

Contributing to Planning for Sustainability: Advancing User Involvement for User-Centred Geoparticipation Applications

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Abstract

Public participation, including the use of geospatial technologies, is pivotal in planning for sustainability. Contributory participation initiatives, however, face challenges, such as the quantity and quality of the data provided by the public. User-centred applications can address these issues, but since developers often lack understanding of public users, appropriate user involvement in application development processes is crucial. Despite the manifold practices that exist, there is a need to further support user involvement in development processes. This paper contributes to this through findings from three projects aimed at developing applications tailored to the public.

Analysing and comparing user involvement in the three projects, several key results emerged. In order to increase developers' knowledge about public users and to deliver particularly user-centred applications, (i) user involvement should be considered not only in development activities such as requirement-gathering, evaluation and testing, but also in design and implementation; (ii) user involvement can vary in type and extent (i.e. ranging from informative and consultative to participative), allowing user integration in the different development phases; (iii) the combination of process models and design approach, which delivers project-specific development workflows, is suitable for involving users in a project-appropriate and structured manner in development activities.

Keywords:

participatory design, process model, user-centred design, planning for sustainability, geospatial technologies

1 Introduction and research questions

Planning for sustainability covers a variety of topics related to sustainable and liveable communities. Public participation and the use of geospatial technologies play an important role here (UN Habitat 2020, Wheeler 2013). Examples that underline this by combining both aspects are smart city projects (Clarival 2021), spatial planning initiatives (Ahern 2005), and green infrastructure approaches (Vaño et al. 2021).

Public participation can be at different levels. The so-called 'ladder of participation' refers to informing, consulting (i.e. community input, including data contribution), involving,

collaborating and empowering. For participation, traditional (i.e. analogue) and web-based tools, including geospatial technologies, are used (Steinmann et al. 2004). The current focus is on informative and consultative participation (Haklay 2021; UN Habitat 2020), and the use of geodata and geospatial technologies, also referred to as geoparticipation. Forms of geoparticipation include public participation GIS (PPGIS), participatory GIS (PGIS), and volunteered geographic information (VGI).

Geoparticipation brings several advantages for planning for sustainability. The use of geodata and geospatial tools contributes to proactive and innovative planning because structuring is supported, and planning processes are further inspired (Ahern 2005). Involving the public in participatory projects brings benefits such as transparency, increasing interest in public and policy issues, and an increase in the amount and scale of available data (UN Habitat 2020; Hecker et al. 2019). But participatory initiatives also face challenges in terms of the quantity and quality of the data contributed, and the sufficient involvement of the intended target group (Hennig 2020). This is because the public, who include laypeople with some degree of competence in information and communication technologies (ICT) and geoinformatics (GI), often find applications (too) complex, (too) non-intuitive, or (too) unsuitable. Tools must be (more) centred on the public, their requirements, preferences, knowledge and skills. This is described as one of the success factors for participatory approaches (Haltofová 2019). Despite the many possibilities of involving users in application development processes, there is still a need for approaches that allow a better understanding of users and combine the best elements of various promising techniques (Damodaran 1996; Kujala et al. 2005).

The development of user-centred applications, including geoparticipation tools intended for the public, is challenging. One reason for this is that the public is very diverse, and less known to developers than traditional GI users regarding their needs and barriers when using ICT and GI tools (Tsou & Curran 2010). To counter this situation, sufficient consideration of users and their participation in development processes (including requirements specification, application design and implementation, and testing) is key (Hickey & Davis 2004; Kujala et al. 2005).

Comparable to the ladder of participation, various concepts exist to capture user involvement in development processes. Damodaran (1996) explains that the level of user involvement can vary between informative (users provide and/or receive information), consultative (users comment on predefined services or facilities), and participative (users influence decisions relating to the whole system). François et al. (2017) distinguish between informative (user involvement in requirement specification), consultative (user involvement in requirement specification, testing/assessment), and participative user involvement (user involvement in requirement specification, design including implementation, testing/assessment).

But how can participatory applications be developed that do in fact meet the needs of users who are members of the general public? Which aspects of application development are suitable for supporting user involvement? These questions are answered based on findings from the projects YouthMap 5020 (Hennig & Vogler 2016), citizenMorph (Hennig et al. 2020; Hennig et al. 2021), and Covid-19 Impressions. Among other things, these projects aimed to develop user-centred applications that rely on the use of geospatial technologies, and which are related to planning for sustainability in different ways (Table 1).

Descriptions and references to the three projects throughout this paper are always based on the literature cited above, without this being explicitly cited again in each case.

Table 1: Background to the YouthMap 5020, citizenMorph and Covid-19 Impressions projects

Project (timescale, funding)	Aim of the user-centred application to be developed	Relation to planning for sustainability (relation to the United Nation's Sustainable Development Goals [UN SDG]; UN 2022)
YouthMap 5020 2013-2014 FFG Talente Regional	Youth-centred city map presenting youth-relevant urban infrastructure (provided through crowdsourcing) with a youth-centred design	Learning about youth-specific urban infrastructure as an aspect of meeting the call for child- and youth-friendly cities as a contribution to sustainable cities (SDG 11: Sustainable cities and communities)
citizenMorph 2018-2020 FWF-TCS/FFG Talente Regional	Citizen-centered system for observing and reporting landform data to enrich remote sensing data on landscape dynamics	A better understanding of landscape dynamics, which are increasingly affected by climate change, contributes to sustainable development and planning; raising public awareness of climate change (effects) (SDG 13: Climate action)
Covid-19 Impressions 2021 (ongoing) FFG Talente Regional	User-centred platform to collect and share the public's everyday experiences related to the Covid-19 pandemic (focusing on the changing relevance of nature)	Contributing to raising awareness and understanding of the public's changing demands and perspectives on nature, and spending time in nature because of the Covid-19 pandemic (SDG 3: Good health and wellbeing)

In all projects, the use of methods that are usually applied in the development of applications in the context of user involvement allowed learning about the intended users and their needs. The use of qualitative research approaches, such as focus groups, observation and content analysis (Frechtling & Sharp 1997), resulted in information that was relevant not only for the development of the respective applications but also regarding the possibilities created by the development frameworks for delivering user-centred tools.

To answer the questions above, the three projects were analysed and compared. This related to the underlying development workflow (including process models and design approaches), the methods used, the artefacts and solutions delivered, and the type and extent of user involvement. The findings were discussed in the context of the existing literature, differentiating between phase- and activity-related user involvement with reference to the concepts of Damodaran (1996) and François et al. (2017) mentioned above.

2 Project-specific development workflows

The application development processes within the three projects followed individual workflows. Each workflow was developed to appropriately involve users in development activities, for all of which easy-to-handle off-the-shelf tools were used (e.g., ESRI ecosystem tools: ArcGIS online, Survey123 for ArcGIS online, Operations Dashboard). The three workflows encompass the common tasks of application development (i.e. requirement specification), application design and implementation, and testing (Sommerville 2012); they are characterized by a project-specific combination of a development process model and a particular design approach. Development process models and design approaches are briefly described below.

Application development comprises the above tasks, but the focus and order of these tasks may vary, according to the specific development process model used. Within these models, the activities related to requirement specification, design, implementation and testing are organized into different phases, which also assign varying degrees of importance to the activities. Examples of process models include the waterfall model, the incremental model, and the prototyping model (Mohammed et al. 2010; Munassar & Govardhan 2010; Stoica et al. 2013; Subbarayudu et al. 2017). Process models are widely used in application development, including GI tool development (Kujala et al. 2005; Mwangi et al. 2019). They structure the development process, help coordinate and communicate the tasks needed to achieve the product as effectively as possible, and deliver a comprehensive picture of the development process to the people involved in the development activities (Mohammed et al. 2010; Stoica et al. 2013).

In design approaches the users are at the centre of the development process. Examples of design approaches, which are also related to the field of human-computer interaction, include user-centred design and participatory design (Baek et al. 2007; Mithun & Yafooz 2018; Wilkinson & De Angeli 2014). User-centred design aims for early and repeated user feedback during application design and implementation. This allows for the iterative refinement of the design and implementation, including the requirement specification. ‘User-centred design’ refers to methods and tasks (depending on the project) to enable users to assess a tool for its usability. User-centred design can be integrated into a process model (Roth et al. 2015). Participatory design aims to design with, rather than for, users. Users take part in all activities of the development process (Baek et al. 2007; Wilkinson & De Angeli 2014). A distinction is made between strong and weak participatory design. In strong participatory design, users participate throughout the entire development process and in decision-making. In weak participatory design, user input is solicited, but decision-making is undertaken by the developers (Baek et al. 2007; Kensing & Blomberg 1998). The use of development process models is considered helpful in meeting and supporting the demand for appropriate ways to involve users in the different development tasks (Peris et al. 2011; Sanders 2002).

2.1 YouthMap 5020 web map application development

The workflow for developing the YouthMap 5020 web map application followed a modified waterfall model. The traditional waterfall model was the first process model to be introduced; it is the classic description of an application development process. It refers to an easy-to-understand, linear-sequential process model in which each phase (requirement specification, design, implementation and testing) must be completed before the next phase can begin, with no overlap (Stoica et al. 2013). The modified waterfall model uses the same phases as the traditional waterfall model, but the phases may overlap. Tasks can be performed in parallel, and feedback loops exist. This introduces flexibility into the development process (Munassar & Govardhan 2010). To fit the needs of the YouthMap 5020 project, the modified waterfall model was adapted. As shown in Figure 1, the YouthMap 5020 development process consisted of four phases: (i) gathering user requirements; (ii) realizing a database on youth-relevant urban infrastructure; (iii) designing and implementing the city web map application; (iv) testing and optimizing it. In each phase, different school classes were involved. In addition, the YouthMap 5020 web map application development process was shaped using strong participatory design. Thus users (i.e., young people) took part in all development phases and activities, including decision-making. Various methods, as presented in Figure 1, were used.

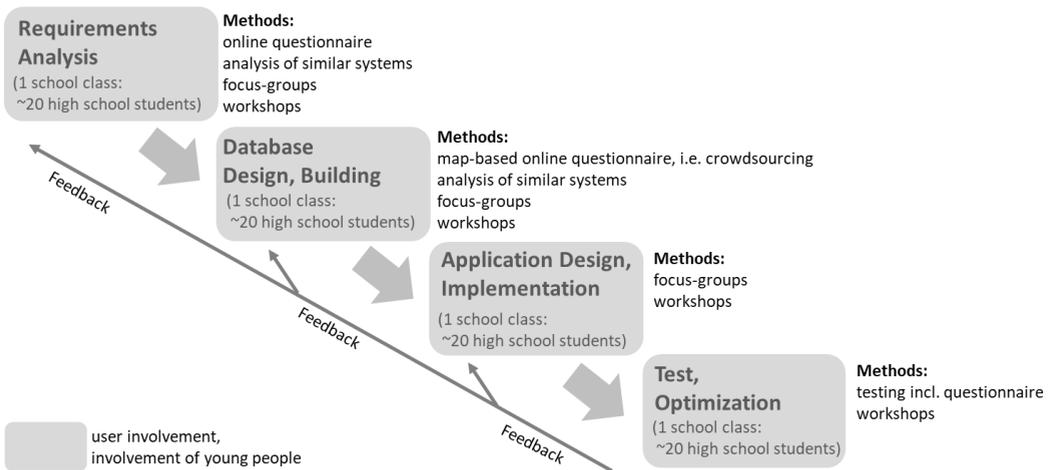


Figure 1: Schematic and simplified workflow for the development of the Youthmap 5020 web map application

2.2 citizenMorph system development

The development process of the citizenMorph system followed the prototyping model. This model is characterized by its iterative nature. Starting from an initial specification, further requirements for the application are identified and continuously refined until the stakeholders, including the end-users, are satisfied. This relies on several loops, including the design and implementation of prototypes, their discussion, and evolution. The model allows for the comprehensive learning of requirements and the specification of the final user requirements,

which form the basis for the design, implementation and testing of the final product (Agarwal et al. 2010; Kumar 2021).

To develop the citizenMorph system, the weak participatory design approach was used in addition to the prototyping model: user input was solicited, but decisions were made by the developers. The involvement of the users, that is citizens, in the development relied on the use of various methods (Figure 2). Here, not all groups of citizens were integrated in all development activities.

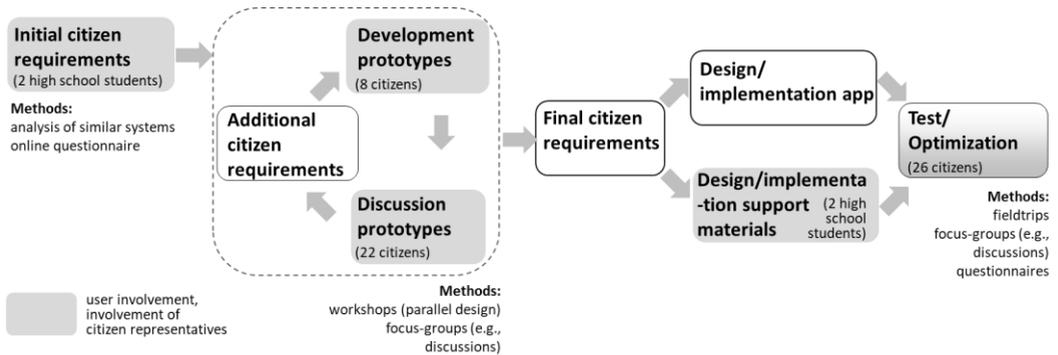


Figure 2: Schematic and simplified workflow for the development of the citizenMorph system

2.3 Covid-19 Impressions platform development

The workflow for developing the Covid-19 Impressions platform is shaped by the use of the incremental model (Figure 3). In this process model, the requirements are divided into subsets; standalone increments are developed based on the respective requirements. The development of each increment includes requirement specification, design, implementation and testing (Stoica et al. 2013). The development process of the Covid-19 Impressions platform consists of three increments that reflect the different phases of participation and their aims (West & Pateman 2016): pre-participation (e.g., information), initial participation (e.g., data contribution), and ongoing participation (e.g., feedback).

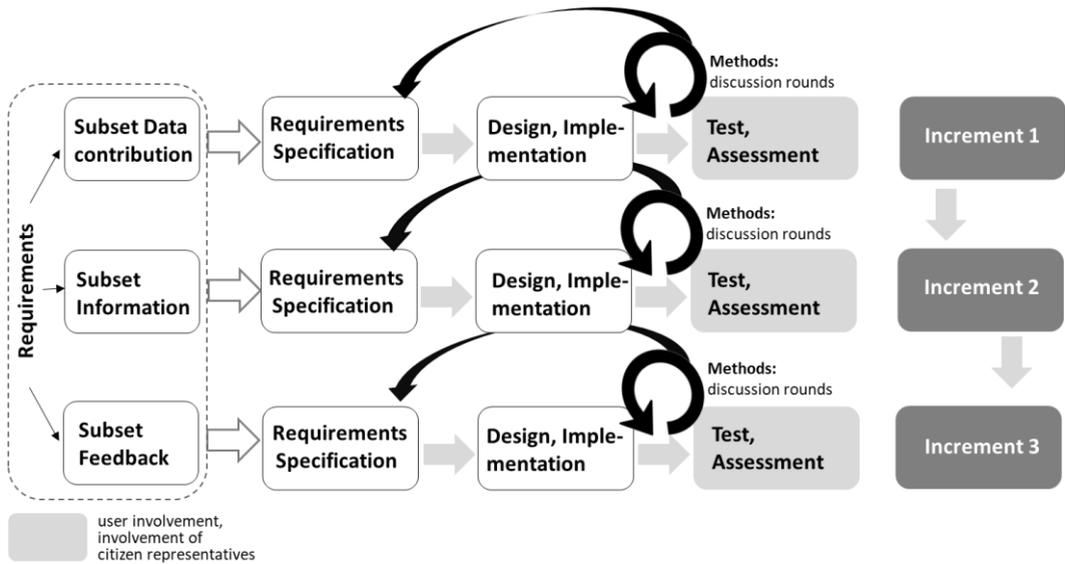


Figure 3: Schematic and simplified workflow for the development of the Covid-19 Impressions platform

A user-centred design approach was also used. While users' requirements were identified by the developers through document-centric techniques and Analysis of Similar Systems (AoSS), citizen representatives were involved in the development process in several rounds of discussion.

3 Project-specific development results

Through project-specific user involvement, based on different methods (Figure 1, Figure 2, and Figure 3), insights into users' backgrounds, requirements and preferences were gained. This is reflected in the three applications, each of which has a particular structure, design and content. Examples are briefly outlined below and summarized in Table 2.

Cooperating with young people in developing the YouthMap 5020 web map application, it was confirmed that young people form a very heterogeneous and complex user group (e.g., with an age range of 12 to 20; different skills and knowledge levels) and that they have particular characteristics regarding ICT use, namely low patience levels, quickness to judge applications, and low willingness to read instructions and explore tools. In focus groups and workshops, the young people outlined design preferences and needs regarding the map content, which differ from what developers (i.e. adults) consider relevant to young people. Accordingly, the YouthMap 5020 web map application was developed with a youth-specific interface and map design, and youth-relevant map content.

The citizenMorph project, the aim of which is to collect data on landforms, is related to geomorphology, a topic that the public is less aware of, as communicated by the citizens who participated in the development process (e.g. in citizen surveys and workshops). Taking this

into account, the solution created considers people’s personal resources related to the topic and the data contribution tasks – i.e. their motivations, and their knowledge and skills to observe, map and report landforms. To meet these demands, the system consists of three components: a data contribution component, a content management system (CMS) project website, and aspects contributing to community building. These components encompass numerous elements related to project-related information, feedback, and instructions for contributing landform data; they are also characterized by a design tailored to the preferences and needs of the citizen representatives.

During the development of the Covid-19 Impressions platform, repeated user feedback was given on the three increments. Several critical issues were identified and discussed by the citizens involved, thanks to which the products developed in the context of the different increments were improved. The ‘information increment’ was created to provide relevant information and to support smooth user-onboarding. The ‘feedback increment’ focuses on using various feedback possibilities (e.g., web hook, dashboard).

Table 1: Selected aspects of the YouthMap 5020 web map application, the citizenMorph system and the Covid-19 Impressions platform

	YouthMap 5020 web map application	citizenMorph system	Covid-19 Impressions platform
Structure, components (C)	Information component (C1) web map component (C2)	Data contribution app (C1) CMS project website (C2) Community building (C3)	Information page (C1) Data contribution page: smart form incl. web-based questions (C2) Dashboard page (C3)
Elements, embedded in components (→ Component 1 C1, Component 2 C2, Component 3 C3)	Image slider (→C1) Map legend (→C2) Layer switcher (→C2) Basemap switcher (→C2) Feature pop-ups (→C2)	Smart form incl. web-based question (→C1) Introductory video* (→C1, C2) Instruction audio files* (→C1, C2) Landform fact sheet* (→C1, C2) Interactive web map: reported landform data* (→C2) Dashboard/coordinated view: contributed landform data* (→C2) Timeline* (→C2) Picture gallery* (→C2) Social Media (Facebook) (→C3) Analogue methods: in personal events (→C3)	Web hook (acknowledgement of contribution by personal email; triggered by data contribution) (→C2) Dashboard/coordinated view: contributed data (→C3) Feature pop-ups (→C3) Social media (e.g. Facebook) (→C1) Analogue methods: in personal events (→C1)

Design	Youth-specific application interface/map design (colourful; limited number of functionalities etc.) Youth-specific design of feature pop-up; youth-specific pictorial map symbols	Considering usability/accessibility issues: e.g. easy to access/use, self-explanatory, well-written text with short, well-structured, understandable content, customizable text/image size, online/offline, using mobile/desktop devices, Project-specific map symbols	Considering usability/accessibility issues: e.g. easy to access/use, self-explanatory, brief and understandable text/content
Content-related aspects	Youth-preferred basemaps (OSM, satellite imagery) Overlays: youth-relevant urban infrastructure (e.g. WiFi hotspots, party places, sites to meet/hang out) Youth-specific content of feature pop-up	Project baseline information (background, aims, domains behind, team etc.) Data contribution instructions Ethical issues (personal data, data contribution etc.) Dashboard: interactive web map, landform-related interactive 3-D models	Project information (background, team etc.) Instructions Ethical issues (personal data, data contribution etc.) Dashboard: interactive web map, list/charts supporting selection-change events, indicator (number of contributions) etc.
Strategies, concepts considered	Counteract information overload	User-onboarding (no registration/login, personal welcome, context-related instructions etc.) Information architecture/hierarchy (regarding data contribution instructions)	User-onboarding (no registration/login, brief instructions etc.)

* Support materials associated with the data contribution app meeting citizens' motivation and skills to take part in the project

4 Results and discussion of phase- and activity-related user involvement

Analysing and comparing the three projects (taking into account the particular development workflow, including development process and design approaches, the methods used, the artefacts and solutions delivered, and the type and extent of user involvement) resulted in distinguishing phase- and activity-related user involvement of different types and extents. This and the related benefits are discussed below.

User involvement in the development workflows of the three projects can be characterized using the concepts of Damodaran (1996) and François et al. (2017). This allows the characterization not only of the development processes per se, but also of the individual phases with regard to user involvement (informative, consultative or participatory) (Figure 4). There are benefits to be derived from considering different types and levels of user involvement in the contexts of requirement specification, design, implementation and testing (i.e. assessment).

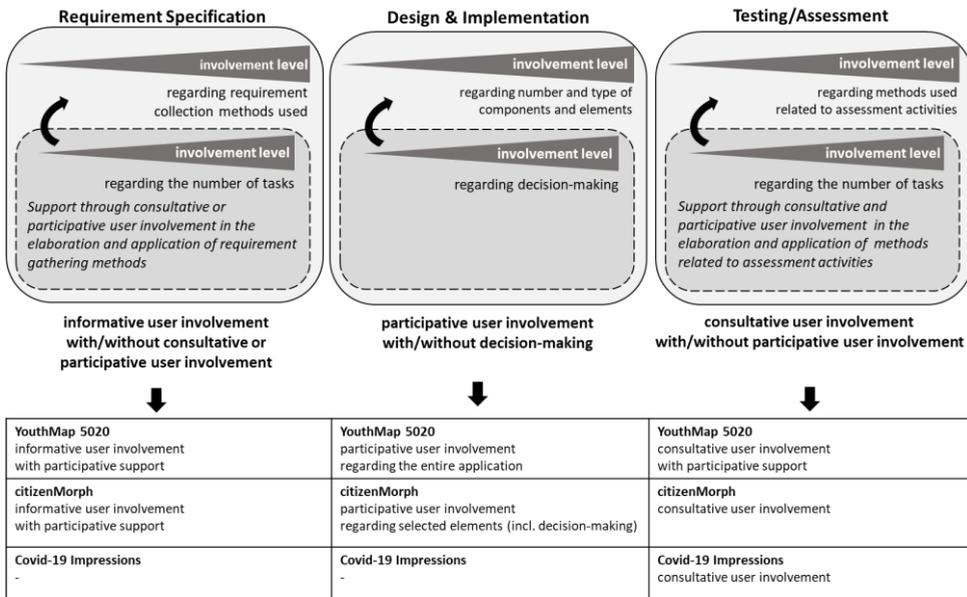


Figure 4: Types and levels of user involvement in the requirement specification, design, implementation and testing/assessment (adapted from Damodaran (1996) and François et al. (2017)), as well as findings from the YouthMap 5020, citizenMorph and Covid-19 Impressions project

4.1 User involvement in requirement specification

There are a variety of methods to collect requirements. Several were used in each project, since a combination of different requirement-gathering methods gives the best results (Spath et al. 2012). Because users are good primary sources of information (Kujala 2003), the use of methods related to informative user involvement was essential for the YouthMap 5020 and citizenMorph projects. The information gained through methods such as questionnaires, focus groups and prototyping provided knowledge about the specific user groups (Table 2): regarding the citizenMorph project, this referred to understanding and addressing people’s motivation and interest in geomorphology, and their skills to contribute landform data; regarding the YouthMap 5020 project, this related to knowing youth-centred urban infrastructure. Through collaborating with the users in the elaboration and application of the requirement-collection methods (i.e., participative user involvement), additional information about the users and their needs was revealed. This follows Kujala et al. (2005) and Steen et al. (2007), who highlight that users must be effectively integrated into application development because they are experts in their own requirements. For instance, questionnaires realized together with the users were more tailored to the people being surveyed by asking the right questions, using appropriate language, and avoiding technical terms. In AoSS, users participated in the identification of the systems to be analysed, the elaboration of the list of criteria to analyse the systems, and the analysis of the systems. In this way, the developers learned which applications are used by the public, which assessment criteria are important to them, and how they rate applications.

4.2 User involvement in design and implementation

With user involvement in the design and implementation, users are in a ‘making’ situation. Participatory user involvement ensures that developers can learn about users’ tacit and latent needs, which is not possible by simply listening to or watching users. It also ensures that the information about the users gained during the requirements phase is actually used in the implementation of the tool, which is not always the case. This leads to solutions that allow users do whatever they aim to do in a better way, and delivers a better user experience (François et al. 2017; Sanders 2002; Steen et al. 2007). Against this background, the participatory involvement of the users in the YouthMap 5020 and citizenMorph projects took place in different ways and to different extents. While users participated in the design and implementation of the entire system in the YouthMap 5020 project, in the citizenMorph project they did so only with regard to selected materials. Other elements (e.g., the survey form) were inspired by participants’ ideas revealed during the discussion of the prototypes. This is where the benefits of using the prototyping model and its influence on the requirements analysis become clear. Following Agarwal et al. (2010) and Kumar (2021), the prototyping model is suitable if the demands of the future users of an application are relatively unknown at the beginning of the development process, or if developers are dealing with a new issue. This was the case with the citizenMorph project, where citizens’ motivations and skills for landform data collection were largely unknown.

4.3 User involvement in testing

Testing refers to checking applications not only for errors but also for whether they meet the requirements of the users (i.e. user assessment, usability testing). Users are requested to provide feedback on a product, and they might be observed using a product. Based on this, applications can be adapted and improved (François et al. 2017; Roth et al. 2015). Testing and user assessment took place in all three projects. Unlike the citizenMorph and Covid-19 Impressions projects, the YouthMap 5020 project used consultative user involvement supported by participative user involvement. The users participated in the elaboration of the questionnaire to obtain feedback from the testers. This allowed the questionnaire to be better tailored to the young people testing the city web map (Section 4.1). In the Covid-19 Impressions project, the products resulting from the three increments were repeatedly assessed and discussed. The use of the incremental model proved beneficial here: it is useful when user feedback on the components of an application is important, when developers have little experience of the topic or user group, or when a quick release of the product, with its crucial aspects, is required (Sommerville 2012; Stoica et al. 2013).

5 Conclusion

User-centred solutions are a success factor for geoparticipation initiatives, and user involvement is key for their development. Despite the manifold practices that exist to involve users in development processes, there is a need to further support user involvement in development processes. Experiences gained from the YouthMap 5020, citizenMorph and

Covid-19 Impressions projects contributed to answer how, by involving users in a suitable manner, participatory applications can be developed that in fact meet the needs of users from among the public.

The findings showed that the use of a process model in combination with a design approach is promising in the development of people-centred applications. While design approaches relate to ways of putting the users at the centre of a development process, process models determine the order of the development phases and focus on the individual tasks differently. Thus, using a process model and design approach together defines the development framework and allows the integration of different types and levels of user involvement in the development of an application, in the contexts of requirement specification, application design, implementation and testing, with the levels of user involvement ranging from informative and consultative to participative. Involving users in different ways and to different extents in development tasks and activities has several benefits for the development process and the final product. For instance, participatory user involvement in requirement-gathering and product assessment together with having them collaborate on the design and implementation of materials such as questionnaires provides additional understanding of users' needs; preferences come to light (e.g. use of language) which do not emerge when user involvement is purely informative.

This hybrid approach of combining process model and design approach – with the use of informative, consultative or participative user involvement (with or without decision-making by the users) in the context of the different development phases and activities – is clearly applicable to other projects. It is important, however, that the following should be taken into account: (i) the benefits and challenges of the particular process model and design approaches to be used; (ii) the appropriateness of the process model and design approach selected regarding the project topic, aims and resources, and the background of the users to be involved in the development process; (iii) the need to compose a multidisciplinary project team comprising, among others, domain experts, developers, moderators and mediators, and (most importantly) skilled and motivated people from the public to act as peer-tutors; (iv) provision of suitable tools, materials and methods for public users to participate in the various activities; (v) the possibility to recruit a sufficient number of users from the target group to be involved in the application development process.

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