This paper was presented at The XXXIII ISPIM Innovation Conference "Innovating in a Digital World", held in Copenhagen, Denmark on 05 June to 08 June 2022.
Event Proceedings: LUT Scientific and Expertise Publications: ISBN 978-952-335-694-8

Developing data analytics capabilities for circular economy SMEs by Design Factory student projects

Anne-Mari Järvenpää*, Jari Jussila, Iivari Kunttu

Häme University of Applied Sciences, Visamäentie 35A, Box 230 FI-13101 Hämeenlinna, Finland.
E-mail: firstname.lastname@hamk.fi

Abstract: Circular economy (CE) is a key strategy for achieving corporate sustainability. However, it is still difficult for many firms to translate the concept of circular economy into their strategies, business models, and operations. Utilization of data and digital tools are among the key capabilities facilitating the transition to CE. Therefore, firms need to develop new dynamic capabilities for the utilization of data, as a part of circular economy implementation. In this paper, we investigate how data analysis capabilities in the CE SMEs are developing in the joint action between university and companies. We introduce a comparative multiple case study of three CE SMEs, all located in Finland, who have developed their data analysis capabilities by participating in a collaboration project with university. The main focus of the project was to conduct a data analytics course and related student projects in close collaboration with the CE SMEs. This development of the firms' data analytics capabilities in this collaboration are analysed in this study by employing a framework of relationship learning. As a result, this study presents recommended practices for knowledge sharing, joint sensemaking and knowledge implementation to support the development of SMEs' dynamic capabilities in data analytics through university-industry.

Keywords: Design Factory; Data analytics; Dynamic capabilities; Circular Economy; Small and medium-sized Enterprises; University-Industry Collaboration; Knowledge sharing; Sensemaking; Knowledge implementation

1 Introduction

The circular economy (CE)-based business models aim to reuse materials in effective and sustainable manner. Switching from the traditional linear models of economy to circular ones would not only bring remarkable economical savings, but also significantly reduce the negative impact on the natural environment (Lewandowski, 2016). Therefore, the CE has attracted increased attention as one of the most powerful and most recent moves towards sustainability. CE-based business models also require close collaboration and information transfer between the companies and other stakeholders in the value chain and other actors, as well as well-organized logistics (Järvenpää et al., 2021). Data and digitalization play a central role in this.

However, large part of the CE companies is still facing challenges figuring out how to utilize the opportunities of digitalization and ever-increasing amounts of data. Small and medium enterprises (SMEs) have a key role in implementing the CE, and they also are

responsible for the majority of the jobs in these areas (Prieto-Sandoval et al., 2019). However, particularly in the SME sector, the managers are facing difficulties with ever-increasing amounts of data and finding appropriate analysis methods. Previous research has identified several types of obstacles and barriers to effective data utilization in SME sector (Järvenpää et al., 2021). The barriers and other challenges are emphasized in the SME sector since these companies have typically small organizations with limited competences and resources. CE SMEs tend also be rather streamlined and limited in their financial resources and capabilities (Järvenpää et al., 2020). In addition, whereas large and multinational companies usually have capabilities to fully deploy data in their business on both operational and strategic levels, many SMEs are still lacking competence and resources for data-driven decision-making (Iqbal et al., 2018).

In this study, we investigate how collaboration with universities, and in particular student projects can support CE SMEs to develop necessary capabilities for data utilization. Thus, the aim of this study is to understand how development of CE SMEs data analytics capability can be integrated into university-industry collaboration in a successful way. The research questions are the following: "*How the data analysis capabilities in the SMEs are developing in the joint action between university and companies?*" This research question is further divided into two sub-questions: 1) How does the university-industry collaboration correspond to the data analytics capability needs of the CE SMEs? 2) How did the capabilities of the CE SMEs develop during the collaboration?

We aim at answering the research question by using the theory of dynamic capabilities (Teece, 2018; Teece et al., 1997) as a theoretical lens. According to this theory, to successfully develop and sustain their competitiveness under rapidly changing environmental circumstances, firms need to develop dynamic capabilities that enable them to draw on, to extend and redirect their technological capabilities and R&D resources. We use this theoretical framework as a basis of a qualitative case study consisting of CE SMEs operating in Finland.

2 Developing dynamic capabilities in CE SMEs

Knowledge-intensive firms often operate in the dynamic environments characterized by strong competition, rapid changes, accelerating product life cycles, changing customer expectations and product discontinuities. To successfully develop and sustain their competitiveness under these environmental circumstances, firms need to develop dynamic capabilities that enable them to draw on, to extend and redirect their technological capabilities and R&D resources (Teece et al., 1997). Dynamic capabilities have been defined as: “The firms’ processes that use resources—specifically resources to integrate, reconfigure, gain, and release resources—to match and even create market change. Dynamic capabilities thus are the organizational and strategic routines by which firms achieve new resource configurations as markets emerge, collide, split, evolve, and die.” (Teece et al., 1997). An enterprise with strong dynamic capabilities will be able to profitably build and renew resources, assets, and ordinary capabilities, reconfiguring them as needed to innovate and respond to (or bring about) changes in the market (Teece, 2018).

3.1. Data and digitalization as a dynamic capability in CE SMEs

Circular economy is a key strategy for achieving corporate sustainability, and scholars have argued that firms need to develop new dynamic capabilities for circular economy implementation. The theory of dynamic capabilities provides a theoretical perspective to explore how firms can innovate in rapidly changing environments, and therefore it can be used as a theoretical lens in inspecting the firms' behaviour in the dynamic environments of CE. Moreover, in the research of (Sehnem et al., 2022) dynamic capabilities were found to be among the most investigated research topics in the intersection of CE and innovation. Dynamic capabilities are organizational and strategic routines by which firms achieve new resource configurations as markets emerge, collide, split, evolve, and die".

According to Parida & Wincent (2019), the transition to circular economy is widely driven by digitalization. This, in turn, has facilitated the development of new service-based business models. For this reason, the companies operating in CE have typically high demand for digitalized processes and the utilization of data on both operational and strategic levels, as well as in the business development dimension (Saleem et al., 2021) For these companies, the exploratory utilization of data collected from business processes, customers, competitors, and other sources enable data-driven approaches to various decision-making functions (Lacam, 2020). In addition to that, ever-increasing both business-specific and process-specific data provide opportunities for innovative companies in new business and process development in terms of e.g. material flows, customer behavior, or logistics planning (Lacam, 2020). On the other hand, the data management processes must be used well to benefit the firm (Ham et al., 2017). In addition, operational requirements related to e.g., supply chain management, production, and material flows are significantly higher in CE business than in many other business areas (Järvenpää et al., 2020). In addition, data-driven decision-making can provide the companies with several kinds of benefits, including reduced costs, improved operational efficiency, better stakeholder loyalty, as well as improved communication flows within the organization and ecosystem (Troisi et al., 2020).

3.2. Developing dynamic capabilities in university-industry collaboration

In this paper, we inspect how the CE SMEs can develop their dynamic capabilities in data utilization by intensive collaboration with universities. Previous research has shown that innovative research collaboration between universities and industrial firms may effectively facilitate shared knowledge creation, learning, and joint innovation (Kunttu & Neuvo, 2019; Perkmann et al., 2013). The role of university students and researchers may be significant in transferring the research-based knowledge into the industrial domain. In case of the dynamic environment of the CE SMEs, and in particular the topic of data utilization, the collaboration between the companies and universities may enhance the SMEs' dynamic capabilities in this area.

The concept of relationship learning (Selnes & Sallis, 2003, p. 80) has been applied to the collaborative learning process in the university-industry collaboration in (Kunttu & Neuvo, 2019). The process contains three phases. In the first phase, *knowledge sharing*, the partners share their previous knowledge and capabilities, whereas in the second phase, *joint sensemaking*, the partners work together to build new knowledge in joint action. The third phase, *knowledge integration* is a process of making concrete outcomes from the learnings. The outcomes on the industrial side may be prototype implementations, demonstrations, or proofs-of-concepts of the jointly developed

technology. In this paper, we study the development of the dynamic capabilities related to data utilization in CE SMEs by using the framework of relationship learning.

3 Methodology

The research methodology in this paper is based on the qualitative interview data collected from the case companies. The interview data was collected from the participating CE SMEs in two separate interview rounds in 2020 and 2021. Based on this data, we formulated a comparative multiple case study of three CE SMEs, all located in Finland. The case companies provide services related to waste management, biogas production and material recycling. In addition to the company interview data, we used additional data from the student projects that include course reports, presentation and other outcomes created by the students.

Table 1 Descriptions of the case companies studied.

	Case A	Case B	Case C
Number of employees	100	50	90
Main products/services of the customer company	Waste management and recycling services	Waste management, recycling services and solutions, biogas production	Waste management and recycling services
Duration of collaboration with university	2 years	2 years	1 year
Area of the joint development projects(s) with university	Data Analytics Project 2020-2021	Data Analytics Project 2020-2021	Data Analytics Project 2021
Added value for the industry	Additional resource, outside perspective	Additional resource, outside perspective	Additional resource
Key academic results of the development project(s)	Scientific article	Scientific article	Scientific article
Company interviewees	CEO & marketing manager	CEO	Chief Development Officer

4 Results

Case study results describe university-industry collaboration that took place during 2020-2021. Collaboration started with companies participating as challenge owners and data providers for data analytics student projects in 2020. In 2021 data analytics student project was followed by student trainees for companies that continued the data analytics project in the company, and also planning thesis projects as continuum that could follow the data analytics project course.

Major results from the three case studies in 2020 data analytics student projects were that the data visualization created by the student teams helped companies to increase understanding about their business, generated new ideas for improvement and familiarized the companies with new data analytics tools. The companies were able to implement some of the student teams results in reporting and operations planning. In 2020, many of the case studies companies, however, found it difficult to apply the student project results in their company, due to lack of data analytics capabilities.

Based on the feedback received from the year 2020, special attention was placed in sharing the results and approach used by the students' teams for problem solving of the company challenge. As a result of the recognized gap of companies' data analytics capabilities, a tailored data analytics tools course was developed for participating companies, so that the companies could benefit more from the solutions developed by the students and continue the development in-house. Another important finding was that in some of the cases, a short eight week long data analytics project is inadequate for solving the company challenge by itself but serves as good starting point for student trainees and thesis workers to complete the work.

As an outcome of the changes made in 20200, the following year companies benefited more from university-industry collaboration and were highly satisfied with the collaboration. Another finding was that those companies that participated for the second or third time in the similar projects, were able to better define the problem together with the university and also receive more useful results from the project. From the teachers' and companies' perspective it was recognized that university-industry collaboration is a multisided learning process and the more times you do it the more you can benefit from it.

4.1. Knowledge sharing

In the data analytics student projects, knowledge sharing from the student perspective included sharing the ideas, findings and visualizations created by the student teams and also information about modern data analytic tools and their possibilities in supporting and developing the operations of the company. The companies shared knowledge about their business environment, their products and services, processes, and current approaches in data analytics to the students. Knowledge sharing was done in weekly or bi-weekly meetings with the company, beginning from the first week by a presentation from a company representative. When feasible the students also visited the company to learn more about the target of their project. The knowledge level of data analytics in the studied companies was found to be relatively low in the beginning, and for that reason the students were able to provide valuable knowledge about data analytics tools and the possibilities for data analytics use in the company. For instance, case C representative described the starting situation as:

> "We must start with the basics, it is a big effort."

To address the identified gap in data analytics capability of the CE SMEs, a tailored data analytics tools online course was developed for companies that was provided after the student projects in 2020. Several of the company participants found the course helpful. Case A representative commented after participating in the tailored course for companies:

> "We learned about the possibilities of Excel and Power BI. An online course in data analytics for SMEs is a good continuum for this project."

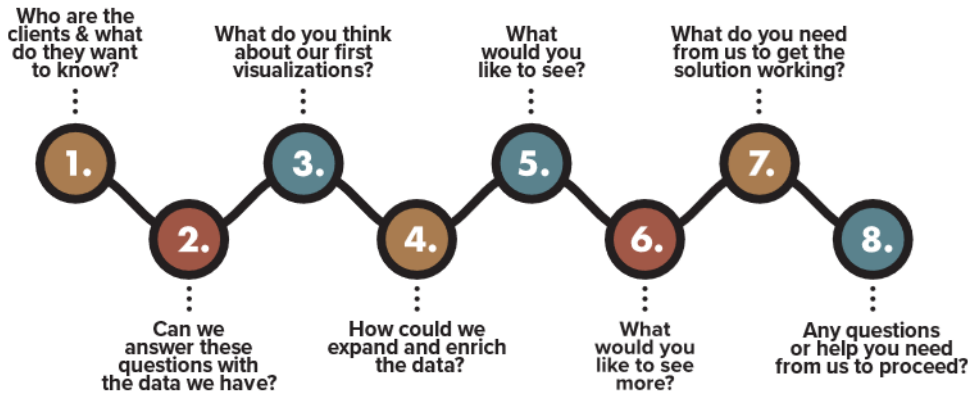

Figure 1. Joint sensemaking process in data analytics projects.

4.2. Joint sensemaking

Joint sensemaking took place mainly in interaction between the students and the case companies. Through discussions and questions every week, students tried to understand better the context of the project they are creating visualizations for. Companies on the other hand gained understanding about their data through the visualizations developed by the students, and got concrete development ideas. By the words of case company representatives:

> "We got a better understanding about data through visualizations." Case A

> "The benefits were data visualization and getting to know new tools (Power BI, Power Pivot)." Case B

> "We got concrete development ideas. There was a better understanding about the issue through visualization." Case D

Based on the experience of the 2020 data analytics projects, the sensemaking process for the students was formalized as eight questions to ask from the case companies each week. These questions were aimed to guide the interaction between the student teams and the case company. Each week contained one key question to support joint sensemaking illustrated in Figure 1. Following this joint sensemaking process the companies can benefit from the students outside-in view of the company problem and solution space. Some of the questions rely on students creating ideas and prototype visualizations to demonstrate for the company and get feedback on the direction of the project. The companies described their experiences of the process in the following ways:

> "The students ask questions and give perspectives that we haven't noticed" Case A
>
> Students provide an additional resource, competence, outside vision, and fresh thinking" Case B
>
> "We're going to use the outputs, but I don't know exactly how yet. We are not very good from a reporting perspective." Case C

The feedback received from the companies about the joint sensemaking process uncovered also some challenges for knowledge implementation and ideas how this could be enhanced in university-industry collaboration.

4.3. Knowledge implementation

Companies were able to implement gained knowledge into the management, reporting and monitoring. In the first round of data analytics student projects, there were also major challenges related to knowledge implementation. While some companies were able to incorporate the developed solutions to their processes, others lacked the capability of making use of the students' solutions.

> "Visualization is incorporated as part of the reporting of our plant, we can monitor the flow of materials as well as the balance of the process." Case B
>
> "When CE SME already has data analytics capability and solutions used in-house, they can more easily make use of the results of the student teams. There were, also opposite examples."Data processing is a type of work that is not going to be undertaken and nobody can do it (currently), but it can give a significant impact on operations management. Visualizations can be used to plan work shifts." Case A

This highlights the challenge of knowledge implementation in instances, where the company does not have staff familiar with data analytics solutions and prior experience of doing data analytics themselves. As a result of these experiences from the year 2020 student data analytics projects, the guidance process of student projects was adjusted to better enable knowledge implementation. Specifically, one extra process phase, "Share results", was added to the process (Jussila et al., 2020; Lahdenperä et al., 2022) that the students followed to create the solution for the company, illustrated in Figure 2.

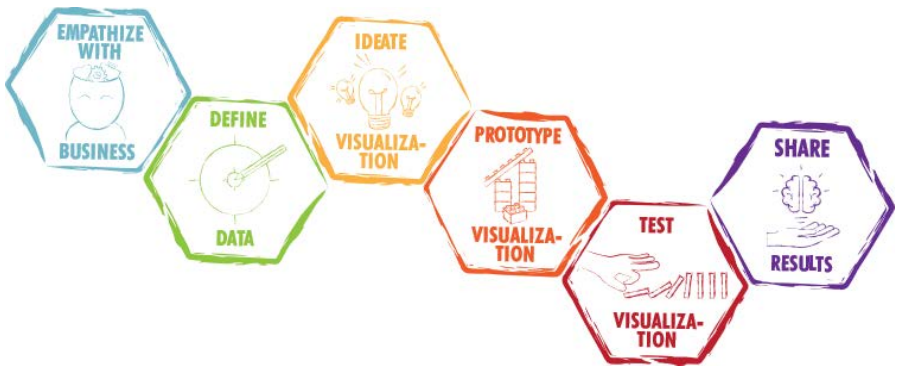

Figure 2. Six step design thinking process for data analytics.

The five steps in design thinking process, namely empathize, define, ideate, prototype and test, were found to work well in student data analytics projects, however, companies lacked capability in making use of the results. Therefore, the “Share results” was added as a sixth step in the design thinking process for data analytics. This required the students to create a short guidebook or instruction manual for the company on how to use the data analytics solution developed by the students. In addition, the guidebook or manual included instructions on how to update and add new data to the data analytics solution in order that the solution could be used also in the future inside the company when new data is collected or acquired. As one company representative noted:

> "This was an exceptional project as we received instructions that help us to getting familiar with PowerBI." Case A

> "By updating the data, we can obtain an advanced prediction of how packaging waste should be collected." Case A

Overall, the companies gained models and functioning data analytics solutions that they can utilize independently of the students inside the company. The data analytics solutions were prepared in such a way that the company can keep using them and following the instructions prepared by the students. As each company had two student teams working for them, they were able to get either two different views on the same topic or solution to two different focus areas related to the problem.

> “It was very interesting to see the different perspectives of two teams. We received concrete material to be used in customer communications and marketing as well as a model of how data can be processed and utilized in our own use." Case B

5 Discussion

This study contributes by introducing solutions to developing dynamic capabilities that answer challenges identified in previous research, for instance, the CE SMEs difficulties with ever-increasing amounts of data and finding appropriate analysis methods and the common SME sector limitation of having limited competences and resources for data analysis. Companies can develop their dynamic capabilities in university-industry collaboration by working with students to solve business problems and simultaneously developing their own data analytics capabilities in interaction with students and the university.

Table 2 A summary of the main findings of this study on university-industry collaboration in developing data analytics capabilities of CE SMEsrelationships

	Knowledge sharing	*Joint sensemaking*	*Knowledge integration*
Co-created student project course	Methods for data analysis are shared between university and companies, university learns about company needs	Weekly or biweekly meetings between students and company create shared understanding on problem and solution space	Student created data analytics solution instruction manual help companies to adopt the results
Tailored course for companies	Company learns about university data analytics methods and tools, university about industry needs and problems	Discussions in tailored data analytics course for the company increase understanding of match between needs and tools used	Companies' data analytics capability is enhanced by tailored course
Student trainees for companies	University gains knowledge about company information systems and problem space and company about data analytics tools and methods	Trainee interaction with company and university increase domain specific understanding on data analytics problem and solution space	Student trainee contributes to development of data analytics solution and absorptive capacity of the company
Thesis projects for companies	Data analytics focused thesis disseminates learnings to company and future student projects	Thesis meetings and work increase domain specific understanding on data analytics problem and solution space	Thesis project provides extended opportunity to integrate knowledge to the company knowledge base

In this paper, we have studied how the dynamic capabilities of the CE SMEs in the area of data utilization can be developed by means of university student projects. In our analysis, we have employed the framework of relationship learning, where the mutual learning process is analyzed in three phases: knowledge sharing, joint sensemaking and knowledge implementation. The results of this study, summarized in Table 2, reveal practices that facilitate learning and new knowledge development in all of these three phases. Thus, this study contributes to the existing research on data-driven decision-making and management by focusing on the SMEs. The study provides also new insights into university-industry collaboration in Design Factory context (Lahdenperä et al., 2022), thus elaborating what different actors benefit from knowledge sharing, joint sensemaking and knowledge implementation in university-industry relationships.

6 Practical implications

As a practical implication, higher education institutions need to pay more attention how the results and approaches for solving the problems are transferred to the industry.

Merely giving the data analysis results or source documents and presenting the solution for the company is not enough. A recommended practice based on the experience of the case studies is to create instructions for companies how to use the results, and how the company can add more data, metrics and dashboards independently from the students and original designers of the solution. Student trainees are effective ways to improve the absorptive capacity (Cohen & Levinthal, 1990) of the company and further develop student data analytics project results into working solutions for the company. In the case of CE SMEs in particular, more attention should be paid to the joint implementation of the results related to the research-based collaboration. One example of this may be the building of prototypes for industrial use. Also, recruiting the students and newly graduated engineers is an excellent way of transferring the newest knowledge from the university to industrial domain.

Acknowledgements

This research was supported by the European Regional Development project *Green Smart Services in Developing Circular Economy SMEs* (A77472). The authors would like to thank designer Jali Närhi for the article illustrations.

References

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, *35*(1). https://doi.org/10.2307/2393553

Ham, J., Choi, B., & Lee, J. N. (2017). Open and closed knowledge sourcing Their effect on innovation performance in small and medium enterprises. *Industrial Management and Data Systems*, *117*(6), 1166–1184. https://doi.org/10.1108/IMDS-08-2016-0338/FULL/PDF

Iqbal, M., Kazmi, S. H. A., Manzoor, A., Soomrani, A. R., Butt, S. H., & Shaikh, K. A. (2018). A study of big data for business growth in SMEs: Opportunities & challenges. *International Conference on Computing, Mathematics and Engineering Technologies (ICoMET)*, 1–7.

Järvenpää, A.-M., Kunttu, I., Jussila, J., & Mäntyneva, M. (2021). Data-Driven Decision-Making in Circular Economy SMEs in Finland. *Springer Proceedings in Complexity*, 371–382. https://doi.org/10.1007/978-3-030-84311-3_34

Järvenpää, A.-M., Kunttu, I., & Mäntyneva, M. (2020). Using Foresight to Shape Future Expectations in Circular Economy SMEs. *Technology Innovation Management Review*, *10*(7), 41–50. https://doi.org/http://doi.org/10.22215/timreview/1374

Jussila, J., Raitanen, J., Partanen, A., Tuomela, V., Siipola, V., & Kunnari, I. (2020). Rapid Product Development in University-Industry Collaboration: Case Study of a Smart Design Project. *Technology Innovation Management Review*, *10*(3).

Kunttu, L., & Neuvo, Y. (2019). Balancing learning and knowledge protection in university-industry collaborations. *The Learning Organization*, *26*(2), 190–204.

Lacam, J. S. (2020). Data: A collaborative ? *The Journal of High Technology Management Research*, *31*(1), 100370. https://doi.org/10.1016/J.HITECH.2020.100370

Lahdenperä, J., Jussila, J., Järvenpää, A.-M., & Postareff, L. (2022). Design Factory – Supporting technology students' learning of general competences through

university-industry collaboration. *LUMAT: International Journal on Math, Science and Technology Education*, *10*(1), 127–150–127–150. https://doi.org/10.31129/LUMAT.10.1.1672

Lewandowski, M. (2016). Designing the Business Models for Circular Economy—Towards the Conceptual Framework. *Sustainability 2016, Vol. 8, Page 43*, *8*(1), 43. https://doi.org/10.3390/SU8010043

Parida, V., & Wincent, J. (2019). Why and how to compete through sustainability: a review and outline of trends influencing firm and network-level transformation. *International Entrepreneurship and Management Journal*, *15*(1), 1–19. https://doi.org/10.1007/S11365-019-00558-9/FIGURES/2

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'Este, P., Fini, R., Geuna, A., Grimaldi, R., Hughes, A., Krabel, S., Kitson, M., Llerena, P., Lissoni, F., Salter, A., & Sobrero, M. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. *Research Policy*, *42*(2), 423–442. https://doi.org/10.1016/J.RESPOL.2012.09.007

Prieto-Sandoval, V., Jaca, C., Santos, J., Baumgartner, R. J., & Ormazabal, M. (2019). Key strategies, resources, and capabilities for implementing circular economy in industrial small and medium enterprises. *Corporate Social Responsibility and Environmental Management*, *26*(6), 1473–1484. https://doi.org/10.1002/CSR.1761

Saleem, H., Li, Y., Ali, Z., Ayyoub, M., Wang, Y., & Mehreen, A. (2021). Big data use and its outcomes in supply chain context: the roles of information sharing and technological innovation. *Journal of Enterprise Information Management*, *34*(4), 1121–1143. https://doi.org/10.1108/JEIM-03-2020-0119

Sehnem, S., de Queiroz, A. A. F. S. L., Pereira, S. C. F., dos Santos Correia, G., & Kuzma, E. (2022). Circular economy and innovation: A look from the perspective of organizational capabilities. *Business Strategy and the Environment*, *31*(1), 236–250. https://doi.org/10.1002/BSE.2884

Selnes, F., & Sallis, J. (2003). Promoting relationship learning. *Journal of Marketing*, *67*(3), 80–95.

Teece, D. J. (2018). Business models and dynamic capabilities. *Long Range Planning*, *51*(1), 40–49. https://doi.org/10.1016/J.LRP.2017.06.007

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, *18*(7). https://doi.org/10.1002/(SICI)1097-0266(199708)18:7<509::AID-SMJ882>3.0.CO;2-Z

Troisi, O., Maione, G., Grimaldi, M., & Loia, F. (2020). Insights on data-driven decision-making from three firms. *Industrial Marketing Management*, *90*(October 2020), 538–557.