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The role of digital technologies in facilitating crowd science in cultural heritage and education

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1. Executive summary

This report looks at the role of digital technologies, and particularly crowdsourcing technologies, in facilitating the uptake of citizen science approaches in the fields of cultural heritage and higher education, tapping into the lessons learnt during the CitizenHeritage project. It starts with a comparative review of existing state-of-the-art digital tools that support crowdsourcing in citizen science settings, considering various aspects, such as their application focus, tasks design, and licenses (Section 2). It then goes on with an overview of the crowdsourcing campaigns organised via the CrowdHeritage platform in the framework of the CrowdHertiage project (Section 3). The report continues with a case study (Section 4) conducted at the National Technical University of Athens that explores the application of crowdsourcing techniques in a computer science higher education course (the study has been published in the Proceedings of the 2023 4th International Conference on Artificial Intelligence in Education Technology 2023). Section 5 considers the feedback collected by users of the CrowdHeritage platform during the various activities of the project and the extensions applied to the platform in light of this feedback. The report concludes with some lessons learnt and recommendations, which can be proved useful for campaign designers and educators who wish to engage students in crowdsourcing tasks.

2. State of the art of digital tools used in CS projects

In this section, we present state-of-the-art digital tools used in citizen science (CS) projects. Our focus is on tools and platforms that center around crowdsourcing and are open, rather than enterprise-focused. These tools are designed to engage mainly volunteering citizens (be it members of a specific community, educators and students, enthusiasts from the general public etc), not just paid workers, and have been widely used in many citizen science projects. Their main goal is to digitize cultural heritage artifacts to enrich digital museums' collections and construct datasets to support machine learning research. In addition, the platforms and tools we present are those that are still in operation and maintained to this day.

For each tool, we provide some basic information (e.g. link, supplier, short description) and outline its main application focus (e.g. academic, CH-oriented etc). We also outline the objectives it can support (e.g. for transcribing handwritten material, for the semantic enrichment of metadata etc) along with the ways in which tasks are designed (e.g. as simple questions, crowdsourcing contests etc) and collected data used. Moreover, we mention some indicative citizen science projects that have utilized each tool and indicate whether it is open for use and under what conditions.

Name	Zooniverse
Link	zooniverse.org
Developed by	Citizen Science Alliance
Short description	The Zooniverse is the world’s largest and most popular platform for people-powered research. This research is made possible by volunteers — more than a million people around the world who come together to assist professional

	researchers.
Main focus	Academic/research-oriented; All disciplines, including CH/humanities
Way of use	Study authentic objects of interest gathered by researchers, like images of faraway galaxies, historical records and diaries, or videos of animals in their natural habitats
Project design	Answering simple questions
Uses of contributed data	Contribution to research projects
Used in CS projects related to CH/digital humanities (indicative)	Criminal Characters, Scribes of the Cairo Geniza, Star Notes
Platform use	Open - anyone can "build a project"

Name	Transcribathon - Europeana Transcribe
Link	transcribathon.eu
Developed by	Facts & Files, Austrian University of Technology
Short description	Europeana Transcribe is an online citizen science initiative for the enrichment of digitised material from Europeana. Engagement with the platform is supported by events known as transcribathons.
Main focus	Academic/research-oriented; Cultural heritage
Way of use	Europeana Transcribe aims to engage the public in transcribing, annotating and georeferencing Europeana's vast collection of digitised items - particularly handwritten materials - amassed from libraries, archives and museums from all across Europe.
Project design	Micro Tasking, Crowdsourcing contest
Uses of contributed data	Enhance Europeana's content
Used in CS projects related to CH/digital humanities (indicative)	Europeana Transcribe
Platform use	Open

Name	DigiVol
Link	volunteer.ala.org.au

Developed by	Australian Museum in collaboration with the Atlas of Living Australia
Short description	DigiVol is a crowdsourcing platform that is used by many institutions around the world as a way of combining the efforts of many volunteers to digitise their data. This data may be in the form of museum object labels, field notebooks and diaries, recording sheets, registers or photographs.
Main focus	Academic/research-oriented; All disciplines, including CH/humanities
Way of use	Data can be extracted from museum labels and field notebooks by transcribing (or typing out) the handwritten words. Other forms of collecting data may be by tagging images or identifying animals and their behaviour in the images.
Project design	Micro Tasking
Uses of contributed data	Helping researchers to have access to data that can be used for a whole variety of studies
Used in CS projects related to CH/digital humanities (indicative)	St Leonards Council Minutes, City of Kew Minutes, Warrego BurdekinII
Platform use	Open to any institution or individual

Name	Smithsonian Digital Volunteers: Transcription Center
Link	transcription.si.edu
Developed by	Smithsonian Institution
Short description	The Smithsonian Transcription Center (TC) is the Smithsonian Institution's largest digital volunteering and crowdsourcing platform, connecting curious learners everywhere with digitized Smithsonian collections. Through collaborative transcription and review, Smithsonian staff and digital volunteers ensure that our historic content is more readable, accessible, and text-searchable across Smithsonian databases and other major search engines. This work unlocks history and helps bring the past to life.
Main focus	Academic/research-oriented; All disciplines, including CH/humanities
Way of use	Transcribe the exact letters and words written in historical documents and on historical objects
Project design	Micro Tasking
Uses of contributed data	Enhance accessibility of digital collections
Used in CS projects related to CH/digital humanities (indicative)	Charles Lang Freer Papers, Art vouchers, 1906-1907, Jervis McEntee Diaries and Letters: Diary, Volume III, 1878 December 15-1883 June 15, Project PHaEDRA

Platform use	Open

Name	VeleHanden
Link	velehanden.nl
Developed by	Picturae
Short description	VeleHanden is the crowdsourcing website of Picturae where archives and museums offer their digitised collections for access to the general public. The aim is to make collections searchable and to ensure that they are available online for everyone.
Main focus	Academic/research-oriented; Cultural heritage
Way of use	Retyping information in fields that can be seen next to a scan, providing photos with a description, recognize old manuscripts
Project design	Micro Tasking - Rewarding
Uses of contributed data	Digitization and disclosure of heritage collections for museums, archives and libraries in the Netherlands and abroad.
Used in CS projects related to CH/digital humanities (indicative)	Actum in camera. Witness statements from the archives of the Bruges aldermen's bench (1700-1795), Death certificates North Holland 1961 -1970, Zaanse transport deeds 1560 - 1811
Platform use	Open to institutions

Name	CrowdHeritage
Link	crowdheritage.eu
Developed by	National Technical University of Athens with the contribution of the European Commission under the Connecting Europe Facility (CEF) Taken over, maintained and further extended by the spinoff of NTUA Datoptron.
Short description	Crowdheritage is an open platform that supports the organisation of online crowdsourcing campaigns for the enrichment and validation of cultural heritage metadata. The platform is mainly used by cultural heritage organisations across Europe and beyond who wish to improve the quality of their collections and engage different target audiences in the process in a playful way.
Main focus	Cultural institutions; All disciplines, including CH/humanities
Way of use	Annotation campaigns
Project design	Crowdsourcing contest
Uses of contributed data	Improving cultural heritage institutions collections' metadata

Used in CS projects related to CH/digital humanities (indicative)	Clothing and Garments in the Arts, Endangered species, Musical instruments
Platform use	Open with certain features/ custom features upon request/agreement with the developers

Name	MicroPasts
Link	crowdsourced.micropasts.org
Developed by	University of Cambridge, UCL, University of Stirling
Short description	MicroPasts is a free and open-source, crowd-sourcing platform which supports massive online data collection about the human past. MicroPasts is developing example projects for common research tasks that require either widespread user contributions or human intelligence .
Main focus	Academic/research-oriented; All disciplines, including CH/humanities
Way of use	Accurate location of artefact findspots or photographed scenes, identification of subject matter in historic archives, masking of photos meant for 3D modelling, transcription of letters and catalogues
Project design	Micro Tasking
Uses of contributed data	Open and freely usable results
Used in CS projects related to CH/digital humanities (indicative)	Photo-Tagging of Scottish Political Archive photographs, Video-tagging about the Roman Empire, Transcribing Woolley's field notes - Ur of the Chaldees
Platform use	Open

Name	Picture Pile
Link	geo-wiki.org/games/picturepile
Developed by	Geo-Wiki, International Institute for Applied Systems Analysis
Short description	Picture Pile is a crowdsourcing platform for efficiently and intuitively classifying images for machine learning.
Main focus	Academic research; Generic
Way of use	Classifying images to help machine learning and artificial intelligence experts
Project design	Gamification - Workers Reward

Uses of contributed data	The collected data is publicly available on the Data Portal to be used in machine learning projects for free.
Used in CS projects related to CH/digital humanities (indicative)	Picture pile
Platform use	Open - a “pile” will be published on the Picture Pile App for the crowd to classify the images

Out of all the platforms that have been introduced, Zooniverse has emerged as the most widely used platform with more than 100 active projects and over one million volunteers. On the other hand, DigiVol and VeleHanden have around 15000 volunteers each and 20-25 active projects. While the Smithsonian Transcription Center and PicturePile have not disclosed the exact number of volunteers, they claim to have a significant number of volunteers in the thousands. Similarly, MicroPasts has over 2000 users who contribute to its 14 active projects. CrowdHeritage is another platform that has garnered significant attention with over 1500 contributors and 10 active campaigns. Finally, Transcribathon has over 3500 members who participate in their projects. As we have mentioned before, the majority of these platforms rely on volunteers (although some provide a form of reward), with the exception of PicturePile, which recruits paid workers.

It’s worth mentioning that most of these platforms were developed through collaboration of researchers, universities and institutions. The only exception of the above-mentioned tools is VeleHanden, which was developed by Picturae, a company that specializes in digitizing cultural heritage and historical collections.

With respect to the type of data they deal with, most of these tools consider manuscripts and images, while Zooniverse and MicroPasts also use videos. Transcribing and annotating these documents seems to be the main focus of all these platforms, in order to preserve cultural heritage artifacts and/or enhance datasets for research purposes.

With respect to the type of tasks participants are solicited to perform, Zooniverse and DigiVol both utilize micro-tasking by asking volunteers to answer simple questions related to research or cultural heritage data, such as identifying animals or transcribing handwritten text. In contrast, Europeana Transcribe and the Smithsonian Transcription Center focus on transcription of historical documents and digitized materials. VeleHanden asks volunteers to retype information in fields that can be seen next to a scan, providing photos with a description, and recognizing old manuscripts. MicroPasts and PicturePile are two platforms with a focus on image classification. CrowdHeritage differs from the other above-mentioned platforms due to its specific focus on enriching cultural heritage metadata, via campaigns that involve annotating or validating tags referring to various types of CH items (images, video, documents etc).

Overall, each platform offers unique ways for volunteers to engage with research and cultural heritage data through micro-tasking, transcription, annotation, and other methods. The platforms provide a range of opportunities for volunteers to contribute to scientific research and cultural heritage digitization and preservation.

3. CrowdHeritage: organising citizen science crowdsourcing campaigns to enrich cultural heritage collections

The table below provides an overview of the five crowdsourcing campaigns that were organised as part of the CitizenHeritage project involving various types of digital collections (e.g. about music, dance, photographs of hungarian history).

Citizen Science Campaigns on CrowdHeritage organised during the project	Short description	Number of items in curated collections	Number of users contributing to the campaign	Number of new annotations	Number of up-/downvotes
https://crowdheritage.eu/en/cypriotic-communities	This campaign offers a glimpse of life in Cypriotic communities, featuring local people and their customs. From casual snapshots to stately posed portraits and evocative landscapes, this selection of images conveys a sense of how Cyprus is seen and experienced by citizens as well as visitors.	535	12	245	254 upvotes 0 downvotes
https://crowdheritage.eu/en/music-citizen	The collections in this campaign feature Italian, classical and American popular music tracks. Participants try to recognise the genre and the instruments of the music tracks and tell what they make them feel.	854	98	8399	49351 upvotes 495 downvotes
https:// https://crowdheritage.eu/en/move-memory	Since 2003, UNESCO recognizes a wide range of practices and traditions as Intangible Cultural Heritage. This hand picked gallery, sourced from Europeana.eu,	170	13	52	51 upvotes 1 downvotes

	is devoted to types of popular dance ('folk dance', 'country dance', 'volksdans', 'danza folkloristica') practiced by local communities.				
https://crowdheritage.eu/en/hungarian-history	This campaign aims to help visitors of Europeana.eu to find what they're looking for among 52 million digitized works of art and cultural artefacts on Europeana. Participants use descriptive keywords from the drop-down list to pinpoint places, people, objects, historic periods, pictorial styles or photographic qualities.	516	13	538	549 upvotes 0 downvotes
https://crowdheritage.eu/en/bulgarian-history	This campaign asks participants to add tags reflecting what they see or know about each picture (places, people, objects, concepts, historical events etc), which in turn will help people to discover them in Europeana.	680	23	2369	3095 upvotes 15 downvotes

4. A case study of applying crowdsourcing techniques in a computer science higher education course

In this section we describe a homework assignment involving students at NTUA in a citizen science-driven experiment that combines music collections sourced from Europeana, crowdsourcing techniques, and semantic web technologies. Part of the material below has been published in the Proceedings of the 2023 4th International Conference on Artificial Intelligence in Education Technology (AIET 2023).

The description of the online assignment which refer to the exploitation of the campaign's results can be found here (in Greek):
https://colab.research.google.com/drive/1HRJxSv1_7ghPp44obx2kUhExx0-urhdm#scrollTo=p54eJA_97-wW

4.1 Introduction

In recent years, we are witnessing an increasing number of studies that explore the use of crowdsourcing in education, embracing various disciplines, topics, and educational levels [22]. Most of the existing work looks into crowdsourcing as a means of creating or assessing educational material and collecting feedback from students [2 , 48 , 50]. Fewer studies tap into how involvement in a crowdsourcing experiment can serve an educational goal in itself [25 , 31]. We argue that incorporating crowdsourcing in the form of real-world and discipline-appropriate exercises in education curricula can bring about multiple benefits for students. First, students can learn about the potential as well as the challenges (technological and methodological) associated with the planning and execution of a crowdsourcing process and how this can be useful within the context of their discipline. Additionally, the design of appropriate crowdsourcing tasks can help students familiarize themselves with important domain-specific concepts in a hands-on way and understand how the data collected through the process can be further exploited and enable new possibilities. Lastly, the participatory nature of crowdsourcing can stimulate learning and engagement [18] and add a collaborative and creative touch to more traditional teaching procedures.

In tandem with its educational potential, crowdsourcing has been extensively used and studied in the context of citizen science, by providing the methodology and tools that enable the engagement of individuals who voluntarily contribute to knowledge production with a scholarly focus [40]. Higher Education Institutions (HEI) can play a significant role in this context, by providing technical, material, and human resources, reinforce open science policies, stimulate cross-disciplinary collaborations, and hone the competences of new generations of scientists, researchers, and innovators as already mentioned. In such a setting, crowdsourcing can be seen as a driver of both citizen-enhanced open science and educational learning. Similarly, students are invited to play a dual role: act as citizens/contributors and as scientists/researchers.

The role that crowdsourcing can play in the Computer Science (CS) programs of HEIs in particular remains quite unexplored. Despite its close interrelations with IT practice and research, considering both the use of digital technology as a facilitator of crowdsourcing and, vice versa, the extensive application of crowdsourcing techniques in the IT domain (e.g. active learning, dataset construction for Machine Learning (ML)), crowdsourcing is not among the subjects which usually make up a CS curriculum. In fact, crowdsourcing as a practice and technology remains peripheral to CS-relevant HE programs, with references to it and hands-on experiments being incidental (note that the crowdsourcing initiatives in education reviewed in [22] include only one case study from CS). Our main objective in this study is to alleviate this gap by reporting on a case study that investigates how crowdsourcing can be incorporated into a CS curriculum as a component and facilitator of a mini-project assignment that can teach students useful lessons. As part of the case study, students were invited to participate in an online campaign with the aim to enrich the metadata of a music tracks collection. Students were then instructed to analyze the enriched dataset and apply semantic web technologies to construct a knowledge base and use it to extract useful information from it.

In this context, our research set out to explore the impact crowdsourcing had along two main perspectives: learning outcomes achieved in terms of new knowledge and skills acquired, especially within the scope and objectives of the CS curriculum (e.g. to what extent did students feel that they improved relevant skills? what did they learn?); and how the participation experience was perceived by students (e.g. did they feel engaged? did they enjoy the process?). Concerning the educational gains, we were particularly concerned with the extent to which crowdsourcing assists students to gain deeper insights into the structure and shortcomings of data, into the processes and technological infrastructures that can be used to acquire richer and higher-quality data, as well as into how the enhanced data can be further utilized. Regarding the extent to which students felt engaged, we were mainly interested in affective characteristics, relating to feelings and attitudes. Another direction we explored regards the role of technological tools, considering the requirements for certain features as well as the way in which the digital platform that was used influenced the experience of the participants (which features were the most appreciated? what issues were identified?). By putting themselves in the position of the contributor and platform end-user and, in parallel, by drawing on their capacity as CS students and technical experts, participants were able to provide insightful perspectives along this strand of inquiry.

Overall, the case study exemplifies how crowdsourcing can fit in a CS course and serve its intended didactic objectives. By describing in detail the methodology that was followed, from the data curation and the campaign setup to the exploitation of results and the evaluation approach, the technological tools that were used, the challenges that were encountered and the way in which these were overcome, the current study points both to the benefits as well as the limitations of the approach and can thus serve as a paradigm and as a source of inspiration for incorporating crowdsourcing in CS curricula and beyond. As confirmed in the survey performed in [46], the availability of such detailed descriptions and accompanying open resources are highly appreciated by educators in tertiary education to facilitate the incorporation of citizen science projects into post-secondary courses [46]. Besides the educational benefits, in line with the principles of open and citizen science, the data generated by the case study is further processed and made openly available, thus contributing to ongoing developments in music tagging research.

Finally, our case study adds one more dimension with a strong interdisciplinary orientation, that of digital humanities. The curated dataset acting as the baseline for the crowdsourcing campaign as well as the design of the associated enrichment tasks were driven by established practices in the cultural heritage (CH) domain. Music was selected as a type of heritage which is quite popular among students and can be enjoyed and appreciated without any special requirements for expert knowledge. Crowdsourcing has been employed quite broadly in multiple settings within these fields – in the context of projects led either by museums' departments or by universities and research institutes - mainly as a process that invites members of the public "to tag and classify, transcribe, organize, and otherwise add value to digital CH collection content" [33]. Such approaches customarily operate within the traditional functioning of digital humanities, looking into how computational tools can be harnessed to support the humanities researcher and CH professional. Although the current study provides useful insights along this perspective, as a demonstrator of how digital technology can be employed for the enrichment of CH collections, it places its main focus on the opposite direction, which so far has received much less attention: How can digital heritage collections, and music collections in particular, be utilised in a CS context? What are the potential benefits for CS students and IT research? And, ultimately, by connecting to the strands of research discussed earlier: how can concepts, processes, and tools used in cultural heritage, computer science, and citizen science be meaningfully combined within a higher education context and what kind of conclusions can be drawn from this interplay?

4.2 Related work

According to the typology suggested in [22], crowdsourcing is used in educational activities to serve four main objectives: create educational content; collect feedback from learners; exchange complementary knowledge by resorting to external crowds; and by providing practical experience. Its most prevalent uses concern educational material generation and assessment [2, 50] and this is also true for CS-related curricula in higher education. For example, [36] describes a tool that can be used as a means to support teachers and students to create and review programming assignments. The main motivation behind such initiatives is premised on the potential benefits of crowdsourcing concerning optimizing the lecturing process and stimulating student involvement through knowledge co-creation and sharing, in line with contemporary learner-centered approaches to education [28]. The current case study employs crowdsourcing in a project-based setting [4], inviting students to grapple with a real-world problem — that is creating a music knowledge base and a recommendation system. Tapping into the multiple prospective benefits of project-based learning, in [25], the potential of resorting to crowdsourcing platforms for sourcing realistic tasks that can replace traditional assignments addressed to students of industrial design is discussed.

The current case study aims to further investigate and leverage the employment of crowdsourcing in such a context, aiming at similar educational gains but from a different perspective: it approaches crowdsourcing not merely as a pool of possible pre-designed tasks, but rather as a methodology and technique that can be adapted to the specific course objectives and that is worth learning in its own right.

Applications in CS-related higher education curricula (informatics, computer engineering, etc) that adopt crowd-sourcing as a means to provide practical experience in a setting relevant to the students' discipline are few. In [24], a crowdsourcing experiment conducted as part of a research project, involving data science students in rating homework reviews, had the unplanned effect of serving as a learning opportunity for students. In [7], students of software engineering were assigned the task to test commercial software and through this process achieved industrial-strength training. The most common practice, which is also followed by our work, is that instructors assume the role of the requester and students that of crowd-workers. An interesting exception to this is [16], where graduate and undergraduate computer science students were asked to design and deploy their own crowdsourcing projects. The current case study adds to this line of work, by placing the focus on the challenges and possibilities of crowdsourced-enabled data enrichment in serving CS-relevant learning objectives and by contributing novel evidence and multi-dimensional insights grounded on an extensive analysis of feedback collected from students about multiple aspects (skills, engagement, usability, etc).

Within the last years, there is an increasing number of initiatives that apply crowdsourcing in citizen science-oriented settings within formal and informal learning environments (schools and universities) [27]. Most such initiatives involve children and adolescents at the primary and secondary levels [37], while citizen science projects in tertiary education remain fewer [46]. In an application of citizen science in an undergraduate environmental studies course [17], students were engaged in reporting roadkilled animals, thus gaining a deeper understanding of ecological problems and their solutions. Another case study [31], involving students from biology and environmental studies in field data collection, concludes that students enjoyed the learning process and improved their understanding of the domain as well as of crowdsourcing as a method for data collection. The crowdsourcing task selected for the current case study involves data enrichment of a music collection [14].

In this respect, the current study contributes to ongoing efforts [3, 6, 20, 29 , 51], many of which resort to crowdsourcing methods, to increase the availability and quality of annotated datasets that can be useful for prototyping systems for Music Information Retrieval (MIR) tasks [8] and particularly tasks concerning genre [9], instrument [41], and emotion recognition [30]. One of the shortcomings of such annotated datasets is that most of the music tracks are released under licenses that do not permit their publication. Due to this limitation, it is common that published datasets only contain features that are derived from audio analysis, without including the raw audio data [5], or that they only publish short samples of the music tracks [34]. With respect to datasets annotated with emotion labels entered by human subjects, in particular, the subjectivity associated with the task makes it especially time-consuming, labor-intensive, and prone to errors, resulting in limited availability of such datasets [43]. In this context, by making openly available a carefully moderated subset of the annotations collected via the crowdsourcing campaign along with the original audio files they refer to, the current study also plays a part in developments in music auto-tagging.

A broad range of crowdsourcing platforms have been proposed and tested in education. For example, [13] describes a platform for the collaborative creation and refinement of large “banks” of subject matter problems in higher STEM education. For CS-related curricula, in particular, the open-source platform CrowdSorcerer supports novice programmers in creating and evaluating programming assignments [35]. Multiple platforms are used in experiments that bring citizen science in education, with the selection depending on the particular circumstances and the task at hand (e.g. platforms for collecting geospatial data, for software testing, etc). For the collection of data that are of interest to the CH domain, technology usage ranges from general-purpose platforms such as Zooniverse [42] to tools tailored to the needs of CH, such as the Transcribathon [12] and the CrowdHeritage [23] platforms. In this work we extended the utilities of the CrowdHeritage platform, creating a more comprehensive environment for crowdsourcing.

4.3 Methodology for preparing the case study

The case study was conducted as part of an assignment involving fourth-year undergraduate informatics students of School of Electrical and Computer Engineering of NTUA who attended the course “Knowledge Systems and Technologies” in the spring semester of 2022. The main objective of the course is to introduce students to the fundamentals of description logics, methodologies for object-oriented knowledge representation, management, evolution, automated reasoning, and semantic data integration algorithms. Specific emphasis is given to the analysis of W3C standards for semantic data and knowledge representation (XML, RDF, OWL, etc), ontology engineering and applications of knowledge-based systems and intelligent web services [45]. The course includes a semester-long multi-step assignment that aims to familiarize students with the above-mentioned concepts and associated tools via hands-on tasks. In line with these educational objectives, the case study set out to introduce concepts from digital CH as well as crowdsourcing to this purely CS-oriented curriculum and broaden the scope of the assignment towards an interdisciplinary direction.

In its first step, the assignment focused on familiarizing students with the curated dataset and on engaging them as annotators in a crowdsourcing campaign as a means to enrich the dataset with additional useful knowledge. The main objective in this respect was for students to understand the shortcomings of real-world datasets and how raw, inadequate, or inconsistent forms of data can be transformed into well-structured, normalized, and inter-linked formats. Next, students were asked to transform the enriched data structure into a knowledge graph containing RDF triples and build an ontology that describes the data by constructing concepts, roles, axioms, and instances syntactically and semantically correct. Finally, students were solicited to use various methods to infer extra information and exploit it to make meaningful recommendations on music. In the following sections, we describe the incremental steps of the methodology we followed to set up the case study: the dataset curation; the definition of the enrichment tasks; and the organization of the crowdsourcing campaign.

4.4 Dataset curation

We decided to use the Europeana digital library to source the data that constituted the starting point of the crowd-sourcing campaign and the subsequent assignment steps. Europeana currently aggregates more than 58 million records coming from CH Institutions (CHI) across Europe, including a diverse set of audio files on the theme of Europe’s Music Heritage. CH items on the Europeana platform are described via a well-defined established metadata structure, the Europeana Data Model (EDM) [11], which conveys important information about the items, such as their title, free text description, creator, etc. These metadata fields are essential for the accessibility and discoverability of the rich and disparate collections made available through the Europeana platform, helping users to find and understand the objects they are interested in. It should be noted that all metadata published on the Europeana platform are licensed under a CCO license (Creative Commons Zero Universal Public Domain Dedication).

The first step towards the preparation of the case study concerned the curation of the dataset that would constitute the starting point of the crowdsourcing campaign and the subsequent assignment steps. We started by scouting the music content available on the Europeana platform through the Europeana Search API, which provides a way to search for metadata records and media on the Europeana repository and supports advanced queries and filtering.

The following selection criteria were used to guide the curation process:

- Quality of metadata that accompanied the music tracks. Metadata records on the Europeana platform often suffer from poor metadata, either due to many empty properties or inconsistent values (e.g. the EDM property "dc:contributor" sometimes includes composers and sometimes interpreters). In order to build an initial knowledge base that can act as a sufficiently expressive starting point for further enrichment, we filtered out metadata records that lacked information considered essential for building an initial knowledge base (e.g. information about the creator, the year of publication, etc).
- Quality and length of audio files. Audio files longer than 6 minutes were discarded, to filter out files that represented more than one music tracks (e.g. recordings of a whole concert or album) as well as to avoid assigning overly time-consuming tasks to students. The sound quality was also evaluated on sample files, which were considered indicative of the overall sound quality provided by a provider.
- Genre coverage. In order to serve the needs of the assignment and facilitate meaningful recommendations, the selection process aimed to cover a wide coverage of music genres (from classical and folk to rock and rap).

Property name	Correspondence to EDM property	Specification
EuropeanaID	rdf:about	the music track's unique Europeana record ID
Title	dc:title	the music track's title
Year	dc:date	the year when the performance was recorded
Duration	ebucore:duration	the duration of the track in milliseconds
Composer	dc:creator	the composer of the music track
DateOfBirth	rdaGr2:dateOfBirth	the date of birth of the music track's composer
DateOfDeath	rdaGr2:dateOfDeath	the date of death of the music track's composer
Biography	rdaGr2:biographicalInformation	the biography of the music track's composer
Publisher	dc:publisher	the publisher of the music track
Place	skos:prefLabel	the place where the performance was recorded

By performing a series of API queries reflecting the criteria described above and evaluating a sample of the results, we ended up using data from the following CHIs: the "Internet Archive”, the "Internet Culturale / Biblioteca Nazionale Braidense - Milano”, and the “Fondazione Biblioteca Europea di Informazione e Cultura (BEIC)”. Eventually, 854 songs were collected. As far as the licenses of the music tracks themselves are concerned, these vary depending on the provider: the Internet Archive has collected recordings from musicians under a trade-friendly statement 2, which allows for the non-commercial exchange of the recordings; the tracks provided by the "Biblioteca Nazionale Braidense - Milano" are not restricted by copyright 3; and the license associated with the tracks aggregated by BEIC is stated as "Preview Only", with no further information.

A post-filtering procedure on the curated metadata records was necessary since not all metadata fields included in the returned records are characterized by consistent values. Either some metadata fields were missing from the majority of records or contained values that were inconsistent with respect to the intended semantics (e.g. in some cases "dc:description" included information about the album of the track and in others about the location of the concert). Moreover, fields that do not contribute information that can be helpful in the framework of a knowledge system for music, such as the name of the data aggregator, have been discarded. The post-filtering process resulted in the metadata properties shown in Table 1. We used the User Gallery tool on the Europeana platform to organize the items and the Europeana Record API to retrieve the metadata records in JSON format, which we processed to create a CSV file with the filtered metadata.

Property name	Correspondence to EDM property	Specification
EuropeanaID	rdf:about	the music track's unique Europeana record ID
Title	dc:title	the music track's title
Year	dc:date	the year when the performance was recorded
Duration	ebucore:duration	the duration of the track in milliseconds
Composer	dc:creator	the composer of the music track
DateOfBirth	rdaGr2:dateOfBirth	the date of birth of the music track's composer
DateOfDeath	rdaGr2:dateOfDeath	the date of death of the music track's composer
Biography	rdaGr2:biographicalInformation	the biography of the music track's composer
Publisher	dc:publisher	the publisher of the music track
Place	skos:prefLabel	the place where the performance was recorded

Table 1. Metadata Specifications

In order to organize the items, we first used the User Gallery tool provided to create 3 galleries, i.e. collections of items selected by the user, on the Europeana platform, one per institution. We used Python scripts to issue requests to the Europeana Record API 4 in order to retrieve the metadata records in JSON format. Finally, we processed the returned JSON structures returned by the calls, applying the criteria described above, in order to create a CSV file with the filtered metadata. The file was used as the basic data for the purposes of the assignment.

4.5 Definition of the enrichment goals

The information conveyed by the original metadata properties sourced from the Europeana platform is quite limited, allowing only for quite basic queries and restricting the potential for their meaningful further exploitation. In order to enable higher flexibility, richer ontology structures, and more reliable recommendations, the curated dataset has to be enriched with more information which can be exploited by the later stages of the assignment. At the same time, the more extensive and specialized information is added, the more expert knowledge, effort, and time is required. For example, retrieving detailed information about the performance and featured artists (e.g. singers, musicians) requires dedicated research. It should also be noted that performing raw audio analysis for extracting sonic characteristics, such as "instrumentalness" or "danceability", used by established music recommendation systems [44] is beyond the scope of the specific CS course. Similarly, taking into consideration the size of the class and time constraints, the analysis of user taste profiles as a means to inform recommendations on music was not considered as part of the assignment.

Weighing in the above considerations and in order to achieve a middleground between desired richness and feasibility, the manual enrichment process focused on collecting data along the following three aspects: "Emotion", "Genre" and "Instruments". These enrichment goals were formulated as crowdsourcing tasks to be carried out by students via their participation in an appropriately designed campaign. The terms for all metadata fields and respective type of tasks correspond to Wikidata URIs and were selected based on specific criteria, as explained below. The use of Wikidata allows students to more effectively exploit the collected information in order to build more complex concepts and queries by consulting additional knowledge that can be derived from the semantic web.

Emotion reflects how the audience feels when listening to a music track. The use of emotion in creating music playlists is a frequently occurring concept with users and can be exploited for making meaningful music recommendations. Obviously, this is partly a subjective issue - every person perceives a music piece on their own way, although a majority of people would usually agree whether a song is melancholic or joyful. The subjective dimension of emotion is an additional reason why an aggregated opinion by the crowd can help us derive an "average" metric about what kind of emotion a song gives rise to. In order to represent emotion within music, we based on the circumplex model developed by James Russell [38]. The model is oriented around two dimensions: arousal represents the vertical axis and valence represents the horizontal axis. The emotion values-tags that we used included: Arousal, Joy, Pleasure, Calmness, Boredom, Sadness, Anxiety and Fear. Their place on Russell's model is shown on Fig. 1. The main advantage of using this model is its simplicity, which entails that users being asked to express emotional ratings should find it fast and easy to engage with [15].

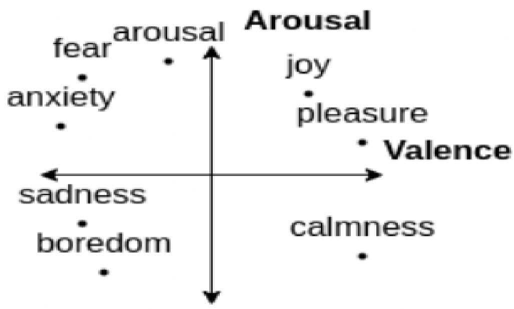


Fig. 1. Emotion tags in circumplex model

Genre is a characteristic that is commonly used to organise music tracks and is exploited by music recommendation systems, sometimes in combination with emotion [52]. Information about the genre of a music track may be included in the original Europeana metadata records under the property "dc:subject". However, the inspection of Europeana data led us to the conclusion that (i) this information is missing from a large number of items; (ii) that its values are frequently inaccurate; and (iii) that they do not follow a common and consistent classification system. In fact, the property "dc:subject" takes free text values, i.e. does not enforce selection from a controlled list of terms. As a result, genre values in Europeana metadata records are highly heterogeneous (for example, in some cases, such as "Art", they are too coarse and in others, such as "Roots Rock", too granular), making it difficult to computationally assess the correlation between different tracks. In order to derive consistent information about music genres, we decided to use a predefined terminology from which students should select the most appropriate term during the campaign. Taking into account the fact that our annotators are not music experts, we selected tags which represent typical music categories (e.g. Rock) instead of tags with highly specific usage (e.g. Alternative Rock). Considering also the coverage of the curated dataset, the following controlled list of terms was used: Pop, Rock, Country, Classical, Opera, Instrumental, Funk, Hip-hop, Reggae, Jazz, and Traditional Folk.

The instruments used in a track is another important musical characteristic. Compared to the other categories mentioned above, it is the characteristic which requires the most familiarity with music. For the musical instrument annotation task, we used 12 different terms. Similarly to our approach on representing genre, we selected rather high-level terms with a broad application (e.g. Brass instead of Trumpet, Trombone etc) as well as basic instruments (such as Piano), whose sound can be adequately recognized even by non-experts. Considering also the most common instruments appearing in the curated dataset, we ended up with the following instrument tags: Piano, Electric Guitar, Acoustic Guitar, Drums, Synthesizer, Violin, Harmonica, Banjo, Bass, Woodwind, Brass. Orchestra was added to the list given the fact that many music tracks of our dataset are performed by a symphony orchestra and it would be difficult and time-consuming for students to discern individual instruments.

In addition to the three musical characteristics represented via controlled lists of Wikidata terms as mentioned above, students were also given the possibility to add free text comments about the music track they listened to. These comments could be exploited in later stages of the assignment, complementary to the "Emotion" tag, in order to further enrich the dataset using Natural Language Processing (NLP) techniques for sentiment analysis. Additionally, we gave the annotators the choice to mark music tracks they liked as "favorites", using a dedicated button on the crowdsourcing platform. This information was used to create users' profiles which helped the students to experiment with recommendations.

4.6 Setup of the campaign by using and extending the CrowdHeritage platform

After preparing the data and defining the enrichment objectives, the next step was to set up and run the crowdsourcing campaign that would allow students to perform the actual enrichment tasks in a well-defined and collaborative way. More specifically, students were invited to listen to the music tracks, recognize their musical characteristics, and tag the items appropriately by selecting values from the controlled lists of terms defined above. The open-source CrowdHeritage platform [23] was used to this end. The platform supports the organization of online crowdsourcing campaigns for the enrichment and validation of CH metadata. Through a user friendly interface which supports playful features such as leaderboards and rewards, users are invited to add new annotations or validate (via crowdvoting) existing ones produced either automatically by AI tools or added by other users of the platform. The platform has been used so far for the organization of multiple crowdsourcing campaigns in the CH domain, engaging different audiences (CH professionals, educators and students, CH enthusiasts, citizens etc) who have conducted various types of enrichment and validation tasks.

CrowdHeritage can parse data in the EDM format and is connected to the Europeana Search and Record APIs, thus facilitating the import of resources from the Europeana platform. Among its enrichment capabilities (e.g. color-tagging, geo-tagging), it supports the semantic annotation of records with terms from controlled vocabularies: users can add tags by typing in a dedicated text field and select from a list of suggested terms derived from a selected vocabulary, supported by an auto-complete functionality. Another particularly useful functionality refers to the validation mechanism supported by the platform, which can be seen as a means of peer-reviewing. Users can up- or down-vote existing annotations, depending on whether or not they agree with them. This validation input is further analyzed to identify questionable annotations and users with malicious or unreliable behaviour. A validation editor allows campaign organizers to review the produced annotations and to post-edit or filter them according to their criteria (e.g. based on the popularity of an annotation). These peer-validation and moderation mechanisms proved helpful for assessing the crowdsourced enrichments and for maintaining reliable end results.

In order to serve the specific requirements that emerged from the needs of the case study, CrowdHeritage was supplemented with some critical novel features, which are also useful for future applications of the platform since they streamline and expand its capabilities. The extensions implemented are detailed in Section 5.3. By making use of the platform's administrative functionalities, a campaign with concrete instructions was set up, which run for 18 days. The campaign setup included the import of the curated dataset; the definition of the annotation tasks by making use of the vocabularies/lists of controlled terms as defined in Section 3.2; and the specification of the campaign's overall objective, associated instructions, duration etc. The curated dataset was divided into eight sets of items with respective micro-tasks, in order to ensure balanced contributions by participants across the data. Students were advised to semantically annotate about 80 music tracks each and were encouraged to also add comments expressing additional information and their thoughts in free text. The completed campaign can be accessed here: https://crowdheritage.eu/en/music-citizen.

4.7 Using the enriched dataset to build and query a music knowledge base

At first, the annotations collected from the campaign underwent a review and filtering procedure and were then parsed and embedded as new properties to the EDM metadata records. The resulting enriched dataset was moderated and provided to the students as a CSV file. Students were advised to transform the tabular data to a knowledge graph [19].

The next step was to build an ontology linked with the graph using the Protégé editor [32]. The objective of this step was to teach the students how to structure the conceptual knowledge that can be inferred from the individual track instances into a generalized semantic model (as captured by the ontology) expressed in the form of concepts and properties. For example, the concepts "Song" and "Composer" can be used to represent the set of all items-tracks and composers respectively, while the property "hasComposer" can be used to connect a song with its composer.

The transformation of the dataset into a graph associated with an accompanying ontology opened the possibility for further automatic enrichment of the data using semantic techniques and enabled the support for advanced queries. The main techniques for further automatic data enrichment introduced to the students included: (i) accessing additional knowledge from external Linked Open Data resources; (ii) applying NLP on the free text comments; and (iii) extending the ontology by creating new concepts through axioms. Regarding (i), the students were advised to exploit the Wikidata URIs included in the metadata records and use the Wikidata SPARQL endpoint 5 in order to retrieve additional information and link it to the knowledge graph's entities. For example, using the composer's name, the students could construct a SPARQL query that fetches the artistic movements that characterize this composer or the location that the composer was born. Regarding (ii), students were solicited to apply a sentiment intensity analysis model [21] to analyze the free text comments added by students through the campaign and extract additional sentiment metadata features. Specifically, the model predicts how positive, negative or neutral a comment is. This additionally retrieved information was incorporated in the knowledge graph and used as an extra characteristic (referring to likeability) for identifying tracks that may be relevant for the user. As for (iii), the students were instructed to create novel concepts in the ontology, in order to support more expressive queries by combining existing information. For example, the concept *CalmJazzSong* can be defined via an appropriate axiom that groups together music tracks that have *Jazz* as its genre and *Calmness* as a relevant emotion; while the concept *NineteenthCenturyComposer* can be used for representing composers who were born in the nineteenth century.

At the point that the students had created a music knowledge base by linking their extended ontology with the enriched knowledge graph, they were able to apply SPARQL queries to it with the aim to identify tracks similar to a given track based on multiple criteria and thus make recommendations. The enriched information added via the crowdsourcing campaign was extensively exploited by the students and allowed them to construct complex and smarter concepts as well as SPARQL queries that can take into consideration multiple aspects that define a music track. Students experimented with different combinations of properties such as h*asGenre, hasInstrument, hasEmotion* to fetch tracks with certain characteristics. An example of a SPARQL query that returns all music tracks that have *Rock* as genre and *Joy* as emotion is shown in Fig. 2, where ns is the namespace for concepts and prop is the namespace for properties. Compound concepts of the extended ontology were used by students as parameters in their SPARQL queries in order to make them more concise. For example, the concept *JoyfulRockSong* can be defined through an axiom that groups together songs which are of genre *Rock* and have emotion *Joy*.

In order to support students in experimenting with and evaluating recommendations, some favorites lists of music tracks were created by considering some artificial users and track selections as well as the favorite lists created by students during the crowdsourcing campaign through the use of the respective functionality of the CrowdHeritage platform. By making use of these lists as a reference, students were able to make recommendations by applying similarity SPARQL queries based on the metadata features of the first song in each favorite list (a decision made to simplify the task of finding similar tracks). In this way, students were able to experiment with SPARQL queries that combined different criteria (e.g. common composer, emotion, genre), compare the results returned against the favorite lists, and get familiarized with the concepts of evaluation metrics, such as precision and recall.

```
select ?x
where {
?x rdf:type ns:Song.
?x prop:hasGenre ns:Rock.
?x prop:hasEmotion ns:Joy.}
```

Fig. 2. Example of a SPARQL query

4.8 Campaign results

Overall, the crowdsourcing campaign involved 98 participants, 68 males, and 30 females, all of whom were students of the course “Knowledge Systems and Technologies” of age 21-23 years old. Below, we provide an overview of the annotations contributed during the campaign.

The campaign led to the addition of 8399 annotation tags in total, while there have been 49351 up-votes and 495 down-votes of annotations added by other users. A moderation process was necessary to review and filter out the results which were considered of questionable validity. The number of up- versus down-votes received by an annotation was used as the main criterion to assess its reliability and resolve issues of ambiguity, subjectivity, malicious or irresponsible behavior via a majority vote. The annotations’ moderation took place by making use of the validation editor provided by the CrowdHeritage platform, which allows campaign organizers to review the annotations produced during a campaign and filter them according to their own acceptance criteria. During the moderation process, only the two top-ranked annotations per **Emotion** and **Genre** were kept and only if these had an up- versus down-votes difference of at least two. For the **Instruments** property in particular, only values with a votes difference above five were kept. This rather strict pruning criterion was decided because many students mentioned in their feedback that they did not have the necessary expertise to recognize musical instruments. In addition to this filtering process, the annotations of a random sample of 80 music tracks were reviewed by two music experts, who concluded that the enriched metadata were of high quality.

As a result of the post-filtering process, 5147 annotations were kept: 1248 of them refer to genre tags, 1643 to emotion tags, 1422 to instrument tags and 834 represent free text comments. In Fig. 3 the statistics of annotation tags per metadata property are presented. For the instrument annotation task, we notice that tracks with knowable and distinguishable sounds such as *Drums* and *Orchestra* are the most annotated ones. Furthermore, the distribution of the Genre tags demonstrates that *Instrumental, Rock, Classical* and *Pop* are the most dominant tags. As for the emotion property, we observe that positive emotions are the most common, a finding that confirms the bias towards positive emotions in music datasets discussed in previous work [53].

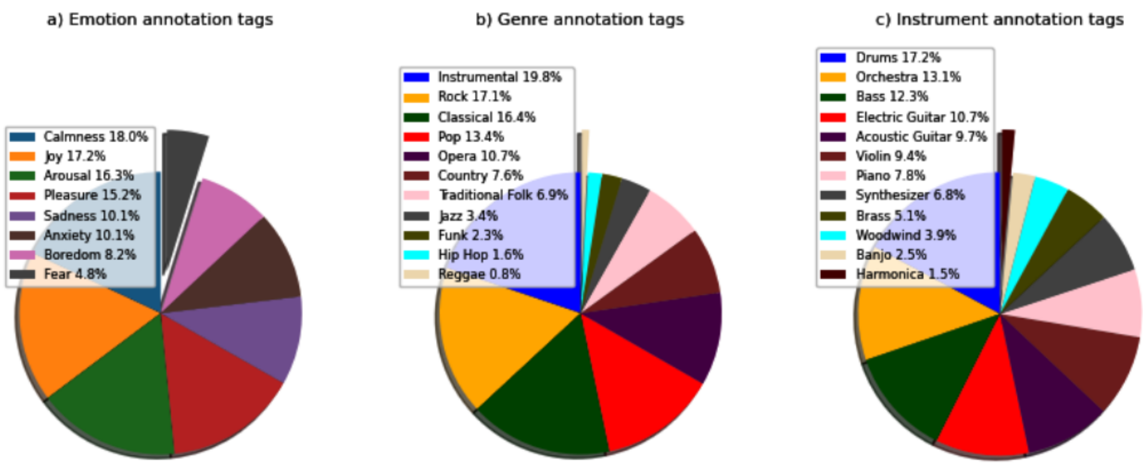


Fig. 3. Annotation tags per category from the campaign

In order to further assess the quality of the collected metadata, we analyzed them by using association rules. We applied the Apriori algorithm [1] on the total of the tag element sets in order to study their correlation. We took into account the support metric in order to observe the most frequently observed pair tags. The support metric is calculated by counting the occurrences of both tags appearing in the same set and dividing them by the total number of set. Table 2 shows which paired tags appear more frequently. We observe that the most common paired tags reflect intuitive knowledge about music (e.g. Rock-Drums, Rock-Electric Guitar, Classical-Orchestra), while paired tags connecting emotion and genre (e.g. Calmness-Instrumental) are also in accordance with prior findings [49].

Support	Pair of Tags
0.201	Joy, Drums
0.192	Rock, Drums
0.185	Drums, Arousal
0.181	Electric Guitar, Drums
0.162	Electric Guitar, Rock
0.147	Classical, Instrumental
0.147	Classical, Orchestra
0.145	Calmness, Instrumental
0.144	Joy, Arousal
0.138	Bass, Drums
0.134	Instrumental, Orchestra

Table 2. Most frequent paired tags

4.9 Open annotated dataset

Although the use of ML was beyond the scope of the CS course in which the case study took place, the annotated dataset that resulted from the crowdsourcing campaign and the respective post-filtering process can be valuable for the prototyping and evaluation of MIR systems. To this end, a subset of the collected music tracks, metadata, and moderated enrichments are made openly available, so that they can be freely reused as data amenable for computational purposes. The dataset can be found here: https://github.com/vaslyb/MusicCrowd. All three categories of enrichments-annotations (genre, instruments, emotion) as well as the properties retrieved from the EDM are included in a single dataset.

Although all metadata with their enrichments can become available under a CCO license, the intellectual property rights associated with some of the recordings do not allow their inclusion in the dataset as audio files. Given that the availability of the audio files is necessary for extracting new music features, we decided to make openly available a subset of the whole dataset, which includes the 699 music tracks that have a license explicitly permitting their non-commercial reuse and that have at least a 30-secs duration. All tracks are annotated with respect to genre, emotion, and identified instruments using the value lists described before. It should be noted that the rather strict filtering criteria already mentioned ensure that only annotations for which there is high certainty for their validity are maintained. The filtering based on the up-/down-voting of annotations in particular compensates for factors commonly identified as leading to poor annotations, such as inattentive labeling, listener fatigue, or other errors [43].

5. User feedback and extensions to the CrowdHeritage platform

5.1 Feedback collected during the citizen science campaigns in Sofia and Budapest

During the crowdsourcing campaigns conducted in Sofia and Budapest (see Section 3), participants were invited to complete a survey. The survey mainly focused on investigating how users perceived their participation in the citizen science event and the collected feedback is analysed as part of O6. The survey also included a question about the ease of use of the CrowdHeritage platform, which participants made use of. Participants were asked to rate the usability of the platform in a Likert Scale from 1 to 5. 19 participants responded to that question, assigning an average score of 4.84. It should be noted that participants did not have any technical knowledge and were not familiarised with the platform before the event. This allows us to conclude that the CrowdHeritage platform exhibits a high degree of learnability and was perceived as very user friendly by users.

The experiment we run with NTUA students (see next Section) allows us to gain some more insight about the participatory elements and the usability of the platform, along with some suggestions for further improvements.

5.2 Feedback collected from NTUA students

An online survey addressed to students consisted of a combination of closed and open questions. First, we aimed to understand how the students experienced the crowdsourcing process as a part of their mini-project assignment. Relevant questions investigated: the degree to which the crowdsourcing objectives were lucid; what students identified as the main benefits of introducing a crowdsourcing campaign in the assignment; the degree and ways in which the process improved or extended students' knowledge and skills; the kind of feelings their participation gave rise to (e.g. boring, joyful, interesting etc); and the types of difficulties they experienced when performing their tasks (e.g. lack of skills, fatigue). Secondly, we aimed to collect feedback about the CrowdHeritage platform as a tool for contributing to crowdsourcing campaigns. Questions in this track focused on the overall usability of the platform; the usefulness and efficiency of different sub-components/functionalities (e.g. item view, annotations views, profile and contributions view, favorites etc); and on identifying certain shortcomings and collecting recommendations for further improvements.

35 students provided answers to the online questionnaire (5 females and 30 males). This low participation in the survey in comparison with the number of students who contributed to the campaign (36% of the campaign participants) is mainly attributed to the fact that answering the questionnaire was not seen as an integral/necessary step of the course assignment. It should be noted, however, that many students opted to use the free commenting functionality of the CrowdHeritage platform as a means to express their perceptions and provide feedback.

The objective of the campaign as well as of the overall assignment was well-understood by the students (97% described the objectives as "very clear/clear" and 3% as "clear enough"). 52% of the students described their participation experience as interesting or very interesting , 37% as neutral (neither boring nor very interesting) and 11% as boring. All students expressed that they had some knowledge gains: 77% of the students declared that their knowledge and skills were improved and expanded to a very large or large degree and 33% to a sufficient degree. 88% of the students stated that they enhanced their practical and technical skills, e.g. learned how to use certain technological frameworks, and 80% that they improved their CS scientific knowledge, e.g. with respect to semantic web principles, (see Fig. 4). Highly appreciated benefits also included: learning about the potential of crowdsourcing and how this is conducted (69%); gaining a deeper understanding of the data, their shortcomings, and the value of their enrichment (63%); the participatory elements that crowdsourcing added to the assignment (56%); and facilitating, through the data enrichment, more interesting things in later stages of the assignment (34%). Only 34% stated that they acquired new knowledge about cultural and musical metadata (e.g. their structure, properties). Knowledge gains in the field of music (e.g. learning about new songs, genres, to identify instruments) were mentioned only by 11% of the students. All students declared that they would consider employing crowdsourcing as a means for data enrichment in the future.

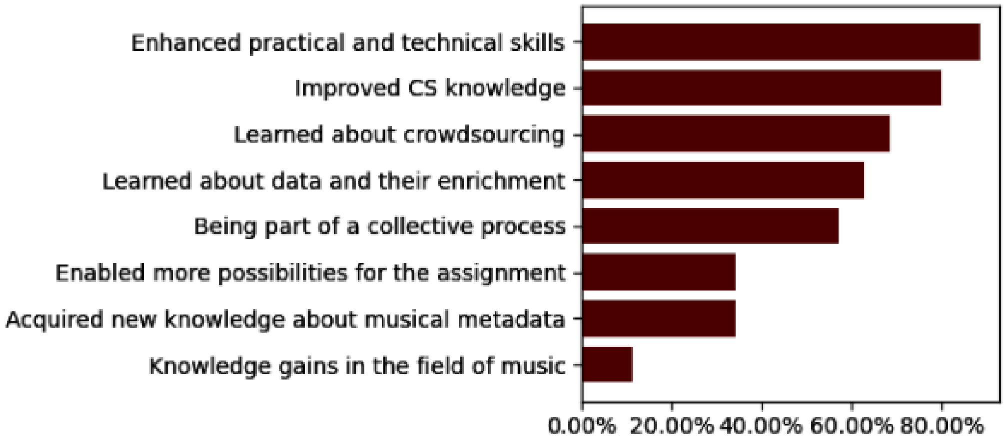


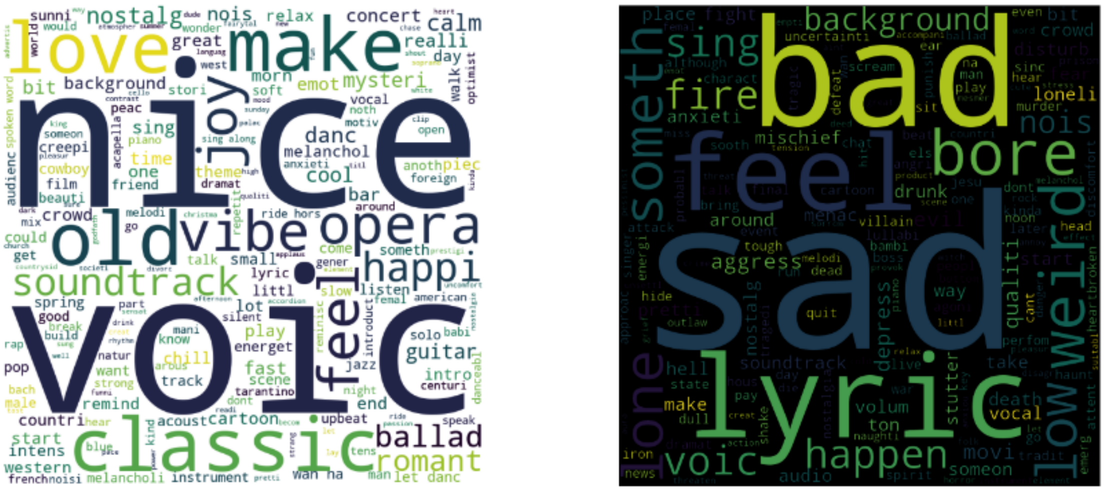
Fig. 4. Most appreciated benefits gained by the students

The most commonly mentioned factor that hampered students' degree of engagement concerned the fact that certain tasks, and particularly the identification of genres and instruments, required a degree of music sophistication which many students did not possess (46% of the students encountered this difficulty). This finding is aligned with the observations made in previous work discussing music content annotation campaigns [39], which express the concern that crowd workers are often expected to annotate complicated music artefacts that demand certain skills that participants may lack. Moreover, the completion of all the annotations tasks expected by a user (each user was encouraged to annotate 80 items) was perceived as too time-consuming (35% of students pointed to this issue). Some students mentioned that, in some cases, the available choices from the controlled vocabulary lists were not sufficient to convey what they would like to express, while others identified some music tracks as being of poor quality.

Overall, 94% of the students agreed or strongly agreed with the fact that the CrowdHeritage platform was very usable and user-friendly. As described in the open answers, students particularly appreciated the structure of the annotations view, the presentation of available choices,and the ease of adding new tags and of up-/down-voting other users' annotations. Most criticism referred to the navigation between the different items and the need for more detailed views that allow users to inspect their contributions and progress. Some students reported that they experienced responsiveness issues, with either the sliding between the different items or the loading of certain tracks taking too long. Some of them also mentioned that it would have been useful if more tag values were made available.

Their involvement in the crowdsourcing process, which put them in the position of the contributor/end user of the CrowdHeritage platform and offered them the possibility to mobilize their expertise in the design and use of digital technologies, allowed students to make some useful recommendations for the further improvement of the platform. Many students made various suggestions for improving and expanding the gamification elements of the platform and its incentives for engagement. They also suggested adding views which would allow users to continuousy monitor their progress. Moreover, they proposed functionalities that would enable users to interact with each other, e.g. in case of conflicting opinions on an annotation, there should be a flag and a chat window for discussing the argument.

Besides the questionnaire, the free text commenting functionality supported by the CrowdHeritage platform can also be seen as an indicator of the engagement of the participants. Overall, students added 834 comments under different tasks-tracks. The high number of free comments demonstrates that students felt the need to express their thoughts besides the framework of the strictly defined enrichment tasks and thus reflects a genuine sense of involvement. Although the commenting functionality was initially intended as an extra means to collect additional information about music tracks, it was also used by students as a means to express their feelings about the music tracks and their overall experience. For example, indicative comments that students wrote include "something bad is happening", "made me uncomfortable", "inner peace", "nice vibes", "party time", "happy attitude". Fig. 5 presents in the form of wordclouds the frequency of words in the comments classified as positive and negative by the sentiment analysis model.



(a) Words in positive comments

(b) Words in negative comments

Fig. 5. Wordclouds about the free text comments added by students during the crowdsourcing campaign

5.3 Extensions to the CrowdHeritage platform

In light of the requirements that arose in the framework of the CitizenHeritage project, most notably from the needs of the concrete case studies that took place as well as the guidelines following from the O2 methodology, the CrowdHeritage platform has undergone a number of extensions. These extensions aimed to serve the needs of the citizen science campaigns conducted during the project as well as support the conduction of similar initiatives in the future, in line with the principles and policies identified by the CitizenHeritage “Report on Citizen Science Methodologies in Cultural Heritage”.

Moreover, the CrowdHeritage platform was augmented with dedicated information addressed to potential users who wish to use it in the context of citizen science initiatives. To this end, a new page has been added which provides information about the use cases of the platform, including its use in citizen science initiatives. The section of the page referring to citizen science applications (see Figure 6) directs the user to the Self-Assessment checklist prepared by KU Leuven in the context of the project. It should be underlined that the checklist includes a number of questions regarding data management, GDPR aspects, and FAIR principles, which should be respected among others by the digital tools used in a citizen science initiative, as well as questions about the use of digital tools. A number of criteria that should be taken into consideration during the selection of the appropriate digital tool fit for the purpose are listed in the checkinst, including aspects such as: user friendliness; terms of use and license (e.g. is it free?) ; commitment to GDPR and ethical ICT; successful use in previous actions with similar objectives; sustainability; possibility to support collaboration among contributors/organisers; training opportunities; provision for data protection; accessibility of data. The dedicated page added to the CrowdHeritage platform can be accessed here: https://crowdheritage.eu/en/applications.

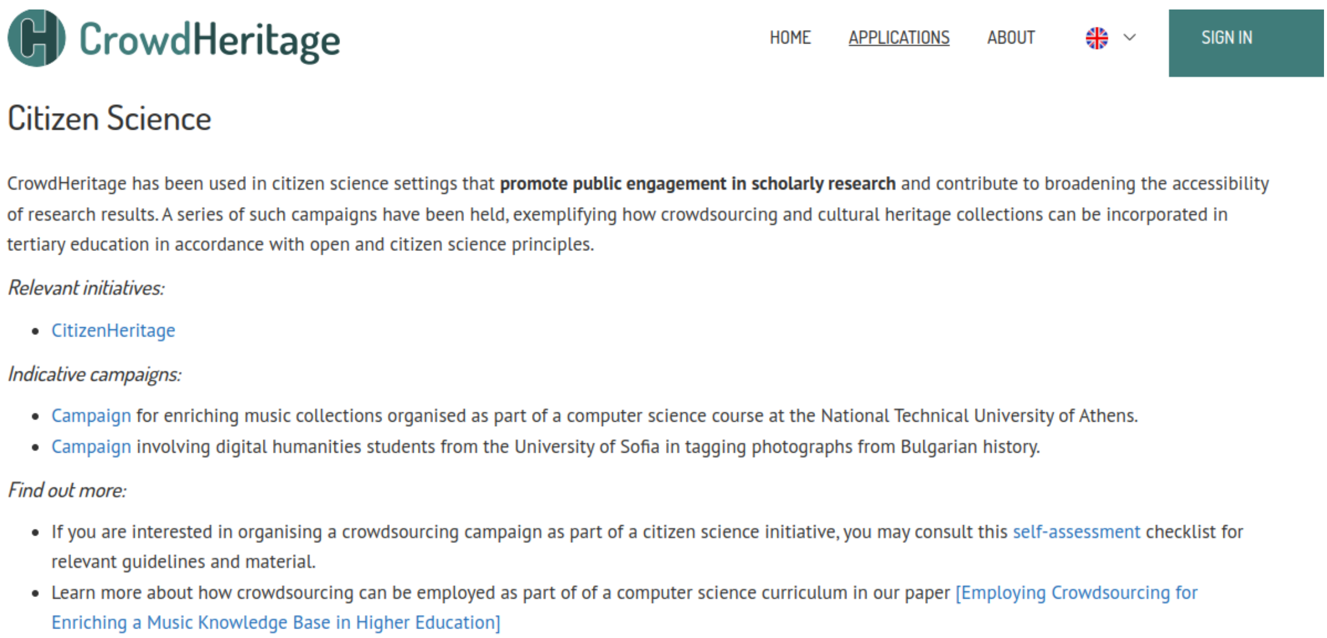


Fig 6: Screenshot of the page describing the citizen science applications of the CrowdHeritage platform, that directs the user to the self-assessment checklist page.

A particular concern indicated by the O2 methodology concerns compliance with European GDPR regulations, inclusion of clear and appropriate documentation regarding privacy issues and consent procedures. To this end, a dedicated Data Protection Policy page has been added to the platform. The policy describes the specific personal data management provisions made by the platform, including the cookies policy, along with an outline of the rights of users (e.g. right for access, rectification, erasure etc). The terms and conditions also clearly state the data usage licenses:

"The Crowdheritage Terms for User Contributions establish that all content and annotations contributed to Crowdheritage by its Users will be made available under the terms of a Creative Commons Attribution-ShareAlike licence. This means that, when a User provides annotations/metadata on digital objects in the Crowdheritage campaigns, he/she irrevocably grants Third Parties the right to freely use such Metadata without any restrictions, releasing these metadata under the terms of the Creative Commons CC0 1.0 Universal Public Domain Dedication".

The platform has also undergone a number of extensions in order to facilitate the setup of crowdsourcing campaigns, starting from the particular needs that arose of the case study performed by NTUA but serving generic purposes that are useful for similar future citizen science initiatives. To this end, the data import capability was extended to support the direct import of a custom collection curated via the Europeana portal, thus allowing us to readily retrieve the curated data and make them available for crowdsourcing. An important limitation of the previous version of the CrowdHeritage platform referred to the expressive power of the annotation model it uses, which builds on the W3C Web Annotation Model [47]. So far, annotations referred to an item as a whole and it was not possible to distinguish between tags targeting different attributes of the metadata record (e.g. emotion or genre in our case). Moreover, it was not possible to assign to users more than one annotation task grouped under the same item. To overcome these limitations, both the backend and the user interface of the platform were extended so as to enable campaign organizers to create multiple tagging modules within the scope of the same item and assign different custom terminologies/vocabularies to each module.

The annotation model was also extended to support the representation of free text comments by the campaign participants. Another improvement implemented in the context of the CitizenHeritage project regards the annotation user interface, so that during semantic tagging the user is presented with the dropdown list of terms upon clicking on the textbox. In order to facilitate the building of a recommendation system, a "favorites" functionality was added, so that the user can select their preferred items. Fig. 6 provides an example of how a CH item and associated tasks are presented to the user. Lastly, the vocabulary ingestion pipeline was streamlined, so as to support the seamless upload and parsing of CSV files with terms, resulting in vocabularies that are decoupled from specific campaigns and can be reused for different purposes across the platform.

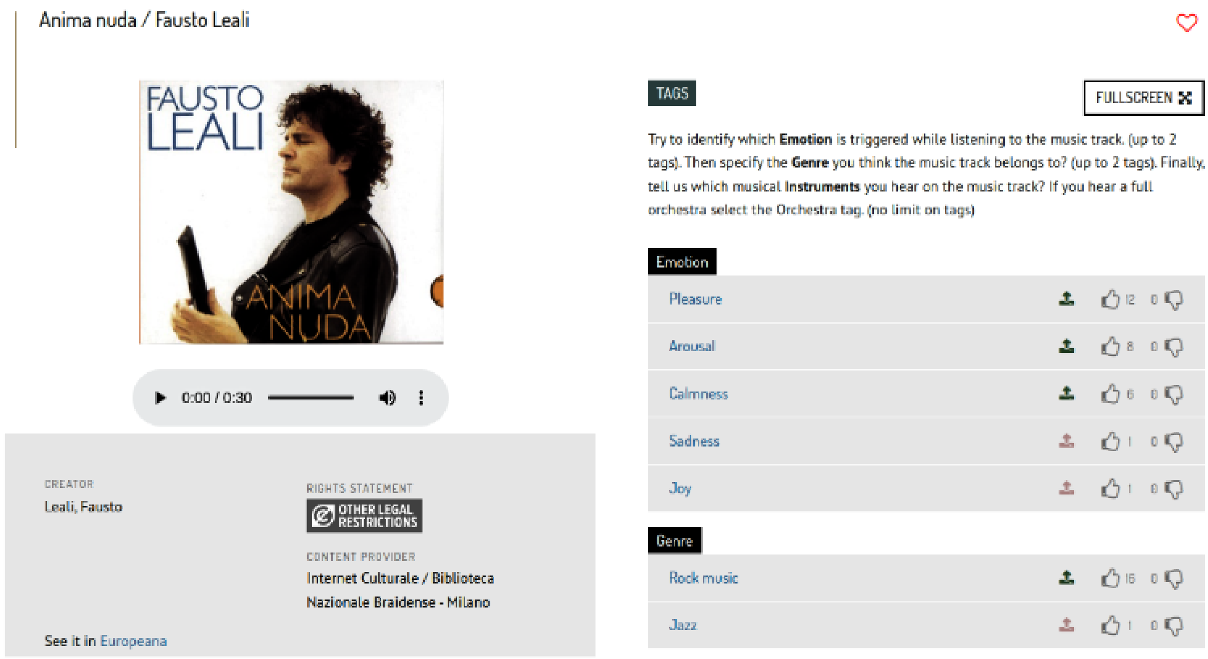


Fig. 7. Campaign snapshot of a music track annotated via the CrowdHeritage campaign.

6. Lessons learnt

The case study conducted in the context of the NTUA computer science course exemplifies crowdsourcing as a promising practice in CS-related curricula of higher education, illustrating how it can be embedded in a homework mini-project and incur benefits both for students and research. The methodology followed, the tools used, and the overall experience accrued can pave the way for embracing crowdsourcing in other frameworks within the scope of CS curricula. For example, crowdsourcing could be used in combination with ML tasks, to enrich an ontology and its relations, or in a course on human-computer interaction, with an emphasis on the UX features that should characterize platforms used for conducting crowdsourcing tasks. The insights and recommendations for improving the CrowdHeritage platform collected by students in the current case study already point to interesting ideas towards this direction. Parts of the methodology that was followed can also be useful for educational purposes in other disciplines, besides CS, such as digital humanities. An interesting direction that can be explored in various disciplines is ways to engage students as requesters in the preparation phases of the crowdsourcing lifecycle and ask them to design their own crowdsourcing projects in order to solve a specific problem.

Revisiting the two main strands of inquiry we set out to investigate, concerning the educational and the engagement implications of crowdsourcing, the assessment of the results and the feedback received from the students point us to some interesting conclusions. Transparency and clarity about the objectives of the crowdsourcing process and its functioning in the overall flow of the CS assignment was considered crucial by the students so as to understand the relevance of the project and how their contributions would be used and their skills would improve, thus attaining their interest and investment in the project.

The knowledge gains from the crowdsourcing enrichment process are evidenced by the deep understanding which students acquired about the metadata structure and its characteristics as well as the gradual process they followed to construct a knowledge graph and an ontology of increasing richness and expressiveness. The multiple and genuine ways in which students exploited the enriched data to develop complex concepts and queries and build added-value features also attest to the conclusion that the assignment served its educational purpose. As manifested by the students' responses, what was mostly appreciated concerned competences which advanced their CS expertise. Students also got acquainted with the practical technical challenges behind crowdsourcing, especially concerning the UX features that make a platform successful. This is reflected in the apt feedback and recommendations students provided about the CrowdHeritage platform. Knowledge benefits from performing the music annotation tasks themselves, in their role as crowd workers, were much less acknowledged.

Concerning the engagement dimension, feelings appeared to be mixed. Although almost all students liked the incorporation of the crowdsourcing campaign in the assignment and perceived the platform as user-friendly, almost half of them described their participation experience as neutral or even boring. Crowdsourcing was mostly appreciated in a rather instrumental way, as a practical means to achieve an interesting end. This can be partly attributed to the quite demanding goal that was set (asking students to annotate 80 tracks each) and the fact that many students felt that certain tasks required quite advanced music sophistication that they lacked.

Even so, we cannot ignore the fact that the commonly praised participatory and affective benefits of citizen science and crowdsourcing were not the most cherished ones by students. This resonates with recent criticisms on the way in which crowdsourced citizen science is touted as an enjoyable and participatory experience, while at the same time its labor ramifications and the repetitive or mundane nature of the crowdsourced tasks are understated [10 , 26]. Further experiments and more in-depth evaluation in higher education settings is required to shed more light on this aspect.

Although the current study lays its primary focus on the role and impact of crowdsourcing within the CS higher education community, the publication of the carefully filtered annotated dataset is also an important outcome that can prove helpful for the research and ML communities. An inspection of the annotations' characteristics allowed us to draw some useful insights concerning the human subjects' behavior, the correlation between tags, and the overall annotations' quality. Further work is required in order to yield the dataset readily amenable for the development and evaluation of MIR models. An expansion of the dataset (e.g. more music tracks covering different genres) would enhance and widen its usefulness for computational models. Further data reliability analysis (e.g. to extract diversity measures, agreement likelihood etc) and experimentation is required to demonstrate the dataset's validity and possible usages and to establish a benchmark for the MIR community.

Building on the practical experience we gained and the feedback we collected from the students, the current case study allows us to draw some recommendations, which can be proved useful for campaign designers who seek to engage students and educators who wish to incorporate crowdsourcing as part of their curricula, in CS and beyond:

- ***The crowdsourcing setup should fit naturally in the objectives of the course and clearly explained to the students.*** The foremost motivation of students attending a course and taking over a project assignment is to improve skills relevant to the course's stated objectives. This consideration should be the primary guiding principle for designing the crowdsourcing process and task, so as to maintain constructive participation on behalf of the students. The tasks should be carefully designed so that they are meaningful within the scope of the particular course and the role of crowdsourcing should be well-defined and well-explained to the students. Connecting to a real-world problem that relates to informatics students is important for making the overall project/assignment purposeful.

- ***The crowdsourcing tasks should not be too cumbersome.*** Granted that the more effort is invested in a crowdsourcing task, the better and more utilizable the end result is. However, the fact that crowdsourcing entails (often repetitive) labor should not be overlooked. Therefore, educators should maintain an appropriate balance between achieving an end result that is of sufficient quality and quantity and avoiding frustration on behalf of the students. Crowdsourcing with its collaborative and playful elements can stimulate additional engagement and motivation, yet, if the tasks are too time-consuming or difficult for students to complete, students' interest and engagement can be compromised. This is particularly so given that in educational settings, intrinsic motivation is the principal driving force for participation. Choosing tasks that are close to students' interests and assessing the required time for completing certain tasks in advance can help keep up engagement

- ***Emphasis should be given to crowdsourcing as a process and not just as a task in itself.*** The learning benefits for students lie less on completing some specific crowdsourcing task (e.g. tagging, validating) and more on familiarising themselves with crowdsourcing as a methodology and understanding its possible uses and associated challenges. Engaging students in conversations about aspects pertaining to this methodology, from the steps it encompasses to the design of the digital tools that are used, can lead to fruitful learning outcomes. Depending on the course's topic, the focus of such discussions can vary. Asking students in particular to make specific suggestions for improving the digital tools can open up many directions for follow-up discussions

- ***Particular attention should be paid to data curation and preparation.*** The effort for selecting, collecting, and cleaning the data to be used should not be underestimated, since it has to satisfy multiple criteria, which depend on the project's focus. Criteria to consider include quality (which may refer to different aspects depending on the application, e.g. may refer to image quality; metadata etc); quantity (which should be sufficient within the project's scope to draw useful conclusions); format (amenable for computational purposes, that is be in appropriate formats to allow its parsing and analysis by students); licenses. Depending on the course's objectives, the tasks of data sourcing, curation and processing could be designed as an assignment for students with potentially useful learning outcomes (e.g. interconnect with APIs, familiarisation with data formats and processing etc)

- ***It is of added-value if the results of the crowdsourcing are made openly available and have an impact beyond the course.*** Depending on the crowdsourcing objectives, the results can be useful for researchers, business or end users of certain platforms. In particular, crowdsourcing provides an excellent opportunity for demonstrating how educational institutions and students can contribute to open science. By knowing that the crowdsourcing process will lead to reusable results that can be helpful for the research community or a particular sector (e.g. as training data, as data published in a digital library etc), students and educators feel that their efforts have a value that goes beyond the narrow scope of the particular course and acquire extra motivation. Moreover, such an approach sets the floor for teaching to students the importance of open data and compliance with FAIR (Findable, Accessible, Interoperable, Reproductible) principles in a hands-on way.

Some additional work may be required to this end (e.g. appropriate post-processing and packaging of results, communication with interested stakeholders).

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