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THE SUMMARY OF THE DOCTORAL DISSERTATION

Leadership and the effectiveness of research and development teams

Patrycja Radek, M.Sc.

Supervisor: DR HAB., PROF. UEW JANUSZ LICHTARSKI
Assistant supervisor: DR HAB., PROF. UEW WITOLD SZUMOWSKI

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The research problem

Leadership is one of the key areas of organizational management practice, and in management sciences one of the under-researched topics. Despite the extensive and significant advancements in leadership scholarship, its constant development can be noted, partly because of the perpetual changes in technological, social and economic environments create new challenges for leadership, while new research areas are opening up that merit further studies.

The leadership in organizations literature is incredibly rich, however, leadership in research and development (R&D) teams working on new technologies remains limited. Although the English-language literature dominates, there are still many unexplored topics, such as leadership of, and in, R&D teams as well as research on behaviours and relationships, and their impact on teams (Buijs, 2007; Elkins, Keller, 2003; Mumford, Licuanan, 2004; Thamhain, 2004; Vessey et al., 2014; Zacher et al., 2016; Zhang et al., 2022). The subject is tremendously important, demanding and crucial in order for organizations as well as national economies to develop. Therefore, homing in on the theoretical underpinnings of this specific topic and a thorough analysis of this theoretical gap are so important.

There are not many models describing R&D leadership and its impact on innovation. Most of the available models are theoretical and there is a clear empirical gap, thus it is imperative to verify these theoretical findings as well as to understand what conditions are conducive to developing this valuable knowledge (Elkins, Keller, 2003; Hill, 2014; Robledo et al., 2012; Rosing et al., 2011).

The dissertation focuses on leadership in R&D teams that develop innovative technological products in various types of organizations. The research and technology development area is another aspect of leadership where new ways of leading, one that is focused on the leader's behaviour, have proven to be effective and more adaptable as well as suitable to the current needs of organizations and people involved. This dissertation is based on this particular theoretical analysis and the empirical research which stem from many years of observations of the specificity of the functioning of R&D teams, literature review, including scholarly publications, reports on the development of innovation and trend analysis. The following issues were key in this analysis, albeit this list is not exhaustive:

- research teams note that leadership in innovative projects needs to be emphasized due to its specificity and the need to create models that are adapted to, and address, this

area, but most of these models are theoretical, thus remain unproven in practice in R&D teams;

- models that are subjected to statistical analyses usually examine simple relationships, do not pay attention to a wider range of leadership behaviours and do not use the possibilities offered by SEM analyses;
- not many studies focus specifically on R&D teams that develop advanced technologies.

A number of interchangeable terms were used in this dissertation: R&D projects, innovation projects, and technological projects. All these terms relate to a group of projects dealing with the development of innovation and whose results might be patented or registered utility models.

A systematic review of the literature on leadership in innovative projects enabled the identification of scientific groups that treat this topic as specific. At the same time, the review shows that only a small part of research on leadership studies leadership in R&D teams. The authors researching this topic, emphasize the specificity of leading scientists and engineers who work on innovations, in startups, mature companies with R&D teams, or R&D teams at universities and other scientific units (Buijs, 2007; Elkins, Keller 2003; Robledo et al., 2012; Rosing et al., 2011; Thamhain, 2014). At the same time, leadership and team management skills are not included in the academic education and training of potential R&D team leaders. These teams have their own specificity; they require collective work, knowledge sharing and advanced collaboration in order to create unique know-how. This is a cornerstone for some researchers to develop dedicated models of leadership and ways of managing such teams. However, most of these topics remain theoretical and are rarely verified empirically.

Furthermore, t the importance of the research, development and innovation sphere should be noted. According to the Boston Consulting Group (BCG) report, from 2016 to 2020, investments in the development of advanced deep tech have increased from USD 15 billion to over USD 60 billion and are unlikely to stop growing. In the same period, investments in technology startups increased sixfold. More than half of the high-tech market is in the United States and China (Deep Tech: The Great Wave of Innovation, 2021). The development of technology is increasingly important, and the number of challenges faced by organizations and governments is not declining. The problems are becoming more complex, such as, for example, the climate crisis, drought, shrinking raw materials sources, and other challenges that have significant societal consequences (United Nations Department for Economic and Social Affairs, 2022).

The identified research and methodological gaps, together with the growing importance of the R&D area, were the basis for conducting the research on leadership in research and development teams. The first step in this research was a systematic literature review. Leadership in R&D teams as a research term was analyzed using the Scopus and Ebscohost Econ Lit databases. Ultimately, the review of the full texts of publications used in this doctoral thesis covered over 100 publications from the years 1963–2022, including, respectively: theoretical and conceptual articles (38), qualitative research articles (20), reviews (4), quantitative research articles (38) and others (10). The conclusions drawn from several books were also important and helped define the research area, including: (Burke, Barron, 2014; Hill, 2014; Thamhain, 2014; Tidd, Bessant, 2013).

The dissertation analyzed the following disciplines: innovation management, strategic management, as well as psychology and social sciences.

The objectives of the dissertation

The dissertation is titled: Leadership and the effectiveness of research and development teams. The general aim of the research was to identify the variables and describe the model, of leadership of R&D teams that results in said teams being effective. Once the theoretical goal was met, the empirical research followed. The model proposed in the theoretical part of the work was verified using correlation studies, based on the assumed empirical goals, the research hypotheses and the exploratory goals. Finally, the developed leadership model was verified by SEM structural equation modelling.

Four key empirical goals for the development of the model of leadership in R&D teams were formulated.

Empirical objectives:

- to identify the components of leadership resulting in effective R&D teams,
- to examine which components of the leadership model relating to the behaviour of leaders have the greatest impact on the effectiveness of the analyzed types of R&D teams,
- to determine the extent to which the type of an R&D team and a type of organization it operates in affects the importance and impact of individual components of the leadership model on the effectiveness of R&D teams.

The result of the systematic literature review was the formulation of four research hypotheses, which were further verified in the research process.

H1: The clearer the vision communicated by the leader, the greater the effectiveness of R&D teams.

The context of examining the impact of the leader's vision at the level of R&D teams is important because these teams often have separate structures in organizations, as well as greater autonomy and freedom of action than other units in organizations. Meanwhile, most research on the vision looks at the strategic level of organizations, which is why the perspective of an R&D team is important in researching innovation development. In Chapter 4 of the doctoral dissertation, it has been shown that among the various components of leadership, a clear vision of the leader is particularly impactful in terms of the effectiveness of teams working on innovative solutions (Ashford et al., 2018; Lynn & Akgun, 2001; Lynn & Kalay, 2016; Men et al., 2020).

H2: The interplay between the leader's opening and closing behaviours translates into greater effectiveness of R&D teams:

a) opening actions are more important for effectiveness than closing actions;
b) effectiveness is highest when both opening and closing leadership behaviours are on a high level.

The development of leadership theories, such as two-handed, accompanying or servant leadership, seems to be of particular importance in research on R&D teams. The authors (Elkins, Keller, 2003; Hill, 2014; Mumford et al., 2002; Paliszkiewicz, 2019; Rosing et al., 2011) emphasize that R&D leadership should be treated as a separate area of research. The very specificity of an innovation process, which consists of alternating phases of divergence and convergence, its unpredictability, teams' make up or whether R&D activities are of strategic importance for an organization means that a different approach is needed to manage such teams. The ability of leaders to mould their behaviours in such a way that they act at the right moment, opening or narrowing the perspective, is reflected empirically in the research of Zacher and Rosing (Zacher, Rosing, 2015), as well as other authors who see the role of ambidexterity (also two-handed) of leaders in the development of innovation projects (Andriopoulos, Lewis, 2009; Baškarada et al., 2016; Birkinshaw, Gupta, 2013; Bledow et al., 2009; Rosing et al., 2011; Turner et al., 2013; Zacher, Rosing, 2015). At the same time, a few empirical studies verified the presented models and assumptions. This dissertation is one such attempt, using the results of the earlier research by Zacher and Rosing (Rosing et al., 2011; Zacher et al., 2016), who undertook an empirical verification of a previously developed model

on a small and very diverse research sample in order to have their assumptions and results rechecked.

H3: The greater the ability of the leader to function in a heterarchy y, the greater the effectiveness of R&D teams.

R&D teams operate in a project reality. The ability to function in a heterarchy within multidimensional and fluid structures is a particularly important yet exceedingly difficult to master, competence. By analyzing the project management literature, in particular R&D projects, a hypothesis was put forward about the impact of the leader's ability to function in heterarchy on the effectiveness of the team. Here again, researchers tend to focus on issues related to strategy, structure, and project management from the side of project implementation, rather than the needs and behaviours of people. Meanwhile, it is people who implement projects, and in the case of R&D projects, it is particularly important, because the product of their work is the unique intellectual property created in a group process.

H4: The greater the flexibility of the leader in adapting to a situation, the greater the effectiveness of R&D teams.

Innovative projects require an agile approach and adjustments to plans and making decisions depending on the results. When creating new technological solutions, the participants of the process do not know the end result, they rely on how the process of innovation usually runs, which makes it easier to manage them. In the case of R&D projects, researchers often emphasize the role of flexible leaders (Day, 2012; Denison et al., 1995; Kerzner, 2019; G. A. Yukl, 2013; Zacher, Rosing, 2015). Flexibility in the implementation of strategies and goals is necessary and results from constant technological changes, customer requirements and constraints as well as obstacles that happen during the development of innovation (Narayanan, O'Connor, 2010).

The variables that are the subject of this research are related to each other to varying degrees. Therefore, initially, only the hypotheses regarding dependencies were formulated, based on the concepts and models of other authors, often unconfirmed empirically. As part of the conducted analyses, the need to answer additional research questions was assumed, namely:

1) Are there any significant differences in the results arising from a type of R&D team, distinguishing between technological startups, R&D teams of universities or research institutes, R&D teams of technological companies?

2) Are there any significant differences resulting from the field an R&D team research?
3) Are there any significant differences depending on the seniority of the respondents?
4) Are there any significant differences depending on the position of the leader in the structure of the surveyed organizations?

The formulated research objectives, hypotheses and related research questions form the structure of the dissertation. It consists of six chapters preceded by an introduction.

The scope of the study

The dissertation is theoretical and empirical in nature and consists of six chapters. Chapter 1, entitled "Leadership on the basis of management sciences", introduces the issue of leadership, its origins, the main research trends and definitions, in order to show how research on leadership has evolved and what are the bases for further development of this area. The chapter refers to the organizational levels at which leadership is analyzed as well as to leadership styles, focusing on the most frequently analyzed areas of innovation: transactional and transformational. The differences between leaders and managers were also pointed out, and in the final part, a reference was made to leaders who work with teams developing technological innovations, thus narrowing the research area to the focus of this research.

Chapter 2, entitled "Development of innovation in research and development teams" presents a broad and multifaceted meaning of innovation in organizations and shows a number of classifications, as well as stages of innovation development and d R&D activities. The macro context has been outlined because the development of innovation is analyzed in the context of the strategic economic development of individual countries. Thus, the context of effective leaders in R&D from the perspective of an innovative country is important. The next part of the chapter discusses the role of leaders in the development of innovation, as well as the essence and elements of a design environment in which innovations are implemented.

Chapter 3, entitled "Models of leadership in research and development teams" analyzes the selected models of leadership in innovation teams. The purpose of this chapter is to present them in the context of the specificity of R&D team leadership. The studies that referred to the context of measuring the effectiveness of innovation and R&D teams were also sought. Based on these findings, the measurement of a dependent variable in the conducted research was proposed.

In Chapter 4, "The model of leadership in research and development projects", based on a systematic literature review, the previously identified dimensions of leadership in R&D teams were developed – these dimensions were understood as areas and ways of a leader's

impact on an innovation team, based on the results of previous research. It also focused on the importance of effectiveness as a measure of a team's research outcomes. These activities were aimed at proposing the first theoretical conceptualization of the elements of an R&D team leadership model, which was then verified quantitively.

Chapter 5, "Methodology of empirical research", presents the process of planning and conducting quantitative research. Most researchers who create models of leadership in innovative projects limit themselves to the theoretical construction of models (Byrne et al., 2009; Gray, 2008; Hill, 2014; Robledo et al., 2012). These models are complex and complicated, and the phenomenon and created constructs are multi-dimensional. Publications in which the derived model is verified empirically are rare (see for example, Rosing et al., 2011; Zacher, Rosing, 2015). The purpose of the chapter is to present the quantitative methodology and tools used in this research, specifying the assumptions and goals, the research hypotheses, and the additional research questions. The chapter describes the conditions and the principles adopted during the empirical research, collecting 237 fully answered questionnaires. The obtained data were then used to conduct statistical analyses.

Chapter 6, entitled "Verification of the model of leadership effectiveness in R&D teams" verified and improved the model by doing statistical research. The purpose of this chapter is to show the entire process of empirical verification of the proposed leadership model, from the analysis of the reliability of the scales to the development of the final model proposal. The regression analyses were used to build an empirical model that was verified using SEM structural equation modelling.

The subject and object of research

The current development of organizations is based on innovation, unique know-how, patent portfolios, trade secrets, utility models, trademarks or industrial designs, and topographies of integrated circuits. Intellectual property protection is complicated, and the development of new products depends not only on capital resources but also on leaders who are able to create innovative organizations. Here, new ways of leadership are needed to be able to create social conditions c within the organization that will be conducive to collaboration and the development of innovation. The phenomenon of R&D teams, whose goal is the systematic development of innovations that can be implemented and the development of new technologies that enable better positioning on the market and meet the needs of users, does not fit into traditional hierarchical structures. Today, effective leadership is based on such personality traits as enthusiasm, determination, willingness to make

sacrifices and creating conditions for the development of complex social behaviours that foster team creativity and innovation (Kuc, 2004).

Technological innovations are developed in a project environment, and their implementation requires a complex effort from R&D teams. They require a structured approach, the ability to build and maintain a team that is able to implement the project and plan all elements of the challenge in terms of goals, scope, costs, resources and implementation schedule and other elements relevant to the project, taking into account the existing risks and requirements of various stakeholder groups. A variety of standards and practices are used to manage innovative projects, including agile methodologies and modern project management tools that support project, programme, or project portfolio management (Archibald, Archibald, 2016).

Technology projects have distinctive characteristics that need to be considered when managing them. These differences result mainly from the volatility of the scope and a significantly high level of uncertainty as well as risk related to their implementation. Such projects often do not even have a precise goal, or methods of implementation which are rarely known in advance. All of this makes it difficult to plan and use typical project management tools. Researchers also emphasize that the very category of R&D projects is so diverse that individual subcategories have different characteristics, which may ultimately result in the need to apply a different approach to project management, therefore, caution is required (Kuchta et al., 2017).

Leadership in an R&D organization, despite operating through projects, is, in fact, a social process of interaction between the supervisor and employees. The leader develops and leads the team in a complex and demanding organizational environment that requires specific management, but also leadership focused on nurturing R&D innovation (Charbonnier-Voirin et al., 2010).

A leader is a person who can influence the behaviour of others, regardless of their formal authority. Leadership is based on the ability to formulate and implement common goals, tap into the potential of employees, develop their talents, accumulate knowledge and use the group's competencies to achieve the set goals (Chrostowski et al., 2013).

Technological innovation is not the result of a single person or one-person genius. It is a monumental team effort. Technological organizations often create innovation teams, which include engineers, technicians and researchers as well as other job functions that support the development of innovation. Because of this, the organizational acceptance score is built into R&D teams, which accelerates the development of innovation (Buijs, 2007). In

addition, conscious companies foster diversity, be it functional, cultural, gender, age or related to experiences of different people, personality styles (Mostert, 2007). All this is important because the development of new products is a complicated process that is iterative, many tasks are carried out at the same time, and their results require frequent corrections of assumptions and amendments to action plans. The development of innovation carries an elevated risk of failure and the need to repeatedly verify and change the project assumptions (Trott, 2017). In fact, there is no single innovation process, because it is a set of different, parallel, competitive and contradictory processes that take place at the same time in a given R&D project (Buijs, 2007).

Considering the context of leadership that determines the effectiveness of a team, it is prudent to look for regularities or a model that allows for this fragment of organizational reality to be captured. Rosing K., Frese M. and Baush A. proposed a theoretical model of two-handed leadership. In their opinion, the key issue is the ability to appropriately respond to the situation using a complete set of leadership behaviours: opening and closing (Rosing et al., 2011). According to the three-vector theoretical model of scientists and engineers developed by Robledo I.C., Peterson D.R., Mumford M.D. (2012), there are three key areas of influence that leaders should develop, namely: group, work and organization. Leaders in the proposed model have many complex roles that distinguish this type of leadership from others, and this shows that leaders are burdened with an all-encompassing responsibility. According to the model, leaders themselves should be creative in order to exert proper influence on the three key vectors of influence (Robledo et al., 2012). Hill L.A., Brandeau G., Truelove E., Lineback K., in the book: “Collective genius”, proposed a model of leading innovation where they emphasized that leadership in innovation is not only about creating a vision and inspiring others to implement it because innovation itself demands a "collective genius" approach. The model consists of three elements that determine the ability to innovate, namely, creative attrition, creative agility and creative problem-solving. The role of the innovation leader is to make sure that all these elements are alive and well in their group.

Taking all of this into account, through the elimination of some of the identified dimensions, it was decided to build a model taking into account the following leadership dimensions: vision, ambidextrousness, flexibility, multi-power, and shaping the effectiveness of R&D teams.

The empirical research methods

The data for the quantitative study were collected using the CAWI technique and conducted in the autumn and winter of 2021. As part of the research procedure, a leader of an R&D team was contacted, the assumptions of the project and the research itself were presented, and a brief description of the research was sent. People who directly deal with R&D work took part in the study. The subjects were sent a link to the online questionnaire, which contained all the necessary explanations and instructions. The Qualtrix tool was used to create the survey. Each part of the questionnaire was on a separate screen, the questions for each of the variables were displayed randomly, and the system additionally mixed the order of questions within the section. In addition to a series of metric questions, the survey consisted of six sets of questions relating to the variables studied. In the research of individual differences regarding preferences and attitudes, a 5-point Likert scale was used. The created tool was tested as part of a pilot project on a group of ten people.

The questionnaire measured six variables, namely: clear vision, opening behaviours, closing behaviours, heterarchy and flexibility as independent variables, and effectiveness as a dependent variable. Most of the scales taken and adapted from the literature were used to measure the variables. Two independent experts translated individual items from English into Polish. A doctoral student developed the rest of the items based on a literature review.

The questionnaire research was planned among entities that develop R&D projects. The activities of entities were classified within the fields of, engineering and technical sciences; medical and health sciences; agricultural sciences; exact mathematical and natural sciences.

The verification of the leadership effectiveness model in R&D teams

Before proceeding with the correlation analyses, an analysis of the internal consistency of the scales used was conducted using Cronbach's alpha coefficient. The model of leadership effectiveness in R&D teams proposed in this thesis has mainly direct dependencies. During the research, all dependencies were analyzed separately, as well as the entire model of interdependencies. Then, the model was reconfigured and optimized.

In order to verify the research hypotheses H1, H3 and H4, a Rho-Sperman correlation analysis was performed. In the case of H1, the correlation showed to be statistically significant. There is a strong, positive relationship between a clear vision and effectiveness. In the case of H3, no significant correlation was found between the ability to cope with

heterarchy and the effectiveness of the R&D team. In the case of H4, the correlation proved to be statistically significant. There is a strong positive correlation between flexibility and the effectiveness of R&D teams. To test H2, a linear regression analysis was performed with the independent variables as opening and closing behaviours and the interaction between them, and the dependent variable as effectiveness. The main effect of the opening behaviour variable was marginally significant and positive, i.e., a higher level of opening behaviour is accompanied by higher team effectiveness. The main effect of closing behaviours was similarly marginally significant and positive. Most importantly, no significant interaction was observed between opening and closing behaviours. The analysis, therefore, showed that these two variables are related to effectiveness independently of each other. If the leader has a given level of opening behaviour, then the higher the level of closing behaviour, the R&D team will be more effective, and vice versa: at a given level of closing behaviours, the higher the level of the R&D team leader's behaviour the more effective the leader is.

Since the variables analyzed within the model were more strongly correlated with each other than expected, they should not be analyzed as single relationships, but rather analyzed in the context of the entire model, which includes all the moderated variables and relationships. Therefore, the assumed conceptual model was verified using regression analysis. Vision and flexibility are dominant in this model. This means that the other variables do not directly affect the effectiveness, but indirectly affect vision clarity or flexibility, or interact with each other.

The observed results do not always lead to direct conclusions, even though theoretical or practical regularity is seen. This is because a given phenomenon may be accompanied by indirect effects – mediation, and direct impact are not always present (Turek, Wojtczuk-Turek, 2015).

The dependence between the individual elements of the model finally took on a complex form of dependence, which was not anticipated by the considerations of the model at the theoretical level. The model, which was additionally developed as a result of statistical analyses, was verified for confirmation employing path modelling in the JASP programme using lavaan R procedures. Thus, the final leadership model determining the effectiveness of R&D teams is shown in Figure 1.

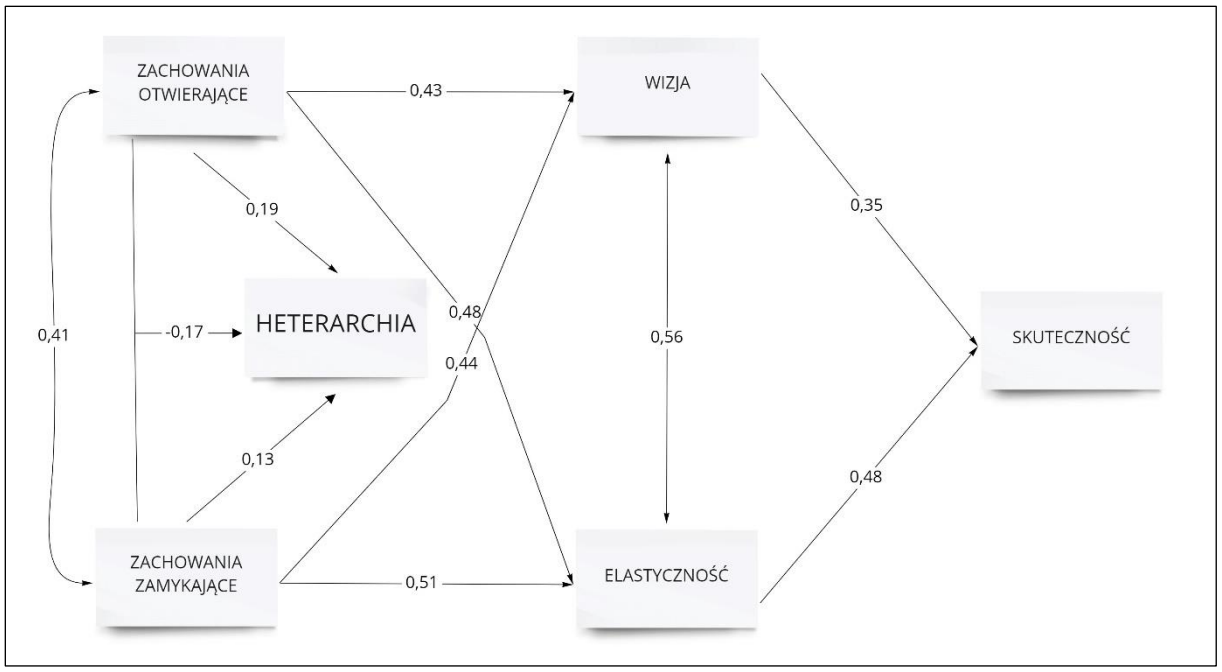

Figure 1. The final model was verified with the use of path modelling (source: own work).

In the last stage of the model analysis, the impact of indirect effects and their strength on effectiveness and in comparison, with direct effects were examined in order to be able to draw rational conclusions regarding such a complex variable as the effectiveness of leadership in R&D teams. For this purpose, mediation analysis using path analysis was used.

Conclusion

As part of the doctoral thesis, a number of theoretical and empirical analyzes were conducted. From deriving a model that determines the effectiveness of leadership in R&D teams on the basis of a systematic literature review, to its verification and optimization in the course of statistical analyses.

The overriding goal of the project was to describe the model of leadership of R&D teams determining the effectiveness of such teams. For this purpose, the behaviours of R&D team leaders from the perspectives of employees of R&D departments were studied. This thesis brings several significant findings that add value to the knowledge of the leadership of R&D teams creating technological innovations.

A complex leadership model was developed, empirically verified and optimized, which took into account all variables and relationships between them. In the direct relationships between the dependent variable (clear vision, opening behaviours, closing behaviours, flexibility) and the independent variable (effectiveness), strong positive

relationships were observed. No such relationship was observed between operating in heterarchy and effectiveness. As part of additional regression analyses, however, the relationships between opening and closing behaviours and their relationship with heterarchy were noted. In the studies (Zacher, Rosing, 2015), which were based on the theoretical model of two-handed leadership presented by Rosing et al. (2011), no interactions between opening and closing behaviours were found. Meanwhile, in the base model of two-handed leadership, Rosing et al. (2011), the researchers suggested that leader-opening behaviours moderate the relationship between a leader's closing behaviours and innovation. Conversely, leader-closing behaviours moderate the relationship between leader opening behaviours and innovation. However, it is difficult to predict *ex-ante* when it is worth exploring and when to exploit, this is why these actions should be *ad hoc*. The authors noted that the so-called time flexibility allows leaders to adapt to communication requirements and this element is essential for two-handed leadership to happen. Thus, showing the relationship between opening and closing behaviours and heterarchy in this doctoral thesis, may open further research around proving the occurrence of this moment of temporal flexibility and the switching between opening and closing communication by the leader depending on the need of the moment.

As a result of the conducted mediation analyses, it was proved that opening and closing behaviours affect the effectiveness of R&D teams, as well as flexibility and a clear vision. It was confirmed that the impact of indirect opening and closing behaviours on vision and flexibility is large and affects effectiveness. This conclusion provides the basis for continuing research for further development of the model. The use of path modelling made it possible to show, within one model, the effectiveness of leadership in R&D teams, the dependencies that have not been presented directly in research so far. These findings have a direct impact on the possibility of using this knowledge in training leaders.

The results confirmed the role of a clear leadership vision at the level of the R&D team. The results are consistent with the research of Lynn and Akgun (2001), which showed that in the case of radical innovations, it was the clarity of vision that was most closely related to the success of a new product. The vision would probably be corrected several times during a project, so it is not crucial that the vision is stable and unchanging, but that it is effectively communicated and developed in collaboration with the team.

The results partially confirmed the research hypothesis H2. The leaders who engage in opening and closing behaviours influence the behaviour of their employees in ways that are consistent with their (opening or closing) behaviours. On the one hand, a leader's opening behaviours create a psychologically safe environment that is essential for exploring and

broadening perspectives. On the other hand, closing behaviours focus employees' attention on achieving goals, feedback and lessons learnt – exploitation. The conclusion regarding the importance of opening and closing behaviours for the effectiveness of R&D teams is very interesting as it provides many new opportunities related to the education of future leaders at the universal level, as a basis for further development, already in specific companies with their specificity and the necessary strategic approach. In addition, the level of opening and closing behaviours also seems to be a good preparation for working on the flexibility of the leader, as well as for working in dynamic R&D teams, in general.

In the case of H3, no significant relationship was found between heterarchy and the effectiveness of R&D teams, so the data obtained did not confirm the assumed hypothesis.

In the case of the research hypothesis H4, the correlation showed to be statistically significant, and the results confirmed the hypothesis. A leader is expected to be able to react appropriately to a given situation. When team members need to increase creativity and start generating ideas, leaders' locking behaviours can hinder exploration. In other situations where efficiency and conscientiousness are required, a leader's closing behaviour may benefit the innovation process. It is the ability to flexibly switch between, and be comfortable in, different roles of opening and closing by the leader that is crucial for ambidextrous leadership and the effectiveness of innovation processes. Flexibility means that when the internal or external environment changes, the team leader reacts quickly to deal with the change and then returns to its original stability.

Additional information was provided by the answers to the research questions. Firstly, the leader's ability to function in a heterarchy (dependent variable – heterarchy) differs significantly, depending on the types of R&D teams (independent variables). The leaders of R&D teams at universities and research institutes are perceived as less able to function in a heterarchical than leaders of R&D teams in technology companies.

Secondly, in terms of the field in which the R&D team conducts research, a weak statistically significant effect was obtained only in the case of the variable heterarchy. This means that the leader's ability to function in a heterarchy (dependent variable – heterarchy) differs significantly depending on the field in which the research is conducted (independent variables). The leaders of teams working in medical and health sciences are perceived as able to function better in a heterarchy than leaders of teams working in engineering and technical sciences. No significant differences were observed in the remaining cases.

Thirdly, depending on the seniority of the respondents, a statistically significant effect was obtained only in the case of the variable heterarchy. This means that the leader's ability to

function in a heterarchy (dependent variable – heterarchy) significantly differs depending on the seniority of the respondents (independent variables). The people with the shortest experience <= 2 years perceive leaders as performing worse in a heterarchy than people with more than four years of experience. No differences were observed in the remaining cases.

Finally, no significant differences were observed in relation to the variable position of the R&D leader in the structure of the surveyed organizations.

Research limitations

In the course of the research, limitations were identified, some of which are intrinsic to the research methods used and the techniques of data collection and analysis, such as the subjectivity of the respondents, and also the result of the difficulties in accessing the surveyed organizations and their participants (additionally aggravated by the impact of the pandemic, during which empirical research was conducted). Efforts were made to minimize these limitations, ensuring anonymity, using validated scales, triangulating respondents and being cautious in analyzing the obtained research results. Some of the limitations, e.g., related to the size of the research sample, also set directions for further research on the impact of leadership on the effectiveness of R&D teams.

The directions for future research

The results indicated the potential future research directions in the area of the impact of leadership on the effectiveness of R&D teams, namely:

1) Verification of the proposed leadership model for various types of R&D teams.
2) In-depth analysis of the impact of the leader's skills in a heterarchy on the effectiveness of the R&D team based on the newly designed measurement scale.
3) Extending the research internationally.
4) Extending the research to other types of teams: ICT, as well as research groups.
5) Further qualitative research.
6) Designing, testing and implementing a development programme for R&D project leaders.

The recommendations of managerial practice

Implementing innovative solutions on the market means very dynamic work of R&D teams, under pressure and interdisciplinary collaboration within the organization, as well as in contact with project partners or organizations supporting financing the development of innovation. At the same time, the subject of leadership in innovation and work with R&D teams is not sufficiently taken into consideration in the curricula of technical universities.

As part of the work, the leadership model was developed in which five variables are strongly correlated with each other (clear vision, flexibility, closing behaviours, opening behaviours and flexibility). Of all the analyzed variables, the strongest predictors of R&D team effectiveness are the ability to formulate a clear vision and the team leader's flexibility. Other variables in the model indirectly affect effectiveness through a clear vision or flexibility.

This thesis emphasizes the role of psychological aspects and leader behaviour in the context of influencing the team and influencing the effectiveness of the team. This knowledge is not taught at technical universities. R&D teams operate in the project reality and in this matter, students primarily receive knowledge about selected project management methodologies, but there is a lack of knowledge about behaviour, relationships, leadership or team development. When formulating these managerial guidelines, it is worth paying attention to the aspect of developing the indicated competencies as part of organizational behaviour. Improving the skills of opening behaviours, fostering solutions-oriented behaviours and closing behaviours, and synthesizing the acquired knowledge is a springboard for further skills development. And these issues can be developed at a general level, as part of open training or as ordered dedicated training for an individual or a team. It is much easier to teach people to formulate opening and closing messages in response to specific situations than the skills to formulate a clear vision or flexibility, which in the described model had the strongest and most direct impact on the effectiveness of the R&D team. Therefore, another recommendation is the continuous development of leadership skills and the inclusion of topics related to the ability to define and communicate visions as well as flexibility in contact with the very dynamic and changeable reality of innovative projects.

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