A Game-based Approach for Open Data in Education

A Systematic Mapping Review

Celis Vargas, Alejandra; Magnussen, Rikke

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A Game-based Approach for Open Data in Education: A Systematic Mapping Review

Alejandra Celis Vargas and Rikke Magnussen
Department of Communication and Psychology, Aalborg University, Copenhagen, Denmark
cacv@ikp.aau.dk
rikkem@ikp.aau.dk

Abstract: Open Data is defined as digital data that is made available with the technical and legal characteristics necessary to be freely used, reused, and redistributed by anyone, anytime and anywhere. Examples of Open Data can be data on mobility or pollution, which an increasing number of cities are making available to citizens. In education, the novel field of Open Data has the potential of empowering a young generation with digital skills and critical thinking through work with real-life Open Data. However, the scarcity of methods and tools for skills development and insertion into educational designs reduces the possibility of achieving this potential. This study is part of the project ODECO, aimed at addressing challenges in the creation of Open Data ecosystems in several contexts, such as education. A systematic mapping review was conducted to uncover the research connections between Open Data education and educational games. Twenty-eight studies were identified and analysed through iterative searching and including keywords related to Gamification, Open Data and Education. In doing this, relevant themes and novel approaches in the current literature were found. This paper discusses how the fields of Open Data education and educational games methodologically and theoretically contribute to outline a game-based approach for Open Data in education. An Open Data Gamified Education Framework leads to authentic learning experiences for real-world problem solving in relation to eight actions: connecting classroom activities to real facts, empowering students to act with Open Data, supporting technical Open Data skills in the classroom, building literacy and developing skills, enhancing civic participation, creating more realistic and appealing narratives, extending teaching outside the classroom by collecting data in real time and local settings, and increasing engagement and motivation.

Keywords: Game-based learning, Open Data, Education, Skills development, Real-world problem solving

1. Introduction and background:

In recent years, the field of Open Data research has expanded into a growing number of research domains, such as policy studies and education (Conradie & Choenni, 2014; Sieber & Johnson, 2015). Open Data strategies are now seen in several different contexts, such as local governments making openly available datasets on social and technical aspects of the city and therefore permitting citizens to freely use, modify and share them (van Loenen et al., 2021). Although Open Data might enhance transparency and accountability in fair and innovative societies, current systems are focused on the data release process, lacking awareness on how Open Data is useful and valuable to users (Bachtiar et al., 2020; Hellberg & Hedström, 2015; van Loenen et al., 2021; Veljković et al., 2014). In order to counter current challenges, there is an increasing call for strengthening a user-centred perspective connected to a broader public engagement (Conradie & Choenni, 2014; Kassen, 2013; Prieto & Rodriguez, 2012; Robinson et al., 2009; Shadbolt et al., 2012; van Loenen et al., 2021). However, the integration of several interest groups implies the development of new Open Data approaches and skill sets. Users need to have the appropriate skills and competencies to use and modify available Open Data and understand what kind of perspectives it opens (Conradie & Choenni, 2014; Kassen, 2013; Prieto & Rodriguez, 2012; Shadbolt et al., 2012).

To assure the inclusive development of Open Data, The International Open Data Charter suggests engaging with schools to incorporate Open Data into educational curricula (International Open Data Charter, 2015). Although previous experiments using Open Data in education have shown how Open Data contributed not just to developing digital capabilities but also to enhancing 21st century skills on students, these have also elaborated on a lack of approaches for implementation (Coughlan, 2019; Saddiqa et al., 2019a; Saddiqa et al., 2021a; Atenas et al., 2015). Despite current challenges, there are indications that lead to authentic learning experiences (Herrington et al., 2014) and active learning theories (Romero et al., 2014).

Game-based Learning (GBL) is grounded in active learning methodologies and encourages learning activities by building on engagement and challenges (Romero et al., 2014). Educational games help to make the knowledge that is abstract and common for experts more concrete and embedded in a situation (Gee, 2006). Authentic learning is a pedagogical approach that situates learning tasks in the context of future use, helping students to transfer robust knowledge to real-life practice (Herrington et al., 2014). One of the main focus points in the

development of science game formats over the past 20 years has been how the medium of games can introduce new approaches to authentic science education (Gee, 2003). Prime examples of this are profession simulation games that simulate some of the objectives and environments of a specific profession by using the technology, tools and/or methods of that profession. As a result, the medium of games has been used to create environments with simulations of complex real-world situations, where students must think like professionals and solve problems in innovative ways, just as professionals do (Clinton & Rieber, 2010; Oh, 2011; Shaffer & Gee, 2005). The authentic approach has been extended in recent years with the so-called scientific discovery games or citizen science games, where gamers contribute to real world research as part of gaming (Cooper et al., 2010; Good & Su, 2011).

The research aim of this paper is to explore the novel field of Open Data education and the connection to educational games to outline a game-based approach for Open Data in education. A systematic mapping review was conducted to understand how connections between the two fields have been explored and to outline potentials for future development of Open Data gamified education. This study is part of the Marie Skłodowska-Curie Innovative Training Network ODECO, which is aimed at addressing challenges in the creation of user driven, circular, skill-based and inclusive Open Data ecosystems (ODECO – Towards a Sustainable Open Data ECOsystem, 2021).

2. Methods:

A systematic mapping review method (Grant & Booth, 2009) was applied to map out and categorise existing literature that connects Open Data education and educational games. The process involved three steps. Firstly, defining the scope of the review and defining keywords; secondly, identifying potential studies through literature searches and thirdly, determining the studies to be included in the in-depth review. The review was conducted across the Scopus database (Scopus, 2022).

The following figure provides an overview of the steps, and findings of the systematic mapping review process. Three search sets were defined to map different components and possible relations within the fields. An initial review led to 62 records, after applying inclusion criteria, this number was reduced to 28 studies. According to Gough et al. (2003) an in-depth review of each study was made to analyse them following a process of screening and categorisation.

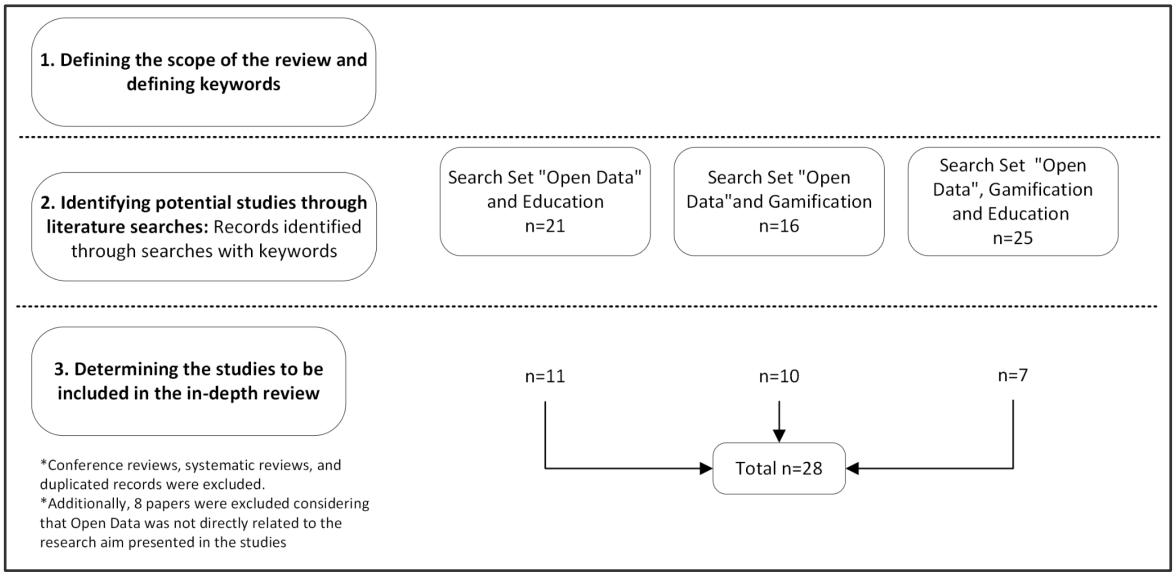

Figure 1: Overview of systematic mapping review process and findings

2.1 Systematic mapping review process:

The systematic mapping review process started defining the scope. With the aim of capturing different perspectives in current literature between Open Data education and educational games. This review looked at exploring the connection between three topics: *Open Data, Education and Gamification*. Keywords were chosen based on a screening of concepts that are referred to in primary research articles in this new field. The following keywords were chosen:

Table 1: Keywords used for searches.

Topic 1:	**Topic 2:**	**Topic 3:**
Open Data Open Datasets	School Classroom Educational resource	Gamification Game-based learning Games

Iterations of searches with various combinations of keywords and screening of titles and abstracts were conducted to enable an overview of the field and ensure the identification of the maximum number of articles showing different connections between Open Data education and educational games. Considering the exploratory aim of the systematic mapping review, three search sets were established to explore different approaches to the field: (1) *Open Data and Education*, (2) *Open Data and Gamification,* and (3) *Open Data, Education and Gamification.* The following table shows the process and results of the conducted literature searches:

Table 2: Literature searches: process and results

Search Set	**Process**	**Keywords**	**Results**
(1)Open Data and Education	Final search considering article title	"Open Data" AND school OR classroom OR "educational resource"	21
(2)Open Data and Gamification	Final search considering article title	"Open Data" AND Gamification OR "game based learning" OR games	16
(3)Open Data, Gamification and Education	Final search considering article title, abstract and keywords	"Open Data" AND school OR classroom OR "educational resource" AND gamification OR "game based learning" OR games	25
TOTAL			62

A literature review identified 62 potential studies. Initially, duplicated records were excluded, and inclusion criteria were considered in order to align the results with the research aim. Regarding standards of records, inclusion criteria led to excluding conference reviews and systematic reviews but considering primary studies. Although the systematic mapping review aimed at exploring connections between Open Data education and educational games, it was important to include studies where Open Data was directly involved. These final criteria led to the exclusion of 8 papers where Open Data was not directly related to the research aim presented in the study. For example, one of the excluded papers presented the learning effectiveness of gamification in a Massive Open Online Course (MOOC) about Open Data but not using Open Data (Castillo-Abdul et al., 2021).

Hereby, 28 studies including articles, conference papers and book chapters were considered for screening of abstracts and articles.

3. Results

The 28 reviewed articles were reviewed in-depth to analyse different approaches and perspectives in relation to three search sets, *Open Data and Education*, *Open Data and Gamification*, and *Open Data, Gamification and Education*. Different themes within the search sets were identified. Results created an overview of this novel field and helped to identify how Open Data education and educational games are related and contribute to the discussion of a game-based approach for Open Data in education. Results are shown in Table 3.

Table 3: Results, taking into consideration the search set.

Search set	Results	Themes	Records
Open Data and Education	11	Connecting classroom activities to real facts	(Radchenko & Sakoyan, 2014) (Selwyn et al., 2016)
		Empowering students to act with Open Data	(Berrio-Zapata & Santana, 2015) (Saddiqa et al., 2019a)
		Supporting technical Open Data skills in the classroom	(Badioze et al., 2021) (Chicaiza et al., 2017)(Piedra et al., 2015) (Saddiqa et al., 2019b) (Saddiqa et al., 2021b) (Watson, 2017) (Vallejo-Figueroa et al., 2018)
Open Data and Gamification	10	Building literacy and developing skills	(Suarez, 2015) (Stato et al., 2021) (Baker et al., 2017)
		Enhancing civic participation	(Handler & Ferrer Conill, 2016) (Wolff, 2017) (Bradley, 2009)
		Creating more realistic and appealing narratives	(Barros, 2019) (Edler, 2018) (Roa-Valverde, 2014) (Warren & Champion, 2014)
Open Data, Gamification, and Education	7	Extending teaching outside the classroom by collecting data in real time and local settings	(Dickinson et al., 2015) (Hsu et al., 2011) (Siriaray et al., 2018)
		Increasing engagement and motivation	(Chen et al., 2014) (Chiotaki & Karpouzis, 2020) (Da C. Júnior et al., 2015) (Vargianniti & Karpouzis, 2020)

3.1 Open Data and Education

Three themes were identified: (1) Connecting classroom activities to real facts (2) Empowering students to act with Open Data, and (3) Supporting technical Open Data skills in the classroom. This search set evidence the strong requirement of mechanisms or tools for integrating Open Data into educational designs developing and supporting skills and capacities to exploit Open Data.

1. Connecting classroom activities to real facts: Two articles explored the potentials and limitations of using Open Data in educational curriculums. Open Data was highlighted as a relevant educational resource when considering that it provides information about real facts (Radchenko & Sakoyan, 2014; Selwyn et al., 2016). Nevertheless, articles showed the need for further research on different technical, organisational and social barriers surrounding the use of Open Data in schools. For example, teachers and students lack skills and school administrators need guidelines. Articles suggested connecting to external developers to overcome current barriers.
2. Empowering students to act with Open Data: Articles elaborated on the relevance of Open Data, not just in providing information about the reality but in giving an input for transforming it. Saddiqa et al. (2019a) experimented on using local Open Data in the classroom, firstly to help students understand real facts, and secondly, to come up with ideas to improve their communities. Furthermore, Saddiqa et al. (2021b), and Berrio-Zapata & Santana (2015) elaborated on the importance of developing skills and competences beyond digital skills, such as the ability to understand local and global issues, and critical and scientific thinking to assess and select open datasets.
3. Supporting technical Open Data skills in the classroom: The literature showed a close relation between the capacities needed among students and teachers for managing Open Data, and possible tools to support them. Firstly, the articles focused on identifying open datasets for school subjects such as maths, science, and geography through mining techniques, interfaces and online communities (Chicaiza et al. 2017; Piedra et al. 2015; Vallejo-Figueroa et al. 2018; Saddiqa et al., 2021b). Secondly, the articles presented experiments with tools facilitating the use of Open Data in the classroom. Badioze et al. (2021) proposed PETS Robots called i-COMEL and the ThinkSpeak server, to collect and share data in a Solar System school class. Watson (2017) proposed helping students to create visualisations using the software TinkerPlots. Finally, Saddiqa et al. (2019b) focused on the development of an EAORE Open Data interface to help teachers and school administrators to achieve requirements of Danish public schools.

3.2 Open Data and Gamification

The different themes in this search set exemplify strengths in connecting Open Data together with games: (1) Building literacy and developing skills, (2) Enhancing civic participation, and (3) Creating more realistic and appealing narratives. Even though an educational aim was not always considered in these studies, Open Data and gamification implicitly supported educational purposes.

1. Building literacy and developing skills: The literature presented the use of games for building data literacy and decision making with Open Data. Suarez (2015) presented two games designed to develop Open Data and decision making skills for disaster management. Stato et al. (2021) worked on an online collaborative digital game to introduce players to Open Data, raise awareness and develop Open Data literacy among public servants, and Baker et al. (2017) elaborated on an Open Data game for developing decision-making skills.
2. Enhancing civic participation: The literature showed the potential use of Open Data games to enhance civic participation. Handler & Ferrer Conill (2016) analysed a case aimed at engaging journal readers. They showed that by using Open Data and game mechanisms, there was increased user autonomy, competence and contextual relatedness in readers. Moreover, Wolff (2017) presented a board game called DataScape to promote citizen engagement for smart cities. In DataScape, Open Data is initially used to help citizens understand their context, later the game dynamic motivated them to create, collect and share Open Data. Finally, Bradley (2009) demonstrated how to engage citizens in scientific experiments with a web-based game where players try to match molecules to various forms, creating collective knowledge and leveraging Open Data.
3. Creating more realistic and appealing narratives: Open Data helped to make entertainment game narratives more realistic and appealing (Barros, 2019; Edler, 2018; Roa-Valverde, 2014; Warren & Champion, 2014). Although games generated with Open Data did not have an explicit educational purpose, some of them facilitated learning, such as a game built with historical and spatial Open Data which implicitly led gamers to learn about cultural heritage (Warren & Champion, 2014).

3.3 Open Data, Gamification and Education

In this search set, articles presented studies connecting Open Data education and educational games. The two identified themes relate to the previous findings and scope in two areas. Firstly, the connection of classroom education to real facts and local context and secondly, the potential of increasing engagement and motivation in school education.

1. Extending teaching outside the classroom by collecting data in real time and local settings: Three studies have shown the use of games, through connecting school activities and learning tasks with real life settings and Open Data. Games enabled data collection in real time, which strengthened data literacy and skills among students (Dickinson et al., 2015; Hsu et al., 2011; Siriaray et al., 2018). For example, a game helped students to collect environmental data while walking to the school (Dickinson et al., 2015), while another game motivated students to navigate their city, collect data about their historical heritage and compare it to Open Data (Hsu et al., 2011).
2. Increasing engagement and motivation: Articles presented Open Data games used in the classroom to teach cultural aspects of their local context (Chen et al., 2014; Da C. Júnior et al., 2015) and environmental matters (Chiotaki & Karpouzis, 2020; Vargianniti & Karpouzis, 2020). Educational games using or collecting Open Data were used to increase engagement and motivation among students.

4. Discussion

A systematic mapping review was conducted to understand how the fields of *Open Data education* and *educational games* have been explored and to outline potentials for future development of Open Data gamified education. During the systematic mapping review, 28 articles were found and 8 themes were identified.

An Open Data Gamified Education Framework, presented in the following figure, highlights that a game-based approach for Open Data education can lead to authentic learning for real-world problem solving by addressing eight actions that connect the fields of Open Data Education and Educational Games: (1) Connecting classroom activities to real facts, (2) Empowering students to act with Open Data, (3) Supporting technical Open Data skills in the classroom, (4) Building literacy and developing skills, (5) Enhancing civic participation, (6) Creating more realistic and appealing narratives, (7) Extending teaching outside the classroom by collecting data in real time and local settings, and (8) Increasing engagement and motivation.

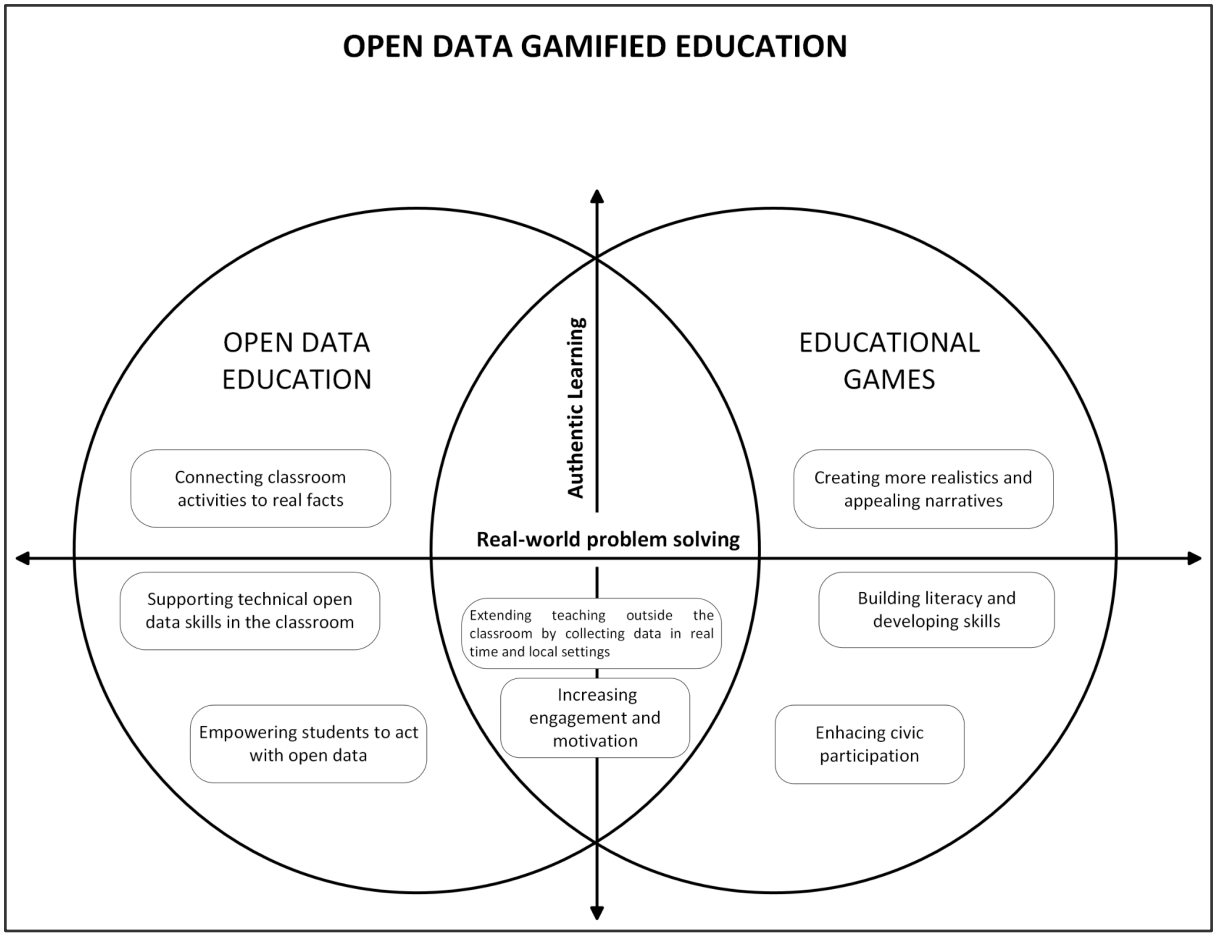

Figure 2: Open Data Gamified Education Framework

Education for real-world problem solving requires situating the learned knowledge in a different context building new meanings and constructing new worlds (Gee, 2006). An Open Data Gamified Education can create a new authentic context and realistic tasks based on Open Data. Acquiring a new language, skills and competences for collection, interpretation, and exploitation of Open Data in a local context can be achieved by using realistic and appealing narratives, and enhancing professional activities in a gamified environment. On the other hand, while technical skills might be supported by several gamified tools or mechanisms, educational games might lead to developing soft skills and competences to act with Open Data.

References

Atenas, J., Havemann, L., & Priego, E. (2015). Open Data as Open Educational Resources: Towards transversal skills and global citizenship. Open Praxis, 7(4), 377–389. DOI: http://doi.org/10.5944/openpraxis.7.4.233

Bachtiar, A., Suhardi, & Muhamad, W. (2020). Literature Review of Open Government Data. 2020 International Conference on Information Technology Systems and Innovation (ICITSI). Published. https://doi.org/10.1109/icitsi50517.2020.9264960

Badioze Zaman, H., Baharin, H., & Ahmad, A. (2021). Fusion Technology and Visualisation to Share STEM Data Using PETS Robots (i-COMEL) for Open Data Readiness Amongst Primary School Children. Advances in Visual Informatics, 184–194. https://doi.org/10.1007/978-3-030-90235-3_16

Barros, G. A. B., Green, M. C., Liapis, A., & Togelius, J. (2019). Who Killed Albert Einstein? From Open Data to Murder Mystery Games. IEEE Transactions on Games, 11(1), 79–89. https://doi.org/10.1109/tg.2018.2806190

Baker, M., Groff, J., Détienne, F., Andriessen, J., Pardijs, M., Hogan, M., Harney, O., Ruijer, E., & Scarano, V. (2017). Technology-supported effective transparency around open data. Proceedings of the European Conference on Cognitive Ergonomics 2017. https://doi.org/10.1145/3121283.3121293

Berrio-Zapata, C. B., & Santana, R. C. G. (2015). Transparency and open data in the classroom: a pedagogical exercise to construct civic awareness about access to public digital data in Brazil. International Journal of Electronic Governance, 7(4), 313. https://doi.org/10.1504/ijeg.2015.074330

Bradley, J. C., Lancashire, R. J., Lang, A. S., & Williams, A. J. (2009). The Spectral Game: leveraging Open Data and crowdsourcing for education. Journal of Cheminformatics, 1(1). https://doi.org/10.1186/1758-2946-1-9

Castillo-Abdul, B., Bonilla-del-Río, M., & Civila, S. (2021). El engagement de participantes en MOOC (Massive Open Online Courses): Análisis del diseño instruccional y elementos alternativos. Bellaterra Journal of Teaching & Learning Language & Literature, 14(3), e944. https://doi.org/10.5565/rev/jtl3.944

Clinton, G., & Rieber, L. (2010). The Studio experience at the University of Georgia: An example of constructionist learning for adults. Educational Technology Research and Development, 58(6), 755–780.

Chen, C.-P., Shih, J.-L., & Ma, Y.-C. (2014). Using instructional pervasive game for school children's cultural learning. Educational Technology and Society, 17(2), 169–182.

Chicaiza, J., Piedra, N., Lopez-Vargas, J., & Tovar-Caro, E. (2017). Recommendation of open educational resources. An approach based on linked open data. 2017 IEEE Global Engineering Education Conference (EDUCON). https://doi.org/10.1109/educon.2017.7943018

Chiotaki, D., & Karpouzis, K. (2020). Open and Cultural Data Games for Learning. International Conference on the Foundations of Digital Games. https://doi.org/10.1145/3402942.3409621

Cooper, S., Treuille, A., Barbero, J., Leaver-Fay, A., Tuite, K., Khatib, F., Snyder, A. C., Beenen, M., Salesin, D., Baker, D., Popović, Z. and Foldit players (2010). The challenge of designing scientific discovery games. In Proceedings of the Fifth international Conference on the Foundations of Digital Games, FDG 2010.

Conradie, P., & Choenni, S. (2014). On the barriers for local government releasing open data. Government Information Quarterly, 31, S10–S17. https://doi.org/10.1016/j.giq.2014.01.003

Coughlan, T. (2019). The use of open data as a material for learning. Educational Technology Research and Development, 68(1), 383–411. https://doi.org/10.1007/s11423-019-09706-y

Da C. Júnior, G. G., Gouveia, R. M. M., & De Medeiros, V. W. C. (2015). Development of an educational application using HCD toolkit and open data on the recife culture. Proceedings of the 14th Brazilian Symposium on Human Factors in Computing Systems.

Dickinson, A., Lochrie, M., & Egglestone, P. (2015). UKKO. Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play. https://doi.org/10.1145/2793107.2810324

Edler, D. (2018). VR ready? A methodological approach to exploring and processing of open spatial data for the 3D visualization of landscapes in game engines. [VR ready? Ein methodischer Ansatz zur Erschließung und Weiterverarbeitung freier Geodaten (Open Data) für die 3D-Landschaftsvisualisierung in Game Engines] Berichte Geographie Und Landeskunde, 92(3-4), 279-296. Retrieved from www.scopus.com

Gee, J. P. (2003). What Video Games Have to Teach Us About Learning and Literacy. New York: Palgrave Macmillan.

Gee, James. (2006). Game-like learning: An example of situated learning and implications for opportunity to learn. Assessment, Equity, and Opportunity to Learn. 10.1017/CBO9780511802157.009.

Gough, D., Kiwan, D., Sutcliffe, K., Simpson, D. & Houghton, N. (2003). A Systematic Map and Synthesis Review of the Effectiveness of Personal Development Planning for Improving Student Learning. London: EPPI-Centre, Social Science Research Unit.

Good, B. M. & Su, A. I. (2011) Games with a scientific purpose. Genome Biol, 12, 135

Grant, M. J., & Booth, A. (2009). A typology of reviews: an analysis of 14 review types and associated methodologies. Health Information & Libraries Journal, 26(2), 91–108. https://doi.org/10.1111/j.1471-1842.2009.00848.x

Handler, R. A., & Ferrer Conill, R. (2016). Open Data, Crowdsourcing and Game Mechanics. A case study on civic participation in the digital age. Computer Supported Cooperative Work (CSCW), 25(2–3), 153–166. https://doi.org/10.1007/s10606-016-9250-0

Hellberg, A.-S. and Hedström, K. (2015), "The story of the sixth myth of open data and open government", Transforming Government: People, Process and Policy, Vol. 9 No. 1, pp. 35-51. https://doi.org/10.1108/TG-04-2014-0013

Herrington, J., Reeves, T.C., Oliver, R. (2014). Authentic Learning Environments. In: Spector, J., Merrill, M., Elen, J., Bishop, M. (eds) Handbook of Research on Educational Communications and Technology. Springer, New York, NY. https://doi.org/10.1007/978-1-4614-3185-5_32

Hsu, S.-H., Shi, Y.-R., & Shih, J.-L. (2011). The learning effectiveness of pervasive game integrated with inquiry-based navigation system. Proceedings of the 19th International Conference on Computers in Education, ICCE 2011, 19th International Conference on Computers in Education, ICCE 2011; Chiang Mai; Thailand; 28 November 2011 through 2 December 2011; Code 89492, 414–421.

International Open Data Charter (2022). Principles. Retrieved March 2, 2022, from https://opendatacharter.net/principles/

Kassen, M. (2013). A promising phenomenon of open data: A case study of the Chicago open data project. Government Information Quarterly, 30(4), 508–513. https://doi.org/10.1016/j.giq.2013.05.012

Oh, E. (2011). Collaborative group work in an online learning environment: A design research study. Unpublished doctoral dissertation, The University of Georgia.

ODECO – Towards a sustainable Open Data ECOsystem. (2021). ODECO. Geraadpleegd op 5 mei 2022, van https://odeco-research.eu

Piedra, N., Chicaiza, J., López, J., & Tovar, E. (2015). Seeking open educational resources to compose massive open online courses in engineering education an approach based on linked open data. Journal of Universal Computer Science, 21(5), 679-711. Retrieved from www.scopus.com

Prieto, L.M., & A.C. Rodríguez (2012). Implementation framework for open data in Colombia. Proceedings of the 6th International Conference on Theory and Practice of Electronic Governance. pp. 14-17

Radchenko, I., & Sakoyan, A. (2014). The View on Open Data and Data Journalism: Cases, Educational Resources and Current Trends. Communications in Computer and Information Science, 47–54. https://doi.org/10.1007/978-3-319-12580-0_4

Roa-Valverde, A. J. (2014). Combining gamification, crowdsourcing and semantics for leveraging linguistic open data. Paper presented at the CEUR Workshop Proceedings, , 1254 Retrieved from www.scopus.com

Robinson, David G. and Yu, Harlan and Zeller, William P. and Felten, Edward W., Government Data and the Invisible Hand (Fall 2009). Yale Journal of Law & Technology, Vol. 11, p. 160, 2009, Available at SSRN: https://ssrn.com/abstract=1138083

Romero, M., Usart, M., & Ott, M. (2014). Can Serious Games Contribute to Developing and Sustaining 21st Century Skills? Games and Culture, 10(2), 148–177. https://doi.org/10.1177/1555412014548919

Saddiqa, M., Rasmussen, L., Magnussen, R., Larsen, B., & Pedersen, J. M. (2019a). Bringing open data into danish schools and its potential impact on school pupils. Proceedings of the 15th International Symposium on Open Collaboration. https://doi.org/10.1145/3306446.3340821

Saddiqa, M., Kirikova, M., & Pedersen, J. M. (2019b). Enterprise Architecture Oriented Requirements Engineering for Open Data Usage in Schools. Lecture Notes in Business Information Processing, 135–147. https://doi.org/10.1007/978-3-030-31143-8_10

Saddiqa, M. , Magnussen, R. , Larsen, B. , & Pedersen, JM (2021a). Digital innovation in education: Perspectives, opportunities and challenges of educational open data and sensor data . CEUR Workshop Proceedings , 2991 , 74-83.

Saddiqa, M., Magnussen, R., Larsen, B., & Pedersen, J. M. (2021b). Open Data Interface (ODI) for secondary school education. Computers & Education, 174, 104294. https://doi.org/10.1016/j.compedu.2021.104294

Sawyer, R.K. (2006). Educating for innovation. Thinking Skills and Creativity, 1(1), 41-48.

Scopus (2022). Search. Retrieved May 4, 2022, from https://www.scopus.com/search/form.uri?display=basic#basic

Selwyn, N., Henderson, M., & Chao, S. H. (2016). The possibilities and limitations of applying 'open data' principles in schools. Cambridge Journal of Education, 47(2), 167–187. https://doi.org/10.1080/0305764x.2016.1143449 Shadbolt et al., "Linked Open Government Data: Lessons from Data.gov.uk," in IEEE Intelligent Systems, vol. 27, no. 3, pp. 16-24, May-June 2012, doi: 10.1109/MIS.2012.23.

Sieber, R. E., & Johnson, P. A. (2015). Civic open data at a crossroads: Dominant models and current challenges. Government Information Quarterly, 32(3), 308–315. https://doi.org/10.1016/j.giq.2015.05.003

Siriaraya, P., Kiriu, T., Kawai, Y., & Nakajima, S. (2018). Using Open Data to Create Smart Auditory based Pervasive Game Environments. Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts. https://doi.org/10.1145/3270316.3271524

Staso, D. D., Kleiman, F., Crompvoets, J., & Janssen, M. (2021). Changing Civil Servants' Awareness about Open Data Using a Collaborative Digital Game. DG.O2021: The 22nd Annual International Conference on Digital Government Research. https://doi.org/10.1145/3463677.3463684

Suarez, P. (2015). Rethinking Engagement: Innovations in How Humanitarians Explore Geoinformation. ISPRS International Journal of Geo-Information, 4(3), 1729–1749. https://doi.org/10.3390/ijgi4031729

Vallejo-Figueroa, S., Rodriguez-Artacho, M., Castro-Gil, M., & Cristobal, E. S. (2018). Using text mining and linked open data to assist the mashup of educational resources. 2018 IEEE Global Engineering Education Conference (EDUCON). https://doi.org/10.1109/educon.2018.8363427

van Loenen, B., Zuiderwijk, A., Vancauwenberghe, G., Lopez-Pellicer, F. J., Mulder, I., Alexopoulos, C.,Magnussen, R., Saddiqa, M., Dulong De Rosnay, M., Crompvoets, J., Polini, A., Re, B., & Casiano Flores, C. (2021). Towards value-creating and sustainable open data ecosystems: A comparative case study and a research agenda. JeDEM - eJournal of eDemocracy and Open Government, 13(2), 1–27. https://doi.org/10.29379/jedem.v13i2.644

van Laar, E., van Deursen, A. J., van Dijk, J. A., & de Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. Computers in Human Behavior, 72, 577–588. https://doi.org/10.1016/j.chb.2017.03.010

Vargianniti, I., & Karpouzis, K. (2020). Using Big and Open Data to Generate Content for an Educational Game to Increase Student Performance and Interest. Big Data and Cognitive Computing, 4(4), 30. https://doi.org/10.3390/bdcc4040030

Veljković, N., Bogdanović-Dinić, S., & Stoimenov, L. (2014). Benchmarking open government: An open data perspective.

Warren, R., & Champion, E. (2014). Linked Open Data Driven Game Generation. The Semantic Web – ISWC 2014, 358–373. https://doi.org/10.1007/978-3-319-11915-1_23

Watson, J. (2017). Open Data in Australian Schools. Data Visualization and Statistical Literacy for Open and Big Data, 29–54. https://doi.org/10.4018/978-1-5225-2512-7.ch002

Wisniewski, M. A. (2010). Leadership and the millennials: Transforming today's technological teens into tomorrow's leaders. Journal of Leadership Education, 9, 53–68

Wolff, A., Cavero Montaner, J. J., & Kortuem, G. (2016). Urban Data in the primary classroom: bringing data literacy to the UK curriculum. The Journal of Community Informatics, 12(3). https://doi.org/10.15353/joci.v12i3.3278

Wolff, A., Barker, M., & Petre, M. (2017). Creating a Datascape. Proceedings of the 8th International Conference on Communities and Technologies. https://doi.org/10.1145/3083671.3083686