

STEAM Stories: A Co-creation Approach to Building STEAM Skills through Stories of Personal Interest

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Abstract

The ever-increasing digitalization of our everyday lives repeatedly and prominently sparks discussion about the need for STEAM (Science, Technology, Engineering, Arts, Mathematics) skills. In terms of education, STEAM initiatives focus on skills development and the use of digital technologies to stimulate students' engagement with societal issues. This paper introduces an iterative co-creation-based approach for enabling and enriching STEAM learning experiences. Our goal is to foster young citizen scientists by having them share and discuss stories of personal interest and experience, while practising and improving their STEAM skills through local engagement. The young citizen scientists contribute to all phases of a story, including its co-creation and conception, data collection, discussion in workshops, and generating outputs relevant to local and regional policymakers. The particular spatial focus of the approach is in the places where the stories take place. The stories are uploaded to a map-based platform, which is used for data collection and visualization, and as a focus for discussion. Through personal involvement, the young citizen scientists are motivated, which fosters local ownership, sustainable use of the platform, and effective capacity building in digital skills.

Keywords:

STEAM, co-creation, citizen science, education

1 Introduction

1.1 STEAM as a Framework for Education

The ongoing process of digitalization in our everyday lives repeatedly and prominently sparks discussion about the need for STEAM (Science, Technology, Engineering, Arts, Mathematics) skills (Anisimova et al., 2020). STEAM is an increasingly widely used concept for education, research, theory and practice which has evolved as an enhancement of the well-established STEM (Science, Technology, Engineering, Mathematics) concept.

There are two essential differences between STEM and STEAM educational initiatives, both of which have motivated the application of a STEAM approach in the case studies we present here. First, STEAM fosters problem-solving skills, as it moves away from the singular focus on individual subjects commonly seen in STEM approaches, and towards inter- and transdisciplinarity (Mejias et al., 2021). Combined with the use of digital technologies, it stimulates students' engagement with societal issues that cut across disciplinary boundaries (Allina, 2018; Holbrook et al., 2020; Mejias et al., 2021). The implementation of the STEAM framework in classrooms has drawn praise for its ability to capture the cross-disciplinarity of real-world subject matters (Yakman & Lee, 2012) and for introducing new ways of knowing and learning (Mejias et al. 2021), particularly by favouring a skills-oriented learning style over a content-focused one (Holbrook et al., 2020).

Second, as the acronym suggests, STEAM introduces the arts into this predominantly science- and technology-centred paradigm. The term 'arts' in the context of STEAM varies widely in its definition (Perignat & Katz-Buonincontro, 2019), ranging from art education with a sole focus on visual arts, all the way to a broad concept of the liberal arts and humanities. Yet other definitions view 'arts' as a specific project-, design- or technology-based learning method (see *ibid.*). In this paper, 'arts' is understood as a thematic element for a set of workshops in which stories of personal interest are created. These stories encompass cultural and humanities-related topics in particular, such as monuments, sites of literary interest, or teenagers' 'living spaces'. This chosen interpretation and implementation of 'arts' does not preclude or deny the connection it has to advanced and applied theories such as spatial citizenship (Gryl & Jekel, 2012), but we refrain from an in-depth discussion on how the various theories can be embedded with each other, focusing on the practical implementation of our approach, in which 'arts' constitute one element.

1.2 Citizen Science for Public Participation

Citizen science (CS) is a widely used approach to encourage active public participation in research for both knowledge-creation and widespread scientific engagement (Hecker et al., 2018). The rapid development and spread of digital technologies and connectivity in the 21st century have reduced entry barriers to historically exclusive scientific research (Silvertown, 2009) through new forms of communication and data collection. In addition, the enhancement of statistical and computational analysis methods for big data or highly heterogeneous datasets has improved the feasibility of many CS projects (Bonney et al., 2014).

Following the advent of CS, studies have argued its potential benefits and pitfalls, particularly regarding methods for participants' involvement and data quality (Dickinson et al., 2010; Kullenberg & Kasperowski, 2016). Some scholars argue that the primary aim of CS is not scientific output but to democratize the scientific process by rendering it needs-driven (Kullenberg & Kasperowski 2016; Hecker et al., 2018). As CS methods and research continue to advance, it becomes clear that rigorous study design helps improve data quality while simultaneously democratizing the research process.

In formal education, CS can accommodate all educational levels thanks to its adaptability. Schools assume the role of multipliers and teachers become intermediate experts. However, aspects including students' motivation, the dedication of educators, integration with school

curricula, and the act of balancing research goals against educational outcomes must be taken into account (Kloetzer et al., 2021). In informal learning environments outside classrooms, CS projects come with additional design challenges regarding the achievement of sufficient data quality and knowledge transfer. In spite of these hurdles, educational CS in informal settings can sustainably boost participation and interest (Roche et al., 2020).

Where CS incorporates geographic data, it draws on elements of spatial citizenship to combine technical knowledge with a consciousness of societal consequences and the critical use of geoinformation (Gryl & Jekel, 2012), thus enabling new insights and learning outcomes. Underpinned by changing cartographic practice and attitude towards maps (critical geography), there has been a shift towards creating subjectively oriented maps (against much emphasis in cartographic practice), which focus in particular on individual connections (Daum, 2012; Daum & Hasse, 2011).

1.3 STEAM Stories: Combining STEAM and Citizen Science

In an effort to combine STEAM and CS, this paper presents a workshop-based educational approach that integrates CS methods into a STEAM educational framework. The approach consists of two phases, in which workshops for geographical data collection, analysis, interpretation and discussion are first collaboratively designed and then carried out. The collected data are geographically mapped ‘stories’ containing the opinions and perspectives of the participants.

The first phase focuses on the conceptualization, design and preparation for the workshops. In practical terms, this involves local stakeholders and young citizen scientists (hereafter referred to as participants), who attend multiple co-creation sessions to identify a set of STEAM-centric interdisciplinary workshop topics. To mark out the ‘arts’ component, the choice of workshop topics focuses on socio-cultural issues and regional interrelationships. This process is defined by a stepwise development of the modules and technical components. The co-creation workshop is designed to support young people in articulating topics of interest and in understanding that these topics are interconnected with spatial circumstances, including the participants’ own potential to influence the spaces themselves (Daum, 2012). Thus, the resulting ideas are frequently related to spaces for leisure-time activities: venues to meet friends and peers, cycling and hiking routes, parks and food.

During the second phase, in which the workshops take place, participants discuss, collect and analyse stories of personal interest according to the respective workshop topics. This phase is centred around digital skills-building and active engagement with the given topic. Both phases aid confidence-building, the reduction of entry barriers into research fields, and digital and scientific skills-development in a STEAM context. An overview of the structure of this approach is outlined in Figure 1.

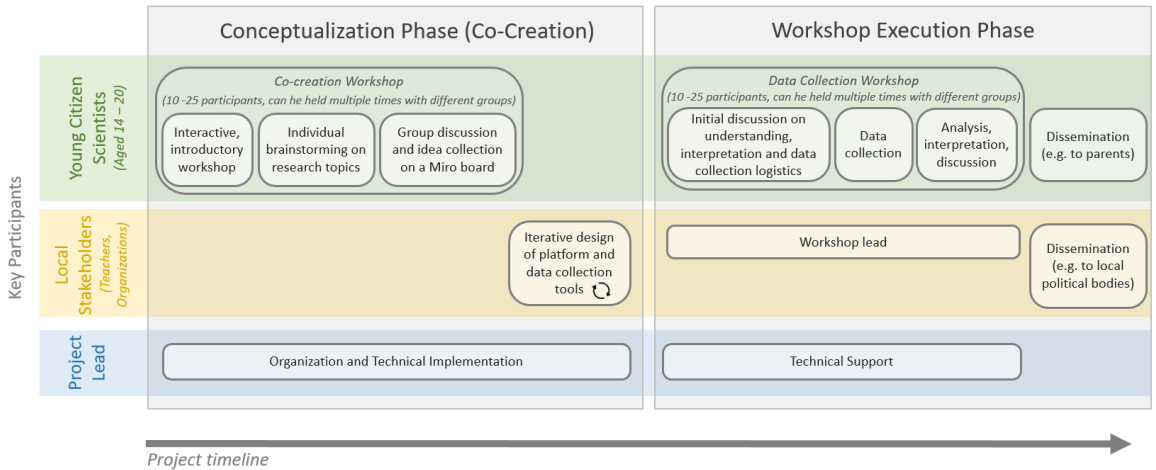


Figure 1: Overview of key participants and main phases of the approach presented

This paper first outlines the project’s methods and design considerations (Section 2.1), the structure of the conceptual phase (2.2), its technical implementation (2.3), and the workshop execution phase (2.4). Two current use cases, MINKT Stories Lungau and MINKT DIGITAL, are then presented, followed by a reflection on the co-creation process, the value of personal knowledge, and the data’s regional relevance. Lastly, opportunities and suggestions for future developments are laid out.

2 Methodology

2.1 Design Considerations

The central aim of this approach is the integration of CS methods with the conceptual STEAM learning framework in order to combine the advantages of both. Amongst the numerous educational benefits that both CS and STEAM offer, our approach emphasizes two elements as central for motivation:

1. The empowerment of young citizen scientists

The notion of empowerment has been defined in many different ways, though there is general agreement that it encompasses an ‘ability for self-determination’ through some form of agency (Galiè & Farnworth 2019). In education, the idea of student empowerment was first introduced by Freire (Freire, 1976; 1979), and the idea remains relevant as technologies for learning, participation and teaching evolve. In this approach, empowerment and agency are understood as a process in which participants develop digital skills for self-expression and participation in STEAM-based research. This is facilitated through a co-creative process, digital data collection and subsequent analyses. In addition to learning skills, participants are encouraged to narrate their own viewpoints as they record geographically located stories on a public online platform.

2. Motivating a sustained increase in interest for STEAM topics and digital technologies

The data collection workshops that are the particular focus of this paper aim to build digital skills and sustain participants' engagement with digital technologies and STEAM topics, which in turn helps young citizen scientists find their own paths towards becoming independently involved in STEAM fields. Such sustained engagement is achieved by nurturing a feeling of ownership over the workshops and by ensuring that the workshop topics are of primary interest to the participants.

To adequately satisfy these two central motivations, our approach incorporates citizen scientists at all stages, from idea-generation all the way to the analysis and dissemination. A practical design consideration here is the investment of time for everyone involved. Especially during the first, co-creation, phase, there is a positive relationship between the participants' time investment and learning outcomes, engagement and ownership. An instructor may find that single-handedly designing a workshop is less time-consuming, but that would be to miss out the key element of involving participants. Likewise, where instructors are pressed for time, the collaborative creation of the technical components with other stakeholders helps save individuals' time while creating sophisticated tools geared specifically towards the workshops. To do this alone would probably require a very significant investment of time and/or considerable IT knowledge. While the collaborative approach is recommended, it should be noted that documentation for reproducibility should help instructors emulate the approach on their own in the future.

This CS approach is designed without predefined thematic orientations to ensure that any use case can be built upon it, and the practical implementation can be adjusted according to the desired focus. For example, two current use cases, MINKT Stories Lungau and MINKT DIGITAL, follow the same general approach yet differ slightly in their particular orientation. MINKT Stories Lungau has a central focus on regional project ownership, while MINKT DIGITAL specifically targets girls and young women as participants.

2.2 The Conceptualization Phase: A Co-Creation Process with Young Citizen Scientists

The conceptualization phase of the data collection workshops is a guided, iterative, co-creative approach. Co-creation in citizen science was first formalized as an idea for citizens' participation in the research and innovation process in 1996 (Senabre Hidalgo et al., 2021); it has continued to evolve with a number of variations (Prüse, 2020). As Kullenberg and Kasperowski (2016) and Roy et al. (2012) point out, most CS projects involve citizens primarily as data collectors.

However, research demonstrates additional virtues related to increasingly participatory CS approaches, such as citizens' increased scientific literacy and creating a more equal relationship between scientists and citizens (Kimura & Kinchy, 2016). The aim for the conceptualization phase is therefore to move away from contributory CS, and towards a participatory research design through co-creation (Fig. 2). To implement this, our approach follows the concept of citizen social science (Kythreotis et al. 2019), which characterizes participants as 'competent

in-the-field experts' (Senabre Hidalgo et al., 2021, p.203) who generate scientific value through their own individual, unique experiences.

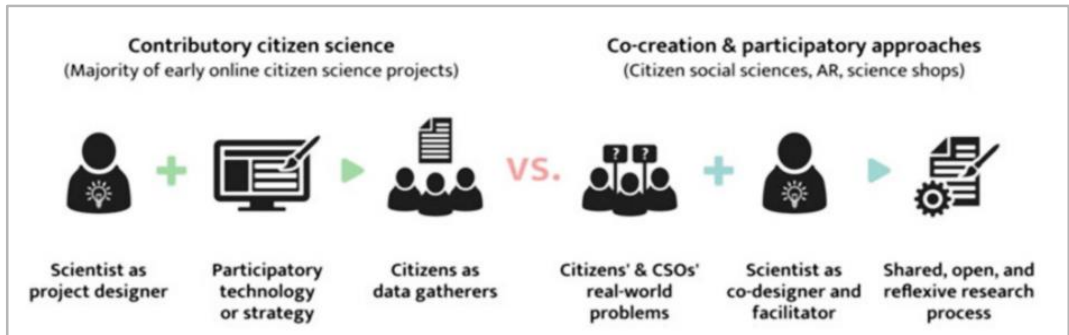


Figure 2: Contributory and co-creative approaches in science. AR = action research, CSO = civil society organizations. Source: Senabre Hidalgo et al. (2021).

As such, young citizen scientists participate in workshops marked by loosely guided brainstorming exercises and discussions to co-create the focus of the research and main research questions. The workshops begin with an interactive session to explore the changing uses and forms of geographic data over time. Participants then draw mind-maps on topics of interest before discussing them in a large group and collating them on a Miro board. This implementation draws on concepts of participatory design introduced by OpenSystems from the Universitat de Barcelona (Senabre et al., 2018; Senabre Hidalgo et al., 2021) to facilitate idea-generation with simple tools such as a Miro board. By leaving the topic choices to the participants, the workshops become needs-oriented and interlinked with local paradigms.

Local stakeholders including teachers and/or members of local businesses are then invited to partake in semi-formal monthly or bi-weekly meetings in which the workshop topics are refined, and their design, i.e. syllabus and technical components, is iteratively decided upon. This stepwise implementation allows continuous feedback among the participating stakeholders who will later assume the roles of workshop leaders.

For both steps described here, recruiting participants relies heavily on social structures and existing contact networks. Approximately half of the project's designated duration is dedicated to the conceptualization phase to ensure that the workshops and the platform are adequately representative of the participants' chosen subject matters.

2.3 Technical Implementation and Reproducibility

The conceptualization phase includes the stepwise creation of a digital platform and any technical components required for data collection, such as mobile surveys. For the purposes of transparency and reproducibility, the relevant technical details are summarised here.

The online platform is created within the ESRI environment, using a Hub website (e.g. <https://minkt-stories-lungau.zgis.at/>). The platform consists of several pages, containing the map, project and workshop information, user guides, and instructions for reproduction. By

publicly sharing instructions for reproduction, including written recommendations, screenshots, curricula, source codes and a comment section, emulators have the means to reproduce and adjust this approach.

The web map used for data visualization is created using the open-source JavaScript library OpenLayers (Open Source Geospatial Foundation, 2022). We opted for an open-source solution in order to integrate additional elements which are unavailable in an ESRI dashboard, such as an interactive image gallery that connects to the map. The map categorizes and visualizes the data based on workshop topics.

The mobile data collection is implemented using ESRI's Survey123 application, which was deemed the best option for collecting and then publicly sharing geolocated data as a web feature service. The survey is structured in a simple, easy-to-use manner, asking users for (1) their location, (2) the title of their story, (3) the textual content of their story, (4) a story category, e.g. 'negative mobility moment', which is selected from a drop-down box containing all previously agreed upon workshop topics, and (5) an image file.

The mix of environments comes with both advantages and disadvantages as it allows for the inclusion of more functionalities, but it also involves a lengthier design process. Possible future work may involve a move to exclusively open-source components, thereby making the entire platform replicable without any commercial fees.



Figure 3: Conceptual model of technical components

2.4 The Workshop Execution Phase: Workshops as Building Blocks for Digital and STEAM Skills

Once both the platform and the workshop designs have been completed, the workshops are conducted by local stakeholders who themselves were involved in the conceptualization phase. Over approximately 3 hours, workshop participants first engage in initial discussions on the given STEAM topic and how best to approach the data collection. As an example, in order to capture positively and negatively perceived living spaces, the discussion will include the generation of a collective definition for a ‘living space’ according to the participants’ perceptions. These initial discussions mimic the co-creation phase, as participants integrate their understanding and viewpoints into the definition of the workshop’s STEAM-related topic.

Next, the smartphone application is used to record images of their interpretation of the subject and submit a geolocated story with a title, category and textual description. This way, the images are supplemented with the users’ own perspectives and opinions. The data collection invites participants to express their thoughts and ideas by recording and locating a story.

In the final workshop stage, the participants analyse and discuss the results with a focus on spatial patterns, but also in consideration of applied usefulness, data collection bias and data quality. Through these discussion topics, participants learn to critically evaluate citizen science data and collection methods. This process calls on participants’ interdisciplinary thinking to link real-world topics to data collection and back into real-world interpretations. By making the overall process of learning interactive and engaging, all stages of the workshop implement a STEAM learning style. Participants are also challenged to make use of digital and geographical technologies, thereby enhancing their digital skills.

3 Current Use Cases

A closer look at two current use cases helps demonstrate the practical adaptability of the general approach described in this paper. The use cases are intended as examples only; they do not preclude alternative ways of implementing this workshop-based learning method.

3.1 Use Case 1: MINKT Stories Lungau

The first of two current use cases is MINKT Stories Lungau. In addition to the primary aim of developing digital skills among workshop participants, the project stresses local ownership for stakeholders from the use case area as a means for community empowerment. The conceptualization phase saw collaboration among two school classes, a local biosphere park and a local cultural organization to generate a set of workshop topics that match local interests and discourse. These topics include positive and negative mobility-related experiences for commuting students (which we refer to as ‘mobility moments’), the regional occurrence and use of medicinal plants, and the location of ‘living spaces’ for teenagers. These topics are then interpreted by workshop participants, who capture images and formulate stories on the subjects. The collective results are then used to inform local and regional policymakers. This

project will ultimately be handed over to local stakeholders entirely, in order for them to use and adapt the platform and workshop formats for their ongoing needs.

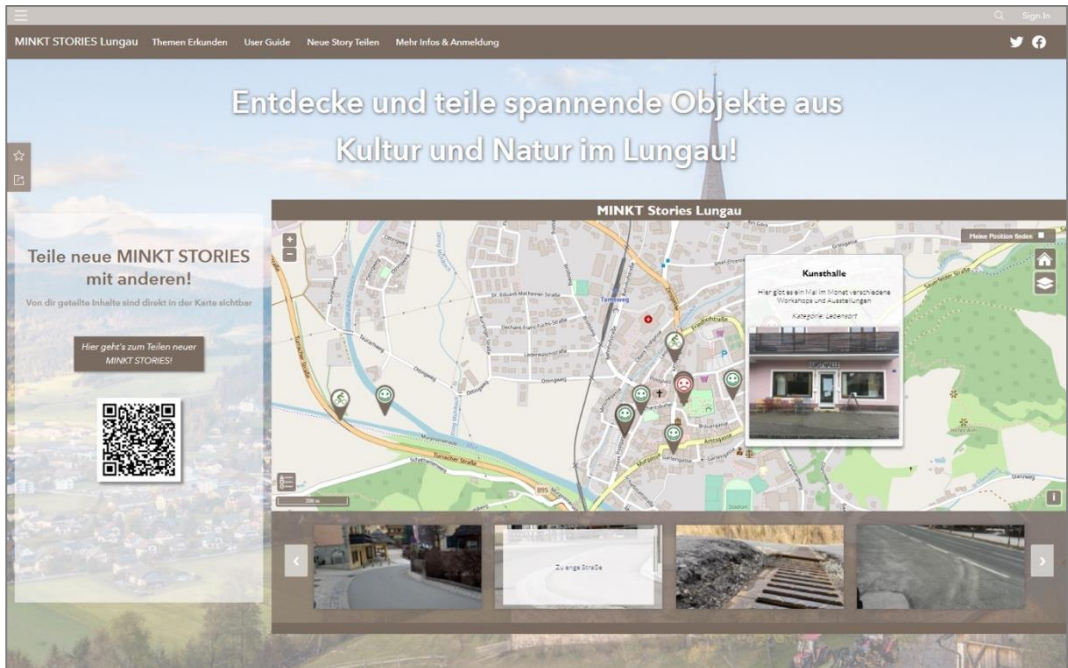


Figure 4: Interface of the web-map platform for MINKT Stories Lungau

3.2 Use Case 2: MINKT DIGITAL

A second use case, MINKT DIGITAL (Figure 5), focuses predominantly on the empowerment of a group of female participants. As West et al. (2019) note, the development of digital skills has become essential in today's increasingly technology-centred society. To prevent a growing gender gap in digital skills sets, this use case creates a platform specifically for girls to explore digital technologies, learn about and create digital data, and build up confidence to explore STEAM-related career fields. The workshops show the participants potential educational paths and serve to reduce entry barriers to STEAM topics.

Female teachers or trainee teachers are proactively targeted as workshop leaders, and therefore as role models for the female participants. The teachers familiarize themselves with the handling of the relevant digital technologies and have the freedom to conduct the workshops according to their own schedules.

In contrast to MINKT Stories Lungau, MINKT DIGITAL aims ultimately for a more permanent integration in the iDEAS:lab at the University of Salzburg (<https://ideaslab.plus.ac.at>), to be used on a continual basis, not just for workshops, but also for more in-depth endeavours such as internships. The platform is also more generic (i.e. less tied to specific workshop topics), and will therefore be made available as a replicable tool.



Figure 5: Interactive web-map for MINKT DIGITAL

4 Reflection and Outlook

There are several components of this approach worthy of additional reflection and discussion. These include, firstly, participants' commitment to the entire process of co-creation and data collection, and the influence of the presence of teachers during workshops; secondly, the value of stories as data representing participants' unique knowledge; and lastly the potential political value of these geolocated stories. Looking forward, we argue that this approach could potentially serve a base to be built upon and added to.

4.1 Co-Creation with Young Citizen Scientists

The approach introduced in this paper is ambitious as it targets young students and teenagers in a co-creative CS methodology which is markedly more participatory than traditional contributory CS methods. Although the participants were recruited via various means, many took part in the context of their school class. These circumstances pose organizational challenges regarding the commitment to, and facilitation of, co-creative CS. Here, we present two challenges related to the co-creation phase, which we experienced during the project.

Firstly, the brainstorming process, which is central to the conceptualization phase, was influenced to varying degrees by the presence of teachers and the particular school subject to which the project related. Teachers were observed to steer discussions, and there are indications that students were more likely to think of ideas related to the particular school subject. Although methods could be sought that diminished this effect, this circumstance

presents future opportunities for a ‘whole-class’ co-creation approach, as described by Bovill (2020). Such an approach would favour mediated negotiations within a single group to arrive at a single topic in the co-creation workshops, as opposed to a collection of individual ideas that are then used as input during the iterative workshop design with stakeholders. Secondly, this approach does not involve a strict commitment for participants in the co-creation workshops to subsequently participate in the data collection workshops. This commitment is often strongly dependent on teachers' schedules and motivations. Although by and large the cases continued to benefit from inputs during the co-creation and data collection workshops, participation in only one of the two phases is likely to result in a lesser overall learning experience for individuals and a reduced perception of ownership of the topics.

4.2 Personal Knowledge as Data in Citizen Science

Individuals’ contributions come saturated with local knowledge, paired with individual experiences, thoughts or recommendations. Thus, this approach shows similarities to the endeavours of subjective cartography, as a form of construction of space; the approach emphasizes individual experience, which is contextualized within larger socio-spatial practices (Daum, 2012; Daum and Hasse, 2011). Maps can therefore be understood as a medium for the practical examination of the participants’ living environments. Figure 6 provides an example of a contribution to the platform, referring to leisure spaces for young people, which was one of the most-mentioned topics of interest during the co-creation phase.



Figure 6: An example of a story contribution, as shown in the web map.

4.3 The Added Value of Regional Citizen Science Data

The collection of geolocated stories resulting from the workshops gives rise to an additional positive externality. Studies have demonstrated how such data can have significant meaning in local and regional political spheres by providing decision-makers with an evidence base (McKinley et al. 2017; Shanley et al. 2019). The approach described here is suitable for application at smaller scales, such as local school politics, since the data collection is also conducted at these scales. For example, one class held a workshop on the topic of positive and negative mobility moments. During the conceptualization phase, the subject of students' safety while cycling to and from school arose as an issue of importance. Following the data collection, the results can be used to advocate for safety measures to the school board, or even the local political bodies responsible for transport or urban planning. The intuitive map-based visualization of positive and negative mobility moments highlights locations of particular concern. In this context, the online platform functions as a presentation and advocacy tool to showcase the collective findings of young citizen scientists. The spatial perspective plays a critical role in the matter of data interpretability and intuitive understanding. As the example on mobility moments shows, a map-based view can highlight locations, or hotspots, where data is skewed towards positive or negative experiences (Figure 7).

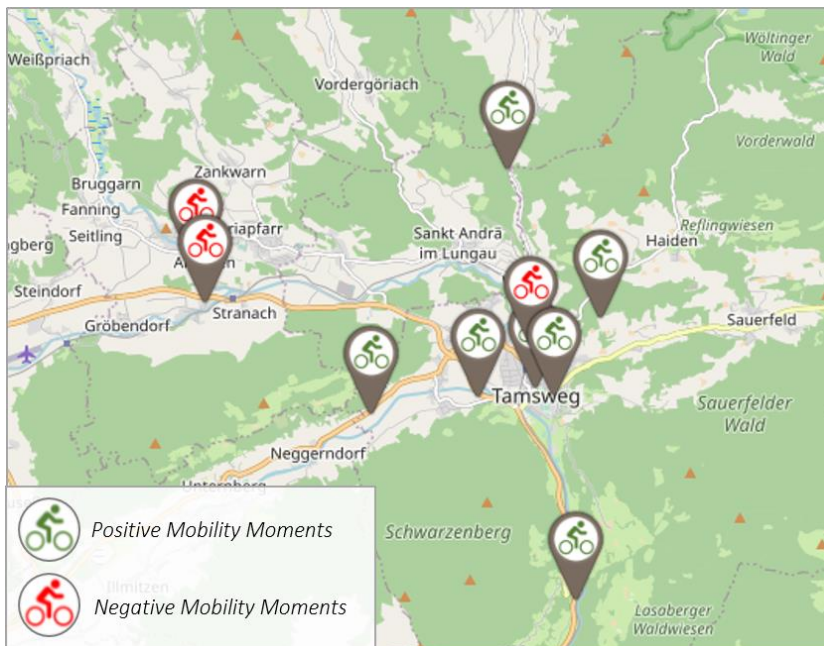


Figure 7: Map-based spatial view highlighting locations of positive and negative 'mobility moments'

4.4 Recommendations for Future Developments: STEAM-Workshops as a Baseline Concept

Although variable in their exact implementation, the data collection workshops each require approximately 3 hours. This scope may be sufficient for an introduction to digital technologies and to spark initial interest, but it precludes a more in-depth learning experience. Future adaptations of this approach may add further components, or use some of its individual parts in other projects. The general structure of the workshop conceptualization and execution is easily adapted to include more fine-grained steps or additional content. Examples include the addition of in-depth data analysis in which participants learn to visualize the data cartographically, or the use of additional sensors for data collection, such as noise-recording or CO₂ sensors, which are included in an easy-to-use senseBox toolkit (SenseBox, 2022).

Future developments should aim at reproducibility and adaptability. Since future co-creation workshops will undoubtedly result in new ideas for data collection, the accompanying platform must be adaptable to new topics. This will require an increasingly open-source and generic implementation, such that emulators may reproduce the platform free of cost or commercial licensing, and without predefined workshop topics. In addition, clear and accessible documentation of technical and organizational elements will help facilitate a sense of local ownership as individual steps and requirements are made easier to understand. Lastly, upon conclusion of the current use cases, a formal review and reflection is called for to assess the strengths, weaknesses and lessons learnt from this approach. It is hoped that others will find this work both insightful and thought-provoking.

5 Conclusion

This paper has outlined a general method for the co-creation of a workshop for engaging young citizen scientists in STEAM fields. The predominant focus has been on dissecting the two main methodological phases and the related practical considerations for implementation. As a key factor for the empowerment of workshop participants and the generation of sustained interest in STEAM topics, an iterative co-creation process is added to more traditional CS research methods. In the course of the workshops, citizen scientists proactively learn and develop digital skills as they conceptualize, record, analyse and discuss their own stories related to the previously identified workshop topic. The benefits resulting from this process apply to the participants themselves, local stakeholders and regional politics.

As methods for public participation continue to evolve and digital technologies become an increasingly integral part of our everyday lives, research and exploration in the field of STEAM learning must continue so as to keep pace with rapid technological innovation. By supporting a learning process that is interdisciplinary and focused on digital skills, this approach stands to benefit many stakeholders beyond the workshop participants themselves.

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