

## Online Appendix

### The Low-Code Phenomenon: Mapping the Intellectual Structure of Research

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Our literature review analysis included 105 publications from 2014-2022. Given page length constraints, a comprehensive reference list of is provided in this online appendix (available at <https://zenodo.org/record/8354060>).

## References

- [1] D. Di Ruscio, D. Kolovos, J. de Lara, A. Pierantonio, M. Tisi, and M. Wimmer, “Low-code development and model-driven engineering: Two sides of the same coin?,” *Software and Systems Modeling*, vol. 21, pp. 437–446, 2022.
- [2] F. Sufi, “Algorithms in low-code-no-code for research applications: A practical review,” *Algorithms*, vol. 16, no. 2, p. 108, 2023.
- [3] A. C. Bock and U. Frank, “Low-code platform,” *Business & Information Sys Eng*, vol. 63, pp. 733–740, 2021.
- [4] N. Prinz, C. Rentrop, and M. & Huber, “Low-code development platforms—a literature review,” *Americas Conference on Information Systems (AMCIS)*, 2021.
- [5] D. Pinho, A. Aguiar, and V. Amaral, “What about the usability in low-code platforms? A systematic literature review,” *Journal of Computer Languages*, 2022.
- [6] S. Käss, S. Strahringer, and M. Westner, “Drivers and inhibitors of low code development platform adoption,” *IEEE 24th Conference on Business Informatics (CBI)*, 2022.
- [7] A. Sahay, D. D. Ruscio, and A. Pierantonio, “Understanding the role of model transformation compositions in low-code development platforms,” *Proceedings of the 23rd ACM/IEEE International Conference on Model Driven Engineering Languages and Systems*, pp. 1–5, 2020.
- [8] R. Waszkowski, “Low-code platform for automating business processes in manufacturing,” *IFAC-PapersOnLine*, vol. 52, pp. 376–381, 2019.
- [9] M. M. Li, C. Peters, M. Poser, K. Eilers, and E. Elshan, “ICT-enabled job crafting: How business unit developers use low-code development platforms to craft jobs,” *International Conference on Information Systems (ICIS)*, 2022.
- [10] Y. Luo, P. Liang, C. Wang, M. Shahin, and J. Zhan, “Characteristics and challenges of low-code development: The practitioners’ perspective,” *Proceedings of the 15th*

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*ACM / IEEE International Symposium on Empirical Software Engineering and Measurement (ESEM)*, pp. 1–11, 2021.

- [11] B. Adrian, S. Hinrichsen, and A. & Nikolenko, “App development via low-code programming as part of modern industrial engineering education,” *Proceedings of the AHFE 2020 Virtual Conference on Human Factors and Systems Interaction, USA*, 2020.
- [12] A. C. Bock and U. Frank, “In search of the essence of low-code: An exploratory study of seven development platforms,” *2021 ACM/IEEE International Conference on Model Driven Engineering Languages and Systems Companion (MODELS-C)*, pp. 57–66, 2021.
- [13] Iho, S., Krejci, D., & Missonier, S., “Supporting knowledge integration with low-code development platforms,” *In ECIS.*, 2021.
- [14] S. S. Bhattacharyya and S. Kumar, “Study of deployment of “low code no code” applications toward improving digitization of supply chain management,” *Journal of Science and Technology Policy Management*, 2021.
- [15] H. A. Alsaadi, D. T. Radain, M. M. Alzahrani, W. F. Alshammari, D. Alahmadi, and B. & Fakieh, “Factors that affect the utilization of low-code development platforms: survey study,” *Romanian Journal of Information Technology and Automatic Control*, vol. 31, no. 3, pp. 123–140, 2021.
- [16] M. Kulkarni, “Deciphering low-code/no-code hype – study of trends, overview of platforms, and rapid application development suitability,” *International Journal of Scientific and Research Publications (IJSRP)*, vol. 11, no. 7, pp. 536–540, 2021.
- [17] T. C. Lethbridge, “Low-code is often high-code, so we must design low-code platforms to enable proper software engineering,” *Lecture Notes in Computer Science*, 2021.
- [18] L. Almonte, I. Cantador, E. Guerra, and J. de Lara, “Towards automating the construction of recommender systems for low-code development platforms,” in *Proceedings of the 23rd ACM/IEEE International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings*, (New York, NY, USA), ACM, 2020.
- [19] H. Henriques, H. Lourenço, V. Amaral, and M. Goulão, “Improving the developer experience with a low-code process modelling language,” *Proceedings of the 21th ACM/IEEE International Conference on Model Driven Engineering Languages and Systems*, 2018.
- [20] M. Lebens and R. Finnegan, “Using a low code development environment to teach the agile methodology,” pp. 191–199, Springer, Cham, 2021.
- [21] A. N. Alonso, J. Abreu, D. Nunes, A. Vieira, L. Santos, T. Soares, and J. Pereira, “Towards a polyglot data access layer for a low-code application development platform,” *arXiv preprint arXiv:2004.13495.*, 2020.
- [22] D. Hoogsteen and H. Borgman, “Empower the workforce, empower the company? citizen development adoption,” *Hawaii International Conference on System Sciences (HICSS)*, 2022.
- [23] C. Ullrich, T. Lata, and G. J. Klingeberg, *Celonis Studio-A Low-Code Development Platform for Citizen Developers*. In *BPM (PhD/Demos)* (pp. 102-105), 2021.
- [24] J. Cabot, “Positioning of the low-code movement within the field of model-driven engineering,” *Proceedings of the 23rd ACM/IEEE International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings*, vol. 2020, pp. 1–3, 2020.

- [25] F. Ihrwe, D. Di Ruscio, S. Gianfranceschi, and A. Pierantonio, *Assessing the Quality of Low-Code and MDE Platforms for Engineering IoT Systems*. 2022.
- [26] G. Daniel, J. Cabot, L. Deruelle, and M. Derras, "Xatkit: A multimodal low-code chatbot development framework," *IEEE Access*, vol. 8, pp. 15332–15346, 2020.
- [27] M. Tisi, J.-M. Mottu, D. Kolovos, J. Lara, E. Guerra, D. D. Ruscio, A. Pierantonio, and M. Wimmer, "Lowcomote: Training the next generation of experts in scalable low-code engineering platforms," *STAF*, 2019.
- [28] Apurvanand Sahay, Arsene Indamutsa, D. D. Ruscio, and A. Pierantonio, "Supporting the understanding and comparison of low-code development platforms," *46th euromicro conference on software engineering and advanced applications (SEAA)*, 2020.
- [29] R. Sanchis, Óscar García-Perales, F. Fraile, and R. Poler, "Low-code as enabler of digital transformation in manufacturing industry," *Applied Sciences*, vol. 10, p. 12, 2019.
- [30] R. Martins, F. Caldeira, F. Sa, M. Abbasi, and P. Martins, "An overview on how to develop a low-code application using outsystems," in *2020 International Conference on Smart Technologies in Computing, Electrical and Electronics (ICSTCEE)*, IEEE, 2020.
- [31] M. Bexiga, S. Garbatov, and J. Seco, "Closing the gap between designers and developers in a low code ecosystem," *Proceedings of the 23rd ACM/IEEE International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings*, 2020.
- [32] C. Zolotas, K. C. Chatzidimitriou, and A. L. & Symeonidis, "Restsec: a low-code platform for generating secure by design enterprise services," *Enterprise Information Systems*, vol. 12, pp. 1007–1033, 2018.
- [33] G. Dushnitsky and B. K. Stroube, "Low-code entrepreneurship: Shopify and the alternative path to growth," *Journal of Business Venturing Insights*, vol. 16, p. e00251, 2021.
- [34] P. Vincent, K. Iijima, M. Driver, J. Wong, and Y. V. Natis, "Magic quadrant for enterprise low-code application platforms," *Gartner Report*, 2019.
- [35] F. Khorram, J. Mottu, and G. Sunyé, "Challenges & opportunities in low-code testing," in *Proceedings of the 23rd ACM/IEEE International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings*, 2020.
- [36] A. Jacinto, Miguel Lourenço, and C. Ferreira, "Test mocks for low-code applications built with outsystems," *Proceedings of the 23rd ACM/IEEE International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings*, 2020.
- [37] F. Ihrwe, D. D. Ruscio, S. Mazzini, P. Pierini, and A. Pierantonio, "Low-code engineering for internet of things: a state of research," *Proceedings of the 23rd ACM/IEEE International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings*, 2020.
- [38] P. Kourouklidis, D. Kolovos, N. Matragkas, and J. Noppen, "Towards a low-code solution for monitoring machine learning model performance," *Proceedings of the 23rd ACM/IEEE International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings*, 2020.
- [39] W.-E. Chen, Y.-B. Lin, T.-H. Yen, S.-R. Peng, and Y.-W. Lin, "Devicetalk: A no-code low-code iot device code generation," *Sensors*, vol. 22, no. 13, p. 4942, 2022.
- [40] C. Silva, J. Vieira, J. C. Campos, R. Couto, and A. N. Ribeiro, "Development and validation of a descriptive cognitive model for predicting usability issues in a low-code development platform," *Human Factors: The Journal of the Human Factors and Ergonomics Society*, vol. 63, no. 6, pp. 1012–1032, 2021.
- [41] R. Arora, N. Ghosh, and T. Mondal, "Sagitec software studio (s3) - a low code application development platform," in *2020 International Conference on Industry 4.0 Technology (I4Tech)*, IEEE, 2020.
- [42] B. Horvath, Á. Horváth, and M. Wimmer, "Towards the next generation of reactive model transformations on low-code platforms," in *Proceedings of the 23rd ACM/IEEE International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings*, (New York, NY, USA), ACM, 2020.
- [43] J. Philippe, H. Coullon, M. Tisi, and G. Sunyé, "Towards transparent combination of model management execution strategies for low-code development platforms," in *Proceedings of the 23rd ACM/IEEE International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings*, (New York, NY, USA), ACM, 2020.
- [44] B. Vaduva and H. Valean, "Designing a low-code CRUD framework," *Carpathian Journal of Electronic and Computer Engineering*, vol. 14, no. 1, pp. 11–19, 2021.
- [45] S. Jahanbin, D. Kolovos, and S. Gerasimou, "Intelligent run-time partitioning of low-code system models," in *Proceedings of the 23rd ACM/IEEE International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings*, (New York, NY, USA), ACM, 2020.
- [46] S.-G. Pantelimon, T. Rogojanu, A. Braileanu, V.-D. Stanciu, and C. Dobre, "Towards a seamless integration of iot devices with iot platforms using a low-code approach," in *2019 IEEE 5th World Forum on Internet of Things (WF-IoT)*, IEEE, 2019.
- [47] J. Salgueiro, F. Ribeiro, and J. Metrolho, "Best practices for outsystems development and its influence on test automation," pp. 85–95, Springer, Cham, 2021.
- [48] N. Jansen, *Exploring interactive application landscape visualizations based on low-code automation*. PhD thesis, 2018.
- [49] K. Talesra and G. Nagaraja, "Low-code platform for application development," *International Journal of Applied Engineering Research*, vol. 16, pp. 346–351, 2021.
- [50] J. Metrolho, R. Araújo, F. Ribeiro, and N. Castela, "An approach using a low-code platform for retraining professionals to ict," in *EDULEARN Proceedings*, IATED, 2019.
- [51] J. C. Metrolho, F. Ribeiro, and R. Araujo, "A strategy for facing new employability trends using a low-code development platform," in *INTED Proceedings*, IATED, 2020.
- [52] M. Setala, P. Abrahamsson, and T. Mikkonen, "Elements of sustainability for public sector software – mosaic enterprise architecture, macroservices, and low-code," pp. 3–9, Springer, Cham, 2021.

- [53] S. Umaroh, K. R. Putra, N. Fitrianti, and M. M. Barmawi, "Low-code platform for health protocols implementation in sabilussalam mosque during the covid-19 pandemic," *REKA ELKOMIKA: Jurnal Pengabdian kepada Masyarakat*, vol. 3, no. 2, pp. 96–105, 2022.
- [54] C. Di Sipio, D. D. Ruscio, and P. T. Nguyen, "Democratizing the development of recommender systems by means of low-code platforms," *Proceedings of the 23rd ACM/IEEE International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings*, 2020.
- [55] M. Overeem and S. Jansen, "Proposing a framework for impact analysis for low-code development platforms," *ACM/IEEE International Conference on Model Driven Engineering Languages and Systems Companion (MODELS-C)*, 2021.
- [56] D. Krejci, S. Iho, and S. Missonier, eds., *Innovating with employees: an exploratory study of idea development on low-code development platforms*, 2021.
- [57] J. Ramalho, H. Lourenco, and J. C. Seco, "From builders to editors: Bidirectional transformations of low-code models," in *2021 ACM/IEEE International Conference on Model Driven Engineering Languages and Systems Companion (MODELS-C)*, IEEE, 2021.
- [58] J. Pacheco, S. Garbatov, and M. Goulao, "Improving collaboration efficiency between ux/ui designers and developers in a low-code platform," in *2021 ACM/IEEE International Conference on Model Driven Engineering Languages and Systems Companion (MODELS-C)*, IEEE, 2021.
- [59] A. Braganca, I. Azevedo, N. Bettencourt, C. Morais, D. Teixeira, and D. & Caetano, "Towards supporting spl engineering in low-code platforms using a dsl approach," *Proceedings of the 20th ACM SIGPLAN International Conference on Generative Programming: Concepts and Experiences*, 2021.
- [60] X. P. i. Palomes, P. Tuset-Peiro, and P. F. i. Casas, "Combining low-code programming and sdl-based modeling with snap! in the industry 4.0 context," in *2021 ACM/IEEE International Conference on Model Driven Engineering Languages and Systems Companion (MODELS-C)*, IEEE, 2021.
- [61] S. Pichidienthum, P. Pugsee, and N. Cooharajanane, "Developing module generation for odoo using concept of low-code development platform and automation systems," in *2021 IEEE 8th International Conference on Industrial Engineering and Applications (ICIEA)*, IEEE, 2021.
- [62] M. Overeem, S. Jansen, and M. Mathijssen, "Api management maturity of low-code development platforms," *Business-Process and Information Systems Modeling*, vol. Cham, pp. 380–394, 2021.
- [63] I. N. Oteyo, A. L. S. Pupo, J. Zaman, S. Kimani, W. de Meuter, and E. G. Boix, "Building smart agriculture applications using low-code tools: The case for discopar," in *2021 IEEE AFRICON*, IEEE, 2021.
- [64] A. Abdellatif, D. Costa, K. Badran, R. Abdalkareem, and E. Shihab, "Challenges in chatbot development: A study of stack overflow posts," *Proceedings of the 17th International Conference on Mining Software Repositories*, 2020.
- [65] R. I. Stromsted, M. Marquard, and E. Heuck, "Towards low-code adaptive case management solutions with dynamic condition response graphs, subprocesses and data," in *2018 IEEE 22nd International Enterprise Distributed Object Computing Workshop (EDOCW)*, IEEE, 2018.
- [66] B. Lopes, S. Amorim, and C. Ferreira, "Solution discovery over feature toggling with built-in abstraction in outsystems," in *2021 ACM/IEEE International Conference on Model Driven Engineering Languages and Systems Companion (MODELS-C)*, IEEE, 2021.
- [67] M. Fryling, "Low-code application development," *Encyclopedia of Education and Information Technologies*, 2020.
- [68] M. Fryling, "Low code app development," *Journal of Computing Sciences in Colleges*, vol. 34, no. 6, pp. 119–119., 2019.
- [69] Ness, C., & Hansen, M. E., *Potential of low-code in the healthcare sector*. PhD thesis, Norwegian School of Economics.
- [70] T. Virta, *Relation of low-code development to standard software development: Case Biit Oy*. PhD thesis.
- [71] E. Vikebø and L. B. Sydvold, *An Inquiry into Low-Code Solutions in Institutions for Higher Education*. 2019.
- [72] N. A. Sattar, *Selection of low-code platforms based on organization and application type*. PhD thesis, 2018.
- [73] M. Missikoff, *A Simple Methodology for Model-Driven Business Innovation and Low Code Implementation*. arXiv preprint arXiv:2010.11611., 2020.
- [74] A. N. Alonso, J. Abreu, D. Nunes, A. Vieira, L. Santos, T. Soares, and J. Pereira, "Building a polyglot data access layer for a low-code application development platform," in *Distributed applications and interoperable systems* (Remke and Hofmann, eds.), pp. 95–103, [Place of publication not identified]: Springer International Publishing, 2020.
- [75] V. S. Phalake and S. D. Joshi, "Low code development platform for digital transformation," in *Information and Communication Technology for Competitive Strategies (ICTCS 2020)*, pp. 689–697, Springer, Singapore, 2021.
- [76] S. Käss, S. Strahinger, and M. Westner, "Practitioners' perceptions on the adoption of low code development platforms," *IEEE Access*, vol. 11, pp. 29009–29034, 2023.
- [77] N. Prinz, M. Huber, C. Riedinger, and C. & Rentrop, "Two perspectives of low-code development platform challenges—an exploratory study," in *PACIS 2022, Pacific Asia Conference on Information Systems*, vol. 235, 2022.
- [78] P. M. Gomes and M. A. Brito, "Low-code development platforms: A descriptive study," in *2022 17th Iberian Conference on Information Systems and Technologies (CISTI)*, IEEE, 2022.
- [79] E. Sahinaslan, O. Sahinaslan, and M. Sabancıoglu, "Low-code application platform in meeting increasing software demands quickly: Setxrm," *AIP Conference Proceedings*, vol. 2334, no. 1, p. 070007, 2021.
- [80] L. Bies, M. Weber, T. Greff, and D. Werth, "A mixed-methods study of low-code development platforms: Drivers of digital innovation in smes," in *2022 International Conference on Electrical, Computer, Communications and Mechatronics Engineering (ICECCME)*, IEEE, 2022.
- [81] S. Gottschalk, R. Bhat, N. Weidmann, J. Kirchoff, and G. Engels, "Low-code experimentation on software products," in *Proceedings of the 25th International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings*, (New York, NY, USA), ACM, 2022.

- [82] V. Phalake, S. Joshi, K. Rade, and V. Phalke, "Modernized application development using optimized low code platform," in *2022 2nd Asian Conference on Innovation in Technology (ASIANCON)*, IEEE, 2022.
- [83] A. Calcada and J. Bernardino, "Experimental evaluation of low code development, java swing and javascript programming," in *Proceedings of the 26th International Database Engineered Applications Symposium*, (New York, NY, USA), ACM, 2022.
- [84] F. Gürcan and G. & Taentzer, "Using microsoft powerapps, mendix and outsystems in two development scenarios: An experience report," *ACM/IEEE International Conference on Model Driven Engineering Languages and Systems (MODELS-C)*, 2021.
- [85] M. A. Da Cruz, H. T. de Paula, B. P. Caputo, S. B. Mafra, P. Lorenz, and J. J. & Rodrigues, "Olp - a restful open low-code platform," *Future Internet*, vol. 13, no. 10, p. 249, 2021.
- [86] A. Indamutsa, D. Di Ruscio, and A. Pierantonio, "A low-code development environment to orchestrate model management services," in *Advances in Production Management Systems. Artificial Intelligence for Sustainable and Resilient Production Systems: IFIP WG 5.7 International Conference, APMS 2021, Nantes, France*, vol. Proceedings, Part I, pp. 342–350, 2021.
- [87] R. Lichtenthäler, S. Böhm, J. Manner, and S. and Winzinger, eds., *A Use Case-based Investigation of Low-Code Development Platforms*, 2022.
- [88] M. Heuer, C. Kurtz, and T. Böhm, *Towards a Governance of Low-Code Development Platforms Using the Example of Microsoft PowerPlatform in a Multinational Company*. 2022.
- [89] J. Hintsch, D. Staegemann, M. Völk, and K. & Turowski, "Low-code development platform usage: towards bringing citizen development and enterprise it into harmony," *Australasian Conference on Information Systems (ACIS)*, 2021.
- [90] J. Kirchhoff, N. Weidmann, S. Sauer, and G. Engels, "Situational development of low-code applications in manufacturing companies," in *Proceedings of the 25th International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings*, (New York, NY, USA), ACM, 2022.
- [91] I. Ibrahim and D. Moudilos, "Towards model reuse in low-code development platforms based on knowledge graphs," in *Proceedings of the 25th International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings*, (New York, NY, USA), ACM, 2022.
- [92] M. Moskal, "No-code application development on the example of logotec app studio platform," 2021.
- [93] E. Martinez and L. Pfister, "Benefits and limitations of using low-code development to support digitalization in the construction industry," *Automation in Construction*, vol. 152, p. 104909, 2023.
- [94] F. Z. Cai, S. Y. Huang, T. S. Kessler, and F. J. Fottner, "A case study: Digitalization of business processes of smes with low-code method," *IFAC-PapersOnLine*, vol. 55, no. 10, pp. 1840–1845, 2022.
- [95] Md Abdullah Al Alamin, Sanjay Malakar, Gias Uddin, Sadia Afroz, Tameem Bin Haider, and Anindya Iqbal, "An empirical study of developer discussions on low-code software development challenges," *IEEE/ACM 18th International Conference on Mining Software Repositories (MSR)*, 2021.
- [96] Md Abdullah Al Alamin, Gias Uddin, Sanjay Malakar, Sadia Afroz, Tameem Bin Haider, and Anindya Iqbal, "Developer discussion topics on the adoption and barriers of low code software development platforms," *Empirical Software Engineering*, vol. 28, pp. 1–59, 2022.
- [97] M. Woo, "The rise of no/low code software development—no experience needed?," *Engineering (Beijing, China)*, vol. 6, pp. 960–961, 2020.
- [98] M. Abdullah Al Alamin and G. Uddin, "Challenges and barriers of using low code software for machine learning," *arXiv e-prints*, pp. arXiv–2211, 2022.
- [99] H. Lourenco, C. Ferreira, and J. C. Seco, "Ostrich - a type-safe template language for low-code development," in *2021 ACM/IEEE 24th International Conference on Model Driven Engineering Languages and Systems (MODELS)*, IEEE, 2021.
- [100] R. Benac and T. K. Mohd, "Recent trends in software development: Low-code solutions," *Lecture Notes in Networks and Systems*, pp. 525–533, 2021.
- [101] J. Wang, B. Qi, W. Zhang, and H. Sun, "A low-code development framework for constructing industrial apps," pp. 237–250, Springer, Singapore, 2021.
- [102] H.-G. Fill, F. Härer, F. Muff, and S. Curty, "Towards augmented enterprise models as low-code interfaces to digital systems," pp. 343–352, Springer, Cham, 2021.
- [103] Bucaioni, A., Cicchetti, A., & Ciccozzi, F., "Modelling in low-code development: a multi-vocal systematic review," *Software and Systems Modeling*, vol. 21, no. 5, pp. 1959–1981, 2022.
- [104] M. Dalibor, M. Heithoff, J. Michael, L. Netz, J. Pfeiffer, B. Rumpe, S. Varga, and A. Wortmann, "Generating customized low-code development platforms for digital twins," *Journal of Computer Languages*, vol. 70, p. 101117, 2022.
- [105] J. Michael and A. Wortmann, "Towards development platforms for digital twins: A model-driven low-code approach," pp. 333–341, Springer, Cham, 2021.