Citizen Science Platforms: Development Status, Service Practices, and Implications—A Case Study of Zooniverse (Postprint)

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Abstract

[Purpose/Significance] Citizen science platforms represent an emerging service model for citizen science, and their development status and service practices hold enlightening significance for the construction and development of citizen science platforms in China. [Method/Process] Taking the citizen science platform Zooniverse as an example, this study summarizes and analyzes the platform's service innovations and practical explorations surrounding citizen science from three perspectives: its development status, support services for the entire lifecycle of citizen science projects, and the creation of a citizen science ecosystem, and discusses considerations and implications for the construction of citizen science platforms in China. [Results/Conclusions] In addition to the natural sciences, Zooniverse also demonstrates particular attention to the humanities and social sciences; the Zooniverse platform provides one-stop support services for the entire lifecycle of citizen science projects and creates a comprehensive citizen science ecosystem to support online interaction and collaborative cooperation; to strengthen the construction of citizen science platforms, China should draw upon Zooniverse's practical experience, consolidate the foundation for platform construction and development, give full play to the role of industry associations and social organizations, and explore the application of emerging ICT in citizen science platform construction.

Full Text

Citizen Science Platforms: Development Status, Service Practice, and Implications—A Case Study of Zooniverse

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Abstract:

[Purpose/Significance] Citizen science platforms represent an emerging service model for citizen science, and their development status and service practices offer valuable insights for the construction and development of citizen science platforms in China. [Method/Process] Taking Zooniverse as a case study, this article analyzes the platform's development status, its process-oriented support services for citizen science projects, and its creation of a citizen science ecosystem, examining Zooniverse's service innovations and practical explorations centered on citizen science. The article further discusses considerations and implications for building citizen science platforms in China. [Result/Conclusion] In addition to natural science fields, Zooniverse demonstrates particular attention to humanities and social sciences. The platform provides one-stop support services throughout the entire citizen science project lifecycle and creates a comprehensive citizen science ecosystem to support online interaction and collaborative work. To strengthen citizen science platform construction, China should draw on Zooniverse's practical experience by consolidating the foundational development of citizen science platforms, giving full play to the role of industry associations and social organizations, and exploring the application of emerging ICT in citizen science platform development.

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Keywords: citizen science; network-based platform; scientific crowdsourcing; service model; online community

Big data is transforming human life, work, and thinking while simultaneously driving the evolution of scientific research paradigms and the rise of data-intensive science. Collecting and processing data from diverse sources, at massive scales, and with varied structural types presents severe challenges for researchers, sometimes making automated computer processing infeasible. In response to this dilemma, citizen science based on crowdsourcing concepts offers an effective and innovative solution [**?**]. Citizen science, also known as community science, mass science, crowdsourced science, volunteer monitoring, networked science, or public participation in scientific research, refers to open scientific activities that involve non-professional scientists, science enthusiasts, and the general public [**?**, **?**]. In recent years, with the vigorous development of information and communication technologies and the proliferation of various online service platforms, web-based citizen science platforms have emerged as a new model for citizen science, demonstrating tremendous potential for growth. Platforms such as citizenscience.org, Zooniverse, CitSci.org, and SciStarter are typical representatives. Some scholars argue that citizen science is closely related to scientific research crowdsourcing, open innovation, and innovations in research models [**?**, **?**, **?**]. Public participation may involve one or multiple aspects of scientific activities, including problem formulation, experimental design, volunteer recruitment, data collection, data analysis and processing, and even publication and translation of research findings [**?**]. Although the term "citizen science" is relatively new, it has historical foundations and antecedents [**?**, **?**],

and has produced influential projects such as the Christmas Bird Count (established 1900), the North American Breeding Bird Survey (established 1966), Galaxy Zoo (launched in 2007 to invite public assistance in online classification of millions of galaxy images), and the Evolution MegaLab project commemorating Darwin's 200th birthday.

Compared with the nearly century-long history and current state of modern citizen science in Europe and America, China's citizen science development lags far behind in both project and platform construction. Chinese citizen science projects are limited in number, scale, and influence, with severe domain imbalances concentrated primarily in natural science fields such as bird observation and plant monitoring [**?**]. Research and practice in humanities and social sciences domains, such as crowdsourced development of library special collections [**?**], museum collection digitization [**?**], and digital archival resource development [**?**], remain in the 借鉴 and exploration stage.

Reviewing the history of citizen science reveals the critical importance of technological progress in the evolution and innovation of citizen science projects [**?**]. Spatially, projects have expanded from small-scale local community initiatives to large-scale national and global activities. In terms of public participation, early projects relied primarily on manual offline participation, gradually transitioning to online participation and hybrid online-offline models with networked, intelligent, and mobile characteristics. Furthermore, in organizational form and dissemination, citizen science projects increasingly depend on internet technology, a trend particularly evident in the "Internet Plus" era [**?**].

2.2 Citizen Science Platforms

The internet actively promotes concepts and spirits of equality, openness, public participation, collaborative innovation, and cross-boundary integration, gradually becoming an important platform for connecting and aggregating mass power and collective wisdom. As mentioned above, internet technology has 孕育 ed transformation in citizen science, promoting the emergence and development of citizen science platforms [**?**]. Europe and America, particularly the United States, have conducted a series of fruitful explorations in citizen science platform construction. However, China's citizen science platform development remains weak, with typical examples including the Chinese Natural Specimen Repository (http://www.cfh.ac.cn/), the China Citizen Science Project Platform (http://gongzhongkexue.weebly.com/), and the Energy and Climate Change Project Team at the Global Environmental Institute (http://www.geichina.org/program/ecc/citizen-science). Compared with platforms like Zooniverse, these platforms offer relatively basic service functions and provide significantly less support for citizen science projects, researchers, and volunteers.

Foreign research on citizen science platforms focuses primarily on model architecture, technology development, platform design, and development surveys.

Researchers from Oxford University—R. Simpson, K. R. Page, and D. D. Roure [**?**]—constructed and analyzed Zooniverse's domain model from a systems perspective, comprising six components: users, data objects, tasks/workflows, classifications, groups, and projects, and analyzed Zooniverse's technical architecture from a platform development perspective. R. Tinati et al. [**?**] investigated the overall development of citizen science projects on Zooniverse, interviewed core members of its design team, and proposed a citizen science platform design requirements framework based on grounded theory and thematic coding, encompassing task characteristics, community development, task design, and public participation. P. Yadav et al. [**?**] designed a collaborative citizen science platform (comprising online games, task allocation middleware, and hosting and computing services) that integrates volunteer computing and volunteer thinking, and analyzed the platform's interaction mechanisms and application scenarios. Spanish scholar N. F. Ferrer [**?**] examined four citizen science platforms—Wikipedia, SciStarter, CitSci, and Precipita—analyzing them across four dimensions: discipline affiliation, project design approach, volunteer participation stage, and volunteer tasks. The results showed that citizen science practice and research in arts, humanities, and social sciences lag seriously behind, while natural and physical science projects receive more funding and are cultivated through top-down approaches. Overall, volunteers primarily participate in the data collection stage.

Domestic research on citizen science platforms is relatively scarce and scattered within studies themed on "citizen science." Some relevant discussions include: Huang Mincong [**?**] argued that citizen science can transform library research service models, and that citizen science's connecting role between scientists and the public, along with its public welfare nature, gives libraries natural advantages as citizen science platforms; Zhao Yuxiang [**?**] suggested emphasizing reflection on the essence of citizen science projects and rational planning of required resources, noting that citizen science platforms involve more than just developing or selecting a website, but should ensure adequate resource construction and configuration to support project implementation and create virtual network communities and practice communities to promote project sustainability and promotion; Zhang Huanzhao [**?**] investigated the U.S. citizen science platform (citizenscience.org), examining project domains, participant scale and characteristics, geographic scope, and expected outputs to reveal the construction status of American citizen science platforms.

3 Overview and Development Status of Zooniverse

This study selects Zooniverse as the central case because it represents a successful platform with a solid foundation, tremendous influence, and ongoing development [**?**]. Compared with other citizen science platforms, Zooniverse more comprehensively embodies the service model and innovative practices of citizen science platforms.

3.1 Overview of Zooniverse

Zooniverse is an online platform owned and operated by the Citizen Science Alliance that serves citizen science by aggregating and connecting the general public, scientific researchers, and their citizen science projects to build a relatively complete citizen science ecosystem. The platform supports researchers in creating and advancing citizen science projects, accelerates scientific discovery and knowledge innovation through broad public participation, helps the general public explore the unknown world and enhance scientific literacy, and ultimately promotes scientific communication and the overall development and continuous innovation of citizen science. Launched in December 2009, Zooniverse evolved from the well-known citizen science project Galaxy Zoo [**?**]. As an active and popular online citizen science platform, Zooniverse had over 1.6 million registered volunteers and had completed more than 92 million citizen science tasks as of January 30, 2018. Details are shown in Table 1 .

As shown in Table 1, citizen science projects hosted on Zooniverse cover an extensive range, including more than ten disciplinary fields such as art, biology, climate, history, language, literature, medicine, nature, physics, social sciences, and space (survey date: December 29, 2017). Given that research objects or content often span large temporal or spatial scales or have rich manifestations, citizen science projects may exhibit interdisciplinary and cross-domain characteristics. For example, the Old Weather project involves both climate and history, while the Science Gossip project spans biology, history, literature, and medicine. Therefore, the totals in Table 1 do not correspond one-to-one, and the statistics primarily reflect the overall distribution and development of citizen science projects on Zooniverse. In addition to numerous actively running projects, the platform also hosts suspended and completed projects, which are equally valuable for examining and analyzing Zooniverse's service model and innovative practices.

Notably, previous scholars have noted that citizen science practice and research in humanities and social sciences lag seriously behind [**?**]. However, this study found that Zooniverse has nurtured a batch of citizen science projects related to history, literature, arts, and languages, demonstrating the platform's particular attention to and support for digital humanities, as shown in Figure 1 [Figure 1: see original paper].

3.2 Citizen Science Projects on Zooniverse

The previous section statistically analyzed the number and disciplinary distribution of citizen science projects on Zooniverse. To gain deeper understanding of the platform's development status, it is necessary to further explore project content, tasks, and objectives [**?**]. The investigation revealed that natural science projects in spatial science, natural environment, biological species, and life sciences are most numerous, including Galaxy Zoo (the predecessor of Zooniverse) for galaxy identification and classification, Planet Four for finding and marking

Martian landforms, The Plastic Tide for addressing marine plastic pollution, Fossil Atmospheres for tracking Earth's climate change through ginkgo leaves, Bat Detective for analyzing bat calls, TreeVersity for identifying and annotating plant species and morphological features, and Bash the Bug for processing and analyzing medical images of tuberculosis infection samples. In arts, humanities, and social sciences, Zooniverse has also cultivated and supported a number of influential citizen science projects (see Table 2).

Comprehensive examination of Zooniverse projects reveals that the platform provides an integrated service environment for citizen science projects. Based on Zooniverse, researchers invite platform users to identify, label, process, and analyze data objects to assist researchers in completing time-consuming and labor-intensive citizen science tasks that cannot be accomplished independently.

4 Support Services for the Entire Citizen Science Project Lifecycle

Zooniverse provides comprehensive technical and platform support services throughout the entire citizen science project lifecycle, including project creation, review, launch, operation and maintenance, and completion, as shown in Figure 2 [Figure 2: see original paper]. The citizen science projects described above are all created, operated, and managed through the Zooniverse platform. This lifecycle-oriented support service represents Zooniverse's innovative service and unique advantage over traditional citizen science websites and general citizen science platforms.

4.1 Project Creation Stage

Through Zooniverse's project creation tool, Zooniverse Project Builder, researchers can conveniently and efficiently create citizen science projects. This tool significantly simplifies the project creation process; anyone can create a personalized citizen science project by simply uploading data and setting corresponding tasks, as shown in Figure 3 [Figure 3: see original paper].

As shown in Figure 3, the left side of the project creation page contains a status bar with two main modules: project details and help resources. In the project details module, users can set and modify basic project information, project tasks and workflow information, and operational objects (datasets). In the help resources module, project creators can access Zooniverse-provided tutorials, discussion forums, and glossaries to assist with citizen science project creation. Additionally, the project preview function allows creators to view project presentation effects at any time to identify and resolve issues promptly.

The basic workflow for the project creation stage is as follows:

(1) **Define the project**: Under the project details module, set and define basic project information including project name, logo, background image,

brief description, and introduction. Project creators can return to modify or add more details at any time before official launch.

(2) **Design project tasks**: Project tasks refer to the series of tasks that researchers (project creators) require volunteers to complete, including project type, content, and quantity. Typically, Zooniverse platform tasks include four types: question tasks, drawing tasks, text tasks, and survey tasks. Question and drawing tasks are the main task types for citizen science projects, as shown in Table 3 .

(3) **Design the workflow**: After creating all project tasks, researchers must specify task sequences to chain all tasks together, forming the volunteer workflow. Generally, if the workflow is short and simple, the public is more likely to complete more classification tasks [**?**]. Therefore, to achieve research goals, workflows should be kept simple and should not include tasks that can be accomplished through automated methods.

(4) **Upload operational objects**: Operational objects are what volunteers work with when completing tasks. An object is a unit of data to be analyzed and requires simultaneous analysis by volunteers. Operational objects are typically images but can also include pictures, audio, video, and other data types. The manifest file must also be uploaded—a two-dimensional table where each row corresponds to an object, listing all uploaded operational objects and their metadata such as unique identifiers, names, sources, URLs, and creators.

4.2 Project Review Stage

After project creation, it is necessary to attract public and volunteer participation. If researchers have their own volunteer groups or only want specific collaborators to work with project data, they can share project links with designated individuals to make the project public. However, to launch a project on Zooniverse for broader public participation, it must undergo the following review process:

(1) **Zooniverse team review**: After submitting a review request, the Zooniverse team examines whether the project complies with Zooniverse rules and typically responds within two weeks.

(2) **Volunteer review**: After passing the Zooniverse team review, volunteers test the project and provide feedback, with most feedback delivered within one week. During stages (1) and (2), project creators should promptly address responses and feedback from the Zooniverse team and volunteers, as well as comments on project discussion pages, to ensure the project meets research quality requirements. If requirements are not met, creators must consider adjusting or redesigning the project and resubmitting the review request.

(3) **Final review**: The final review primarily examines project output usage

plans, reviews results from previous stages, and conducts peer review of the project. This process takes several weeks to months. Once a project passes final review, it becomes an official Zooniverse project, appears in project listings and newsletters and other promotional materials, and enjoys Zooniverse's hosting services and other value-added services.

4.3 Project Launch Stage

Volunteer engagement and long-term participation largely depend on researchers' work during project launch. During this stage, researchers should pay particular attention to: (1) developing a detailed promotion plan including newsletter distribution, volunteer recruitment, social media utilization, expansion of existing networks, and communication with relevant organizations; (2) maintaining communication and discussion with volunteers, keeping project blogs, social media, and discussion boards active, promptly updating blogs and Twitter accounts, ensuring team members can respond quickly to volunteers, and developing deeper public participation methods and cultivating new volunteers; (3) systematically identifying and appointing moderators who have greater voice in discussion areas and serve as important resources for new volunteers—researchers should ensure moderators understand team expectations, initially selecting volunteers who have served as moderators in other projects before choosing from newcomers; and (4) anticipating potential errors and preparing solutions, addressing problems discovered shortly after launch and promptly updating FAQ lists.

4.4 Project Operation Stage

Approximately one week after launch, initial attention will fade and projects transition to steady operation. At this stage, project teams must still devote time to attracting and maintaining volunteer participation. For example, clarifying team member roles and responsibilities; sending occasional reminder emails to volunteers who have forgotten about projects; using blogs, Twitter, and other social media to brief volunteers on project progress, demonstrating their achievements and how they advance scientific discovery; monitoring project operations and closely tracking completion statistics including volunteer participation numbers, completed tasks, processed operational objects, and project completion percentages; and providing volunteers with more participation opportunities including in-depth data analysis, algorithm development, co-authoring peer-reviewed publications with researchers, and helping operate social media accounts.

4.5 Project Completion Stage

When a citizen science project is completed, the research team should thank volunteers and explain next steps, such as inviting volunteers to participate in new projects or other projects by the same research team, reading academic publications based on project outputs, and informing volunteers when new data is available. Additionally, Zooniverse requires researchers to publicly release

project output data within a specified period after project completion (typically two years) and encourages sharing research results based on the project with platform volunteers.

5 Creation of the Citizen Science Ecosystem

5.1 Zooniverse Platform's Interaction Support Mechanisms

Zooniverse provides powerful interaction support mechanisms. In addition to social network services such as blogs, Facebook, Twitter, and Google+, it has built Zooniverse Talk, an online interactive community themed around citizen science. Moreover, with the development of smart devices and mobile internet, Zooniverse also provides mobile application services for Android and iOS. Among these interaction support mechanisms, the integrated online community Zooniverse Talk represents the concentrated embodiment of Zooniverse's service model and innovative practices. Zooniverse Talk is an object-oriented online discussion tool that enables volunteers to initiate discussions, post comments, and share knowledge while completing project tasks, and also serves as a venue for research teams and project volunteers to interact and collaborate.

Zooniverse Talk features discussion boards oriented toward different thematic content, including project creation, project review and testing, data processing, mobile applications, educational tools, citizen science and crowdsourcing, scientific research, and casual chat. Discussion boards are integrated with each project, with each operational object having a dedicated discussion page where substantial research takes place. Additionally, platform users can add tags (Talk Tags) similar to Twitter in discussion areas. Tags help record and organize content related to specific topics, with popular tags displayed on the discussion board homepage. Users can also use search boxes to find and locate specific tags.

5.2 Zooniverse Platform's Collaborative Model

As a citizen science network platform, Zooniverse actively advocates and practices open equality, interactive communication, and collaborative innovation. Based on the above-mentioned rich information exchange tools and communication channels, online interaction and collaborative work among volunteers, scientific research teams, the Zooniverse service team, and other stakeholders become possible. Within the citizen science ecosystem built by Zooniverse, collaboration among stakeholders is primarily manifested in six aspects, as shown in Figure 4 [Figure 4: see original paper]:

(1) **Internal collaboration within the Zooniverse citizen science platform**: Behind Zooniverse's operation and service provision is a closely collaborative working team [**?**]. Team members have different but complementary disciplinary backgrounds and expertise spanning astronomy, astrophysics, computer science, software engineering, molecular biology,

plant genetics, medicine, cognitive science, journalism, musicology, philosophy, and archaeology. They have clear and detailed division of labor including strategic planning directors, data scientists, infrastructure engineers, front-end engineers, software development engineers, project scientists, visual designers, educators, and outreach coordinators. Additionally, Zooniverse has offices at Oxford University in the UK and the Adler Planetarium in the US, with team members physically dispersed and relying heavily on computer and internet information technology for communication and collaboration.

(2) **Collaboration between Zooniverse platform and volunteers**: Zooniverse provides ordinary citizens and science enthusiasts with an online platform to explore the unknown world, engage with scientific frontiers, and enhance scientific literacy. By registering as volunteers for citizen science projects, the general public can establish connections with scientific researchers and find like-minded friends. Moreover, the large volunteer base and active public participation provide Zooniverse with a broad user foundation and source of collective intelligence for serving citizen science.

(3) **Collaboration among volunteers**: Within the same citizen science project, volunteers share basically consistent tasks and objectives, driving project progress and scientific discovery through mutual cooperation. Volunteer collaboration includes unconscious cooperation and conscious cooperation. Unconscious cooperation refers to distributing the same task to multiple volunteers and aggregating different volunteers' results against quality control standards to complete final project tasks—in this scenario, volunteers may not know each other. Conscious cooperation refers to volunteers purposefully seeking cooperation from others, such as posting help requests in discussion forums, participating in task-specific discussions, browsing existing discussion content for "social learning" and imitation [**?**].

(4) **Collaboration between volunteers and citizen science project teams**: Citizen science projects serve as the foundation and link connecting volunteer groups with scientific researchers. Researchers are project creators and managers who hope to accelerate scientific discovery through collective intelligence, while volunteer groups are participants and contributors who drive project progress through pattern recognition and data analysis. Their collaboration channels primarily include project social media, online community discussion boards, and email.

(5) **Internal collaboration within citizen science project teams**: Citizen science projects are systematic endeavors that consume substantial time and intellectual resources throughout creation, review, launch, operation, and completion, requiring reasonable division of labor and close cooperation among scientific researchers (the project team). This includes scientific research planning and overall project design, expected project

outputs and their usage, task and workflow design, data quality control and management, public participation incentive mechanism design, social media account operation, discussion board interaction with volunteers, and project operation monitoring.

(6) **Collaboration between citizen science project teams and the Zooniverse platform**: Citizen science project teams involve diverse entities including higher education institutions (e.g., Oxford University, Tsinghua University, University of Washington), public cultural institutions (e.g., Natural History Museum, UK National Archives), government agencies (e.g., NASA), and research management departments (e.g., NSF). Throughout the project lifecycle from creation through review, launch, operation, and completion, Zooniverse provides project teams with graphical user interface creation tools (Project Builder), normative and quality review services, promotional services targeting platform volunteers, and other technical and platform support services. Through an open collaborative network, citizen science project teams and the Zooniverse platform jointly promote the orderly and sustainable development of citizen science.

6 Implications of Zooniverse for Citizen Science Platform Construction in China

This study selected Zooniverse as a typical case to summarize and discuss how the platform organizes and manages citizen science projects and creates a citizen science ecosystem to support interaction and collaboration among stakeholders. The research found that Zooniverse is an active online citizen science platform serving projects across multiple disciplinary fields, with particular attention to and strong support for humanities and social sciences. Second, Zooniverse provides one-stop support services and an integrated environment for the entire citizen science project lifecycle, including simple and convenient project creation tools, online discussion communities, project operation practice guides, and computer-supported collaborative work. Finally, Zooniverse has created a relatively complete citizen science ecosystem that aggregates and connects various citizen science-related resources, technical tools, and stakeholders including projects, researchers, volunteers, and the general public to promote the continuous development of citizen science, scientific research, and open innovation.

Zooniverse's service innovations and practical explorations centered on citizen science offer implications for citizen science platform construction and development in China. Correspondingly, three questions deserve consideration:

(1) **Should China build citizen science platforms?** Undoubtedly, the rise and development of citizen science platforms have positively impacted scientific research, knowledge innovation, public services, public governance, science popularization, and scientific literacy enhancement. Building citizen science platforms is essential for citizen science and open innovation in the new era. For example, the Obama administration issued

the "Addressing Societal and Scientific Issues through Citizen Science and Crowdsourcing" memorandum on September 30, 2015 [**?**]. Against this backdrop, various citizen science platforms represented by citizenscience.org were subsequently built and improved, leading to rapid citizen science development in the United States characterized by broad domain involvement, numerous participants, diversified age groups, expanding coverage, significant results, and support for public decision-making [**?**].

(2) **What kind of citizen science platforms should be built?** Zooniverse provides rich service models and practical experience for this question. First, citizen science platforms should be orderly and balanced ecosystems that aggregate and connect citizen science projects, researchers, volunteers, and the general public, providing relatively complete interaction support mechanisms and collaborative models. Second, platforms should provide user-friendly, simple, and convenient project support tools serving all stages from creation through completion. Finally, platforms should maintain balanced development across fields, supporting, guiding, and assisting not only strategic scientific and technological domains like astronomy, life sciences, and physical materials, but also citizen science projects in arts, humanities, and social sciences.

(3) **How should citizen science platforms be built?** Zooniverse's experience suggests several key considerations: (1) Consolidate and strengthen the foundation for citizen science platform development. Zooniverse evolved from the citizen science project Galaxy Zoo, which had accumulated years of experience before Zooniverse's formal launch. Therefore, enriching and deepening service functions based on existing mature citizen science projects and gradually transitioning to a citizen science platform may be a viable construction path. (2) Give full play to the leading and exemplary role of industry associations and social organizations. In Zooniverse's development, organizations such as the Citizen Science Alliance, citizen science associations, museums, libraries, and higher education institutions have played important roles in attracting public participation, project organization and coordination, and project promotion. In contrast, China's relevant industry associations and social organizations remain weak and fragmented. Therefore, China should establish dedicated citizen science associations while fully mobilizing the enthusiasm of scientific groups and public welfare social organizations. (3) Explore and expand the application of emerging ICT in citizen science platform construction. Zooniverse's success largely benefits from modern information and communication technologies including internet networks, human-computer interaction, online communities, and mobile terminals. In China's citizen science platform construction process, in addition to information interaction technologies like social media and online communities, this includes data collection and transmission technologies such as IoT, sensors, and smart devices; data organization and management technologies like databases, linked data, and cloud computing; and big

data analysis technologies such as data mining and machine learning.

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