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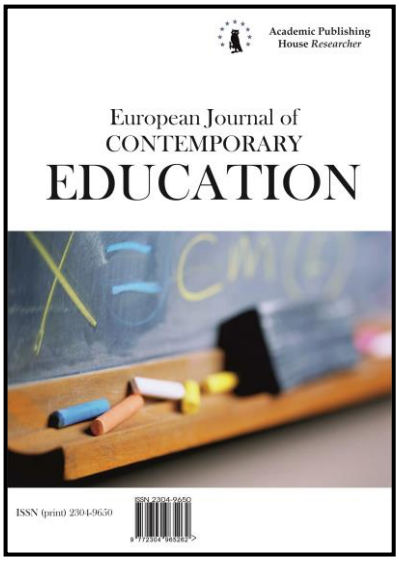

Firms' Problem-Oriented Student Theses as an Innovative Method of Teaching and Knowledge Transfer from Universities to Industry

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Abstract

The objective of this paper is to explore the role of student theses developed in response to specific firms' problems under the supervision of university teachers as an innovative teaching method with a high level of personal engagement. The paper presents the results of research based on 150 interviews conducted in Krakow with team members engaged in preparation of student theses (each consisting of a university teacher, a master or bachelor student, and a company representative). The statistical analysis is based mainly on the Regression Tree Method and Spearman correlation coefficient. The interview-based research among key actors involved in preparation of firms' problem-oriented student theses confirmed the high effectiveness of this method of knowledge transfer from universities to industry. Thesis knowledge generated in this process brings positive effects to firms, university supervisors and students. Along with an increase in the assessment of practical skills obtained by students, the assessment of the suitability of work for the enterprise increases. Also as the satisfaction rating for cooperation increases, the benefit rating in the form of closer contacts with companies also increases. Satisfying results of university–industry relations obtained through the process of applied thesis preparation could be achieved if different kinds of stimulation types were implemented. On the side of the university, there should be incentives dedicated to the institutional level as well as tools dedicated to individual researchers. Studies have shown high usability of problem-oriented student theses. All parties to this process recognize significant benefits, which confirms that this type of collaboration is a WIN-WIN situation.

Keywords: creativity, higher education, entrepreneurship, knowledge transfer.

1. Introduction

Innovation is non-standard solution developed as a trial and error process. Universities create a space in which such processes can be realised internally or through interactions with external partners. In this paper we try to explore an innovative method by which students prepare

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final year theses that are oriented to solving firms' real-world problems. Flows of value within problem-oriented student theses are analysed. We refer to knowledge generated in this process as thesis knowledge; it enables transfer of academic knowledge from a university to a firm, delivers information to academics about the current technological capacity of industry and its preferred fields of implementable research, and makes teaching processes more oriented to innovation.

We analysed the benefits that students gain from working on firms' problem-oriented theses. Direct interpersonal relations are a key value of such cooperation, while cognitive and relational social capital is treated as an important asset in this aspect (Steinmo, 2015). Supervision of firms' problem-oriented student theses requires much more time and engagement from academics than is the case for more theoretical theses. We present the results of questionnaire-based research among 150 respondents from teams consisting of university teachers, students, and representatives of firms in Krakow for which theses were prepared. We especially analyse students' opinions on extending their own skills/knowledge within different areas related to realizing applied theses, as well as views from the perspectives of their supervisors.

Thesis knowledge: benefits for universities and industry

The formalised character of the preparation of students' theses, which complete certain stages of their academic education, covers incentives for engagement in this process both for them and for academics who act as supervisors. Working on real problems defined by firms' managers make this process more attractive and offers several positive effects for all engaged actors. Knowledge generated as part of this process can be referred to as 'thesis knowledge' and flows both ways between companies and universities. Academic knowledge is transferred from universities to firms, while firms provide information to academics about current technological capacity and preferred fields of implementable research. Students have an opportunity to gain work experience and are more attractive to firms as employees than staff recruited in a more traditional way. They can also develop a project realised in the form of a thesis which can be supported by the academic knowledge of their supervisors and university laboratories.

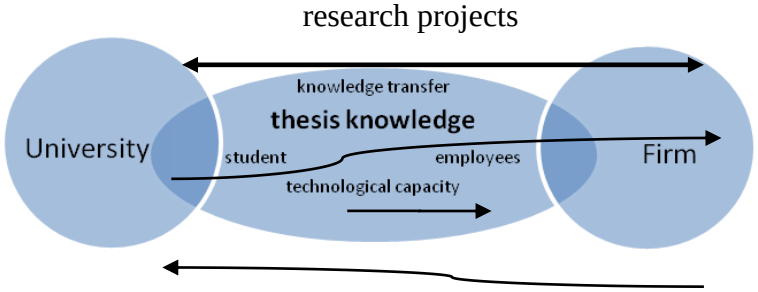

Fig. 1. Flows of value within firms' problem-oriented student theses
Source: own elaboration

Even if the problem undertaken by the student is not solved to a satisfactory standard from the firms' management point of view, they have the opportunity to verify the student's potential usefulness in the organisation, thus minimising recruitment costs and increasing the probability of finding good employees. A qualitative analysis of Scottish technology-based firms revealed that many small units encounter growth constraints in relation to recruitment (Coad, Reid, 2012). Participation in the process of student thesis creation could partly solve this problem and offers an opportunity to establish direct personal relations between company managers and academics. Student theses prepared in co-operation with firms enable the accumulated potential of universities to be exploited. Due to the

probability of finding commercially effective solutions through the process of thesis preparation, costs of education are reduced from the point of view of society as a whole. When new technology is developed in such a process as a result of long-term co-operation (usually 1–5 years), less time is needed for the student who developed it to implement it in practice.

One problem with knowledge transfer from universities to industry is related to overestimating the value of technology developed by public research institutions and the problem of finding venture capital (Clarysse et al., 2007). Even with the low required level of funding, student thesis programs dedicated to firms can not only develop new technologies or improve existing ones, but also encourage future transfer of technologies from universities to business. *Chandraseakaran et al. (2015) point out that collaboration with universities brings industry* an increased recruitment rate of graduates and promotes their brand name as a desired workplace.

The quality of research done at universities determines its utility for industry, which is always looking for world leaders (Mansfield, Lee, 1996). Another determinant of the attractiveness of universities to industry is the critical mass of researchers and equipment (Mansfield, 1995). There is no one universal set of industry preferences regarding the optimal university as a source of innovation; for example, pharmaceutical and chemical firms prefer to locate their R&D units in places with a high density of highly regarded university departments, while others choose regions where relatively low-ranked departments are concentrated (Abramovsky et al., 2007).

Universities have positive impact on economic development (Fotea, Gutu, 2016; Sarkar, Perényi, 2017). Pettigrew (2001) points out that minimal engagement between researchers and practitioners regarding dissemination of their research is not enough because the wrong questions can be asked. Therefore industry–university relations should also be treated as a source of real problems which could be solved by academics. There is an open question as to how many students should be engaged in 'applied theses'. Interdisciplinary teams of students working on real problems. Higher engagement of students in firms' problem-oriented theses could increase the most effective indicators of probable success in student research, as identified by Shaw et al. (2013): research self-efficacy, approach to learning, familiarity with the research environment and positive attitude to research. As attitude towards entrepreneurship determine the entrepreneurial intentions (Wach, Wojciechowski, 2016) student theses developed in response to specific firms' problems can make entrepreneurship more attractive for them.

Benefits for students when working on problem-oriented theses for firms

The motivation of students is increased by working on theses oriented to solving real problems in firms. This also supports their multi-faceted engagement, which, according to Bryson and Hand (2007), plays a key role in inspiring teaching and learning. Students get a chance to use production infrastructure in firms and learn not only about the current technological processes used there, but also can conduct experiments in university laboratories. Higher student engagement in the process of thesis creation is related to interactions with firms, which could also reduce burnout. As shown by the research of Robins et al. (2018), burnout indicators in all dimensions were higher in study than in work. Research among undergraduate students showed that those who reported having acquired skills from interaction with supervisors were significantly more satisfied (Del Río et al., 2018). Research by Jamieson and Gray (2006) showed that most student respondents did not want to discuss their expectations with supervisors. Cooperation with firms or other institutions gives students an opportunity to be engaged in participatory research which should not only be followed by action, but also "it is action which is researched, changed and re-researched within the research process by participants" (Wadsworth 1998: 9). This special kind of action research is attractive for students who are particularly problem or solution oriented. It allows the effectiveness of action research to be verified, as noticed by Hughes et al.: "the key test of validity for action research is not whether research procedures conform to rules established by academics and professional researchers, but whether the knowledge works in practice" (2004, p. 9). There is no better opportunity to verify learned knowledge than by applying it to a real-life problem and receiving feedback from experienced users. Even if a student's proposal in a practical thesis is not implemented by a firm or other institution, the student benefits from a very deep negative case analysis, which is one of the key points in the process of action learning (Smith, 2017). The proposed model of a student's thesis creation process should also reduce at least four out of the six problem categories identified by Hansen and Hansson (2017): inability to apply

research methods, inability to self-study, lack of creativity and lack of motivation. An applied thesis will also support evaluation of students' work in the context of creativity, where 'producing something' is among the six elements of student activity in this field (Jahnke et al., 2017).

Solving firms' problems is also an effective way of engaging this group of stakeholders in the developing of skills expected of graduates and valuable in the labour market. In students' opinions (Jorre, Oliver, 2018), the role of employers in defining the learning outcomes of courses should be broader as this would improve graduates' employment prospects. Direct contact with firms, with students going beyond formal practice and being treated as partners who could increase competitiveness is important for their future employment, especially as a few students engage with the placement opportunities offered by universities' career services (Rae, 2007). Although the impact of technology-based classrooms on students grades is not confirmed (Nicol et al., 2018), cooperation with firms during thesis preparation could compensate for the lack of laboratory equipment at universities. It also supports development of creativity which is however difficult to measure (Ramankulov et. al., 2019).

Threats, benefits, and incentives for students' thesis supervisors

Direct contact with industry related to student thesis supervision oriented to solving practical, technological problems is time consuming, not only due to the costs of establishing and maintaining such relations. Also, awareness that students' work will potentially be used in practice increases psychological pressure on supervisors to control it more than if it were just an academic exercise. Furthermore, such engagement could be perceived as a limitation of pure academic freedom, which is often treated as an opportunity to perform long-term research which is often in conflict with research focused on a pragmatic purpose. Chandrasekaran et al. (2015) point out a number of threats for academics related to university–industry interactions, including loss of academic freedom, long-term research, and academic integrity, stressing that academic research focuses on long-term challenges rather than the time-sensitive product development projects that are typical of industry.

Auranen and Nieminen (2010) point out that systems of university financing based on input measures have higher levels of stability compared to those with output-oriented measures. Probably, higher stability of flow of financial resources supports the engagement of students' supervisors in accepting firm-oriented theses.

2. Materials and methods

Testing period 2017.04.03–2018.03.01. 400 emails were sent to students' thesis supervisors at 5 universities in Krakow (Cracow University of Economics, AGH University of Science and Technology, Cracow University of Technology, University of Agriculture in Krakow and The Faculty of Industrial Design at The Academy of Fine Arts) asking for interviews in cases of a supervised thesis being oriented to solving a firm's problems. In effect, 62 positive answers were received, and 150 interviews were conducted by the end of February 2018 with members of teams consisting of a university teacher, a student and a representative of the company for which each thesis was developed (24 in the field of technology, 16 in industrial design, 7 in economics and 3 in agriculture). Questionnaire-based interviews were performed by groups of students coordinated by us. Interviews covered 9 engineering thesis, 15 bachelor and 26 master thesis. 20 thesis supervisors had a PhD title, 27 were associate professors, and 3 were full professors. In the Polish higher education system, student theses are prepared over a period of 1 to 3 semesters; they require a structured written form, are reviewed by an external reviewer, and are formally defended. Most of the interviews are available in Polish on-line at www.innowacyjnystart.pl, which is a regional platform dedicated to innovation policy (some of the respondents' statements from these interviews are quoted in this paper). The statistical analysis presented below is based mainly on the Regression Tree Method (Breiman et al., 1984) and Spearman correlation coefficient.

3. Results

Opinions of students, their thesis supervisors and firms' representatives regarding applied theses

Students' opinions

Students were generally very satisfied with possibility of realizing their thesis for selected firms. The average rating was 4,52 (in 5 point scale, where 5 means very satisfied and 1 very unsatisfied) and only two of them gave mark lower than 4). One of the explanations for this could

be the practical dimension of theses in the context of future employment: "Students feel that theoretical work does not translate in any way into their further professional career. Therefore, most often, if think about future work in industry, they are looking for a technological practice as part of a master's thesis or engineering." (K. Lalik, AGH University of Science and Technology, October 30, 2017).

Contact with firms gave students rather positive image of them because 4/5 of them declared interest in finding employment in units for which their theses were realized. The initiative of preparing applied theses in almost half cases was in the students' hands while firms played such a role in over 1/3 of them. University initiative in this field was only in 6 cases which could be connected with lack of incentives for such activities within innovation policy.

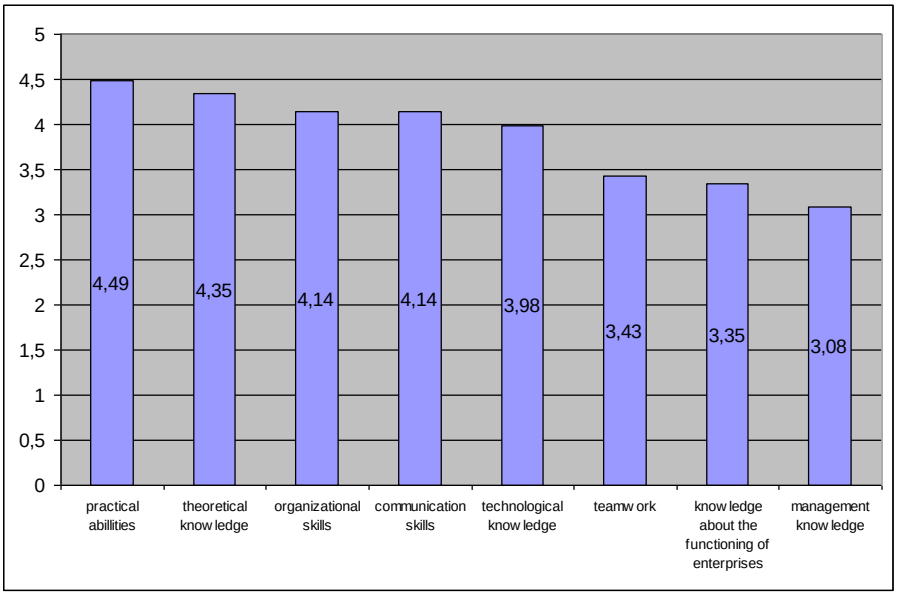

Fig. 2. Students' opinions on extending own skills/knowledge within different areas related to realizing applied theses (in 5 point scale, where 5 means in very high degree and 1 in very low degree), n=50
Source: own elaboration

The highest level of extending own skills/knowledge among students regarded practical abilities (the average score 4,49 in 5 point scale, where 5 means in very high degree and 1 in very low degree) and theoretical knowledge (4,35). The important dimension of practical knowledge is the possibility to verify proposed solutions: "Thanks to the work on this project, I learned that contact with the end user is the most important. It can not be replaced by anything else." (P. Morawa, Faculty of Industrial Design, September 4, 2017).

High average scores over 4 points were given to organizational skills (4,14) and communication skills (4,14). A relatively low score was given to skills within teamwork (3,43) which is partly connected with the fact that individual work of students dominated (42 from 50) while only three were working in pairs, three in three persons teams and two in four persons teams. Also, almost 2/3 of students (34) declared that such theses should be realized in bigger teams. The lowest score was given to increase of management knowledge (3,08). Students declare that supervision of applied theses required high engagement from university teachers but that they also formulated skepticism regarding their common interest in working with students in this formula: "A large part of professors, on the other hand, simply do not want to participate in such endeavors, because it requires them to have their own involvement, and not just a signature in the right place." (J. Marcinowski, Cracow University of Technology, September 1, 2017).

Following hypothesis was verified

H1: There is a relationship between the declared degree of extension of student skills within individual competences and the level of suitability of work for the company.

The verification of this hypothesis was carried out using the Shapiro Wilk test however due to the distribution of all variables significantly different from normal ($p < 0.05$), the Spearman correlation coefficient was used.

Table 1. Benefits for students versus usefulness of applied theses for firms – Spearman correlation coefficient

Benefits for students		usefulness of applied theses for firms
Student – theoretical knowledge	*rho*	-0,037
	p	0,820
	N	40
Student – organizational skills	*rho*	0,028
	p	0,863
	N	40
Student – teamwork	*rho*	-0,136
	p	0,404
	N	40
Student – practical skills	*rho*	0,378
	p	0,016
	N	40
Student – knowledge about the functioning of enterprises	*rho*	-0,068
	p	0,676
	N	40
Student – technological knowledge	*rho*	0,058
	p	0,722
	N	40
Student – management knowledge	*rho*	0,086
	p	0,599
	N	40
Student – communication skills	*rho*	-0,004
	p	0,982
	N	40

rho – Spearman correlation coefficient; *p* – statistical significance, *N* – number;
* $p < 0,05$; ** $p < 0,01$; *** $p < 0,001$
Source: own elaboration.

There was a statistically significant correlation (rho = 0.38; p <0.05) between the assessment in the scope of extending practical skills and the assessment of the usefulness of work for the enterprise; the correlation was moderately strong as evidenced by the rho <= 0.5; it was a positive correlation, which means that along with an increase in the assessment of practical skills obtained, the assessment of the suitability of work for the enterprise increases. The hypothesis should be adopted only in this respect.

Supervisors' opinions

Orientation for real problem solution in supervisors' opinion increases the level of student engagement I the process of thesis preparation compared to standard types theses. In 3/5 cases they described students engagement as much higher than in standard thesis preparation, in 1/10 cases slightly higher and in the rest the same as regular theses, but never lower. Supervisors underline interest of students in the realization of applied theses and think that work for firms is valuable for both sides.

The level of student engagement in preparation of applied theses could be stronger if they work part time at the firm during the last year of study: "It is in such cases, when they work in a given company, that students usually go out with the initiative of writing this type of work. Such works are more interesting, they give a specific added value. Frankly, as a promoter, I love them, because then students write them more dynamically and with greater commitment." (A. Boratyńska-Sala, Cracow University of Technology, June 28, 2017).

Analysis of supervisor opinion about benefits obtained from realization of applied theses showed that the most important was better preparation of the student for professional work (average score 4,20 in 5 point scale, where 5 means very high benefits and 1 very low). In second place of importance was strengthening contact with the company (3,49) and better knowledge of the company's current technological capabilities (3,45). Supervisors know the value of student work for firms: "I have a feeling that we are doing something that has practical justification. The company is certainly very happy, because it would never be able to build such a laboratory even for reasons of costs, but also because of experience." (M. Jaszczur, AGH University of Science and Technology, September 1, 2017).

In last place was increase in university income due to cooperation with the company (only 1,37) which shows that procedural solutions in this field are necessary. Despite this, supervisors treat applied theses as a win-win situation: "I used to look for a losing side and only the one who does not participate in it loses." (K. Lalik, AGH University of Science and Technology, October 30, 2017).

Thesis supervisors do not see almost any form of appreciation of their activity connected with applied thesis from universities (only two of them from AGH University of Science and Technology declared that it was appreciated in the form of rector's award for didactic achievements). Supervisors know that much more important is the process of applied thesis creation that achieved solutions or products: "There is no easy way: order - work - implementation. As a rule, the student prepares several concepts that are later verified by the company in terms of financial, legal and production capacity." (M. Liskiewicz, Faculty of Industrial Design, September 6, 2017).

Following hypothesis was verified

H2: There is a relationship between the degree of entrepreneur satisfaction with cooperation with the university and the degree of benefits achieved by the university from the implementation of student work for companies.

Table 2. Supervisors opinion versus degree of entrepreneur satisfaction with cooperation with the university – Spearman correlation coefficient

		Degree of entrepreneur satisfaction with cooperation with the university
Supervisor – strengthening contacts with companies	*rho*	0,360
	p	0,026
	N	38
Supervisor – increase of university income from cooperation with companies	*rho*	-0,004
	p	0,982
	N	38
Supervisor – better knowledge of current technological capabilities of companies	*rho*	0,202
	p	0,223
	N	38
Supervisor – better preparation of students for professional work	*rho*	0,092
	p	0,584
	N	38

rho – Spearman correlation coefficient; *p* – statistical significance, *N* – number;
* $p < 0,05$; ** $p < 0,01$; *** $p < 0,001$
Source: own elaboration.

There was a statistically significant correlation (rho = 0.36; $p < 0.05$) between the degree of employer satisfaction with cooperation with the university and the degree of achievement by the university of benefits in the form of closer contacts with companies; the correlation was moderately strong as evidenced by the rho <= 0.5; it was a positive correlation, which means that as the satisfaction rating for cooperation increases, the benefit rating in the form of closer contacts with companies increases. The hypothesis should be adopted only in this respect.

Firm's representatives opinions

The average score of usefulness of students' theses for enterprise was 4,02 (in 5 point scale, where 5 means very high and 1 very low). Also according to firms' representatives, the possibility of implementation received the same high score. The level of innovation of proposed solutions was estimated a little bit lower (average score 3,93). Students engagement in work was estimated as very high (average score 4,73). Every four firms out of ten has previous experience in cooperation with universities. All of them except one declared that it was positive. An important aspect of students' roles in firms were the non-standard ideas formulated by them, as people with external perspective: "Cooperation with the student is always interesting and satisfying. Young people know and can use the modern management model and add freshness to the organization. It must be emphasized that the cooperation between our company and the student was great" (B. Bajor, Bajo, June 22, 2017).

Entrepreneurs declared high hopes that projects implemented for them within students theses, but prepared by a team of representatives of different fields of study related to the issue, will be useful for the firm (the average score was 4,2 (in in 5 point scale, where 5 means very high usefulness and 1 very low). The level of satisfaction of contact with universities was generally high (average sore 4,34 in in 5 point scale, where 5 means very high level of satisfaction and 1 lack of satisfaction). In one case they really see the uniqueness of a product developed in this way, although it is a niche one: "In the case of the BCS 622 bundle, the biggest reward for me is that it is the only such machine in Europe." (B. Burkiewicz, Agro – Partner, September 22, 2017).

Entrepreneurs understand the role of individual engagement in project realization: "On the one hand, what counts for us is the innovation and the chances of the project for commercialization, on the other hand the team of people behind the given project is very important. Without determined people who know what they want to achieve, even the best idea has little chance of success" (S. Gruszka, Wolf Group, September 11, 2017).

Determinants of usefulness, innovation and possibility of implementation of applied theses for firms

Independent variables used in the regression tree models are: type of students thesis, number of students involved, type of university, supervisor's academic degree, previous experience of firm with university and thesis writing initiative. Dependent variables are usefulness of thesis for the enterprise, innovation level of proposed solution and possibility of its implementation.

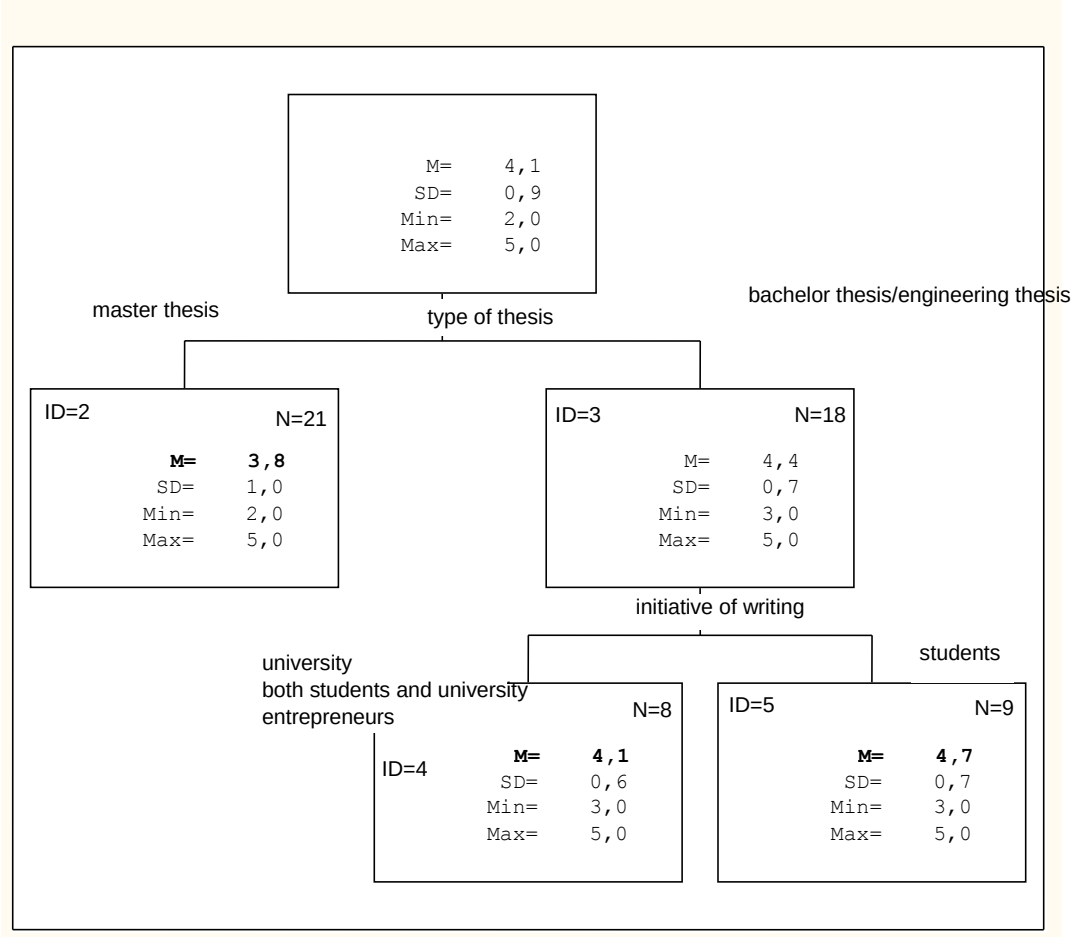

Fig. 3. Chart regression tree model: usefulness of thesis for the enterprise (dependent variable)
Source: own elaboration

Figure 3 presents regression tree model where the dependent variable is usefulness of student's thesis for the enterprise. If writing of applied thesis (bachelor or engineer) was initiated only by students its usefulness for enterprise in 5 point scales is 4,7 (9 thesis, ID5) while in other cases only 4,1 (ID4). Master's theses also received weaker marks compared to others in the aforementioned scale (3,8, ID3).

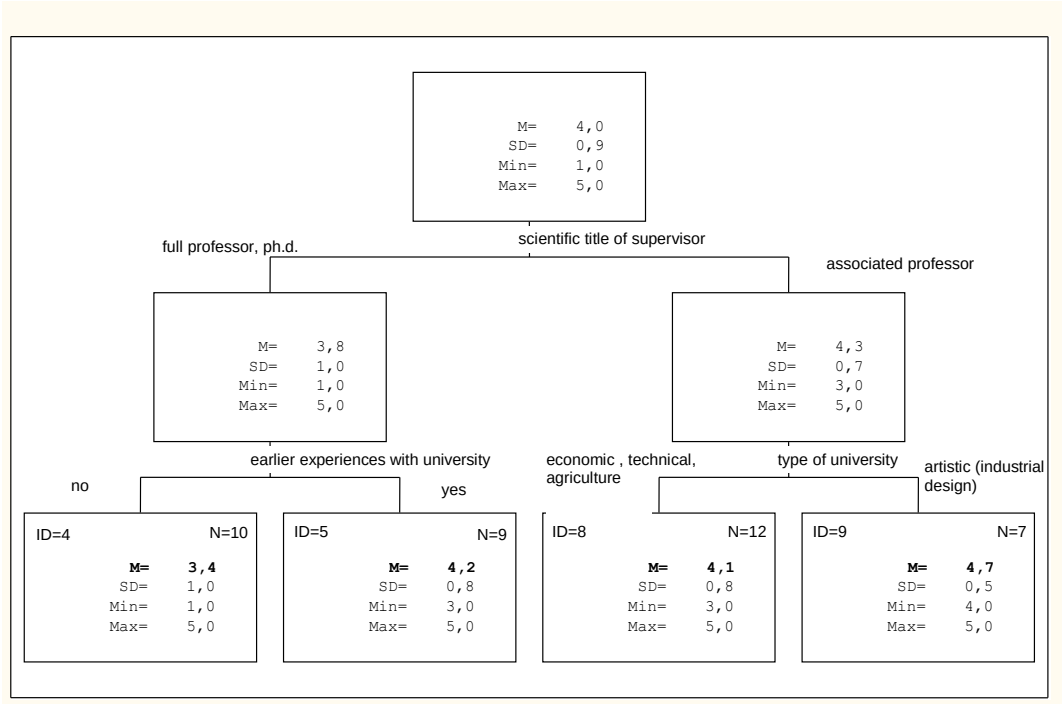

Fig. 4. Chart regression tree model: level of innovativeness in opinion of firms representatives (dependent variable)
Source: own elaboration

If the theses were supervised by full professor or Ph.D. and firms has not had earlier experience with university, the level of innovativeness of applied theses was ranked as 3,4 in 5 points scale (ID4). In case of the same group of supervisors and earlier contact of firms with university, the level of innovativeness was ranked as 4,2. Theses supervised by associated professors were evaluated as much more innovative in the opinion of firms' representatives (mark 4,3) compared to theses supervised by full professors or Ph.D. (3,8). The possible explanation could be that supervisors with a Ph.D. have not had enough experience and full professors have limited time to engage in co-operation process with firms. If the theses were supervised by associated professors from an artistic university (Faculty of Industrial Design) its average innovativeness was ranked as high as 4,7.

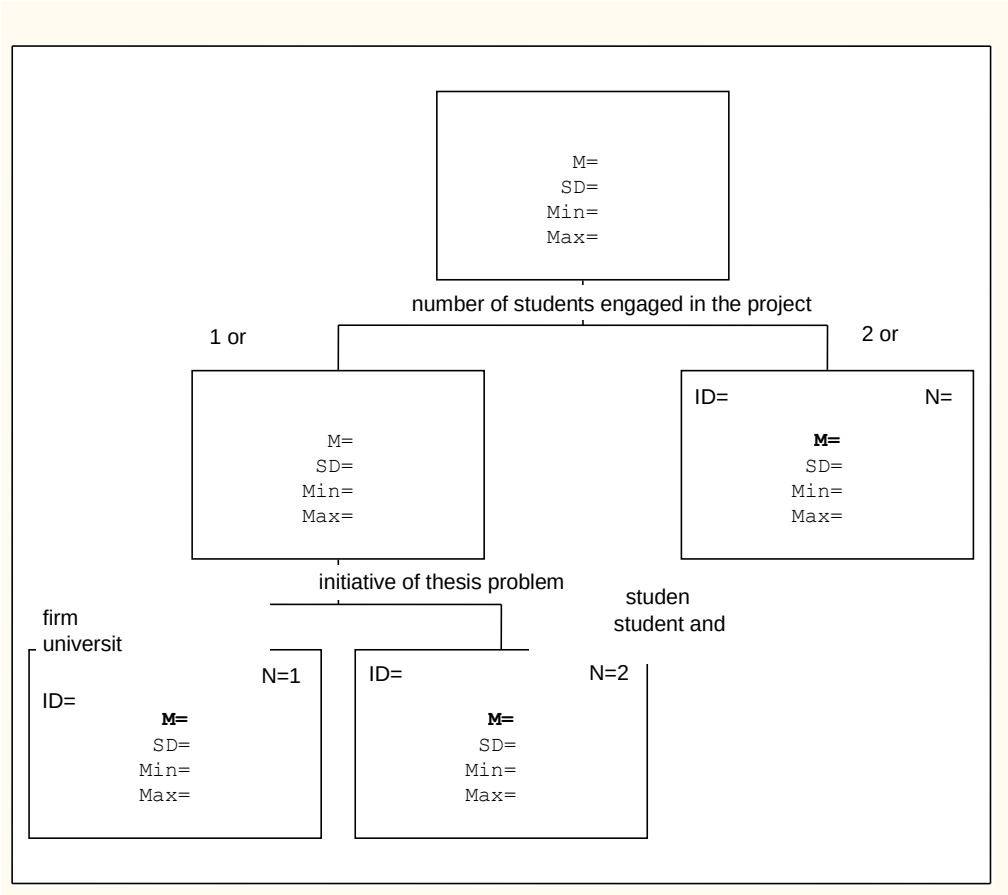

Fig. 5. Chart regression tree model: possibility of thesis implementation from the perspective of firm representatives (dependent variable)
Source: own elaboration

The possibility of students' thesis proposals being implemented in firms in the case when 2 or 3 of them were engaged in the project is higher (average mark 4,8) than when it was 1 student or 4 of them. It shows that both individual work and work in bigger groups is not as effective as in case of 2-3 person teams. In cases where it was 1 or 4 students and the initiative of choosing thesis topic was initiated by students or both from students and entrepreneurship, the mark is much higher (average mark 4,4) than in case when it was an initiative of the firm or university. It confirms that students' motivation plays a critical role in determining the possibility of implementing the solutions proposed and developed in theses.

4. Discussion

Preparation of theses dedicated to solving selected firms' problems is appreciated by students. Most important for them in the context of extending their own skills/knowledge was improving their practical abilities as they feel that this is important for their future career development. Firms for which theses were prepared are also seen by students as desirable workplaces. Applied student theses could support firms in resolving identified problems of growth constraints in relation to recruitment (Coad, Reid, 2012). These companies gain an opportunity to employ creative workers with basic knowledge of the firm's problems. This system of applied theses strengthens contact between industry and universities in a natural way and could increase the role of employers in defining course learning outcomes (Jorre, Oliver, 2018). The high level of satisfaction of the interviewed company managers within the process of problem-based thesis creation confirmed that industry–university collaboration is a WIN–WIN situation (Chandraseakaran et al., 2015). The research showed that the level of engagement of student thesis supervisors who work to solve specific firms' problems is much higher than in other cases. Because higher interaction with supervisors is positively evaluated by students (Del Río et al., 2018), this process of thesis preparation increases their general satisfaction with their studies.

Even if as a result of thesis preparation there are no positive findings that can be applied in firms, students receive a chance to undertake deep negative case analysis, which is treated as a key point in the process of action learning (Smith, 2017). The research showed that students' own motivation has a crucial impact on the usefulness of proposed solutions in theses from the perspectives of firms. Academics feel almost no support or gratitude for their supervision of students' applied theses. Because it is much more time consuming than in the case of more theoretical thesis supervision, wider implementation of the proposed model requires changes in university remuneration policy.

5. Conclusion

The interview-based research among key actors involved in preparation of firms' problem-oriented student theses confirmed the high effectiveness of this method of knowledge transfer from universities to industry. Thesis knowledge generated in this process brings positive effects to firms, university supervisors and students, making it a win-win process for all stakeholders. Along with an increase in the assessment of practical skills obtained by students, the assessment of the suitability of work for the enterprise increases. As the satisfaction rating for cooperation increases, the benefit rating in the form of closer contacts with companies also increases. Still, as noticed by Agasisti and Catalano (2006), universities rely on the number of enrolled students as the main factor determining access to public funds. The introduction of a formula of remuneration for activity in the field of real firm/institution problem-oriented students' theses could stimulate higher impact of universities (or students) in socio-economic development.

Satisfying results of university–industry relations obtained through the process of applied thesis preparation could be achieved if different kinds of stimulation types were implemented. On the side of the university, there should be incentives dedicated to the institutional level (for example, governmental or regional subsidies for those who have a certain percentage of theses oriented to solving specific real-world problems) as well as tools dedicated to individual researchers. This last category could include both financial rewards and formal conditions related to a minimal share of supervised theses realised for real-world needs.

The research results relate to theses indicated by thesis supervisors. Supervisors might prefer cases which, in their opinion, are more likely to achieve positive results or success. In fact, the system of applied theses might be not as positive as presented here. It could be interesting to choose a group of cases which did not produce positive results, not because an applicable solution was not found, but rather when the thesis could not be continued because of conflicts in relations or other obstacles. It could also be interesting to verify whether the writing of applied theses supports students' future career development.

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