2010 A survey on user involvement in software development life cycle from practitioner perspectives Proc. 5th Int. Conf. on Computer Sciences and Convergence Information Technology (Seoul, South Korea) pp 240–3
McCully W, Lampe C, Sarkar C, Velasquez A and Sreevinasan A 2011 Online and offline interactions in online communities Proc. 7th Int. Symp. on Wikis and Open
Environ. Res. Lett. 17 (2022) 085004 S Hennig et al

Collaboration—WikiSym ’11 (New York: ACM Press) pp 39–48

Mooney P, Minghini M, Laasko M, Antoniou V, Olteanu-Raimond A-M and Skopeliti A 2016 Towards a protocol for the collection of VGI vector data ISPRS Int. J. Geo-Inf. 5 217

Morais A M M, Raddick J and Coelho Dos Santos R D 2013 Visualization and characterization of users in a citizen science project Proc. 8758 875801

Muller M J and Druin A 2012 Participatory design. The third space in HCI The Human–Computer Interaction Handbook ed J Jacko (Hillsdale, NJ: Lawrence Erlbaum Associates) pp 1051–68

Napieralski J, Barr I, Kamp U and Kervyn M 2013 Remote sensing and GIScience in geomorphological mapping Treatise on Geomorphology: Remote Sensing and GIScience in Geomorphology ed J F Shroder and M P Bishop (San Diego, CA: Elsevier) pp 187–227

Newman G, Zimmerman D, Crall A, Laituri M, Graham J and Stapel L 2010 User-friendly web mapping: lessons from a citizen science website Int. J. Geogr. Inf. Sci. 24 1851–69

Nielsen J 2006 The 90-9-1 rule for participation inequality in social media and online communities (available at: www. nngroup.com/articles/participation-inequality/) (Accessed 6 April 2022)

Peter M, Diekötter T, Höfler T and Kremer K 2021 Biodiversity citizen science: outcomes for the participating citizens People Nat. 3 294–311

Rambaldi G, Chambers R, McCall M and Fox J 2006 Practical ethics for PGIS practitioners, facilitators, technology intermediaries and researchers Participatory Learn. Action 54 106–13

Remondino F, Spera M G, Nocerino E, Menna F and Nex F 2014 State of the art in high density image matching Photogramm. Rec. 29 144–66

Renz J, Staubitz T, Pollak J and Meinel C 2014 Improving the onboarding user experience in MOOCs EDULEARN14 Proc. (Barcelona, Spain) pp 3931–41

Schaffer V and Tham A 2020 Engaging tourists as citizen scientists in marine tourism Tourism Rev. 75 333–46

Senaratne H, Mobaheri A, Ali A L, Capineri C and Haklay M 2016 A review of volunteered geographic information quality assessment methods Int. J. Geogr. Inf. Sci. 31 1–28

Shirk J L et al 2012 Public participation in scientific research: a framework for deliberate design Ecol. Soc. 17 1–20

Silva C N 2020 Introduction: smart digital technologies and the ‘ladder’ of citizen-responsive urban e-planning Citizen-responsive Urban E-planning: Recent Developments and Critical Perspectives ed C N Silva (Hershey, PA: IGI Global) 1–12

Simm D 2008 Boring, boring … geomorphology? The need for higher education to engage with schools and further education Geophenema 102 6–10

Skarlatidou A and Haklay M 2021 Geographic citizen science design: no one left behind Geographic Citizen Science Design: No One Left Behind ed A Skarlatidou and M Haklay (London: UCL Press) pp 3–12

Steinmann R, Krek A and Blaschke T 2004 Analysis of online public participatory GIS applications with respect to the differences between the US and Europe Proc. 24th Urban Data Management Symp. (Chioggia, Italy)

Thielmann T, van der Velden L, Fischer F and Vogler R 2012 Dwelling in the Web: towards a Googlization of Space. HIIG Discussion Paper Series No. 2012–03 (Berlin: Institut für Internet und Gesellschaft)

Usability.gov 2022 Improving user experience basics (available at: www.usability.gov/index.html) (Accessed 6 April 2022)

Veenendaal B, Brovelli M A and Li S 2017 Review of web mappings: eras, trends and directions ISPRS Int. J. Geo-Inf. 6 1–31

W3C WAI Web Accessibility initiative 2016 Accessibility, Usability, and Inclusion (available at: www.w3.org/WAI/fundamentals/accessibility-usability-inclusion/) (Accessed 6 April 2022)

W3C WAI Web Accessibility initiative 2022 WCAG 2 Overview (available at: www.w3.org/WAI/standards-guidelines/wcag/) (Accessed 6 April 2022)

Wilkinson C R and De Angeli A 2014 Applying user centred and participatory design approaches to commercial product development Des. Stud. 35 614–31