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Technology transfer between universities and companies: two cases of Brazilian universities

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Abstract

Universities have a history based on the contribution to the advancement of knowledge and technology on the economic and social context of a country, through teaching, research and extension courses. The knowledge developed by students and researchers can lead to the interaction within different entities, including the government and companies, resulting in a technology transfer from the university to the market. Technology transfer can be considered a process which starts by the disclosure of an invention followed by its patent registration, licensing, commercial use of the licensed technology, and, finally, royalties received by the university. This article researched how technology transfer occurs, based on the Schumpeterian approach to innovation trilogy focusing on the interaction between the university and the company. The methodology used for this study was the analysis of two cases with exploratory and qualitative approach. The case study subjects were two Brazilian universities: University of Campinas (UNICAMP) and University of Vale do Rio dos Sinos (UNISINOS). Semi-structured interviews were employed as the data collection technique, while content analysis was used as the analysis technique. The main results showed the need of companies and universities to understand that working in collaborative technology research contributes to the transformation of applied research into technological innovations that can transform society.

Keywords: Case study; Innovation; University–industry interaction; Technology transfer; Brazilian universities

Introduction

The interaction between universities and companies arise from the need of the productive sector to develop a new technology, product or process, or even when there is an adequately mature invention to be transferred from the university to the company, which is one of the ways interaction may occur (Sankat, Pun, & Motilal, 2007).

Technological innovation depends on in-depth and specific knowledge. Thus, the university's role is important so that the invention reaches the industry fully developed and ready to be produced. Technology transfer, included in the technological diffusion referenced by Schumpeter in the innovation trilogy (invention, innovation and diffusion), can be seen as a simple exchange, a technique transfer, or even a change of ownership; however it is called process, which is an important definition to guide some concepts (Garnica, 2007).

Technology transfer (TT) may be explained as a process in which all the involved parties share information, knowledge, costs and benefits. According to Sankat et al. (2007), a transfer process consists of invention, patent, licensing, commercial use and, finally, receiving the royalties.

This article's main objective is to investigate how the technology transfer and the interaction between universities and companies happens in the cases analyzed.

In order to achieve this purpose, the methodology used was the descriptive qualitative research based on the analysis of two cases. The case subjects were: University of Campinas (UNICAMP) and University of Vale do Rio dos Sinos (UNISINOS). UNISINOS was invited to participate in this research

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since it has more than 20 patent applications on the Brazilian National Institute of Industrial Property (INPI) as well as a science and technology campus, technology transfer offices, business incubators, fundamentally there is a structure prepared for the university–industry interaction.

Between 2009 and 2015, UNICAMP was responsible for 450 national patent applications and 99 international patent applications via the Patent Cooperation Treaty (PCT). UNICAMP is a reference in Brazil with respect to technology transfer, with 125 licensing agreements in 2015, which justifies its importance to take part in this research (UNICAMP, 2016).

With this research, we were able to conclude that the university–industry interaction, in the cases studied, is in process of improvement, and needs to advance on organizational aspects. It is necessary that all of the investments return as new products, services and technologies that have a local, regional, national and even international impact, through the implementation of new types of businesses, new markets, thereby generating an economic impact to the country, namely, innovation.

This article's theoretical framework is guided by the university–industry interaction and by the Schumpeterian Trilogy, defined by invention, innovation and diffusion. This section is followed by methodology, data presentation and analysis, and, finally, final remarks.

Theoretical framework

University–industry interaction

University–industry interaction starts when the production sector needs new technology or even when the scientific sector produces or generates new knowledge with practical applications. In this context, the interaction between these entities emerges for the advancement of technological innovation (Sankat et al., 2007).

Technological innovation depends on a deeper scientific knowledge, which is the reason why the university–industry interaction is one of the most reliable alternatives. With this interaction, it is possible to build a link between the knowledge generated at the university and the practice as well as the marketing experience of the organizations – a partnership that can modernize a country's industrial park (Sankat et al., 2007).

According to Carayol (2003), formal interactions demand efforts from each of the parties in order to make the process work, since the involved ones have their own priorities and investments. Thus, the relationship will only be interesting for the parties if it brings them more advantages than efforts. The universities need to recognize that the interaction contributes to the qualification of professionals, which is the main objective of this kind of institution. On the other hand, there is a profit objective for the company or organization, which needs to be perceived directly on their economic return.

The university must take an entrepreneurial attitude, seeking to find research conducted within the academia that can serve as potential technologies to be put into practice. This entrepreneurial attitude can be noticed when it gets involved with entrepreneurship education, technology transfer and the formation of new companies through the business incubation process. Entrepreneurial culture can be considered an incentive for the university professors, who traditionally have an intellectual focus on their research, while creating a perspective to a new potential – the market potential (Etzkowitz & Leydesdorff, 2000a). When interacting with businesses, an entrepreneurial attitude from the university may need to be supported by another important entity in the process, which is the government. This entity, along with businesses and universities, form what is called *Triple Helix*. These three helices are responsible for expanding government policies, encouraging universities' entrepreneurial attitude, and fostering the interaction between companies and research centers in universities or technological parks, among other possibilities (Etzkowitz, 2016).

In the next sections, we will address the role of the entities *entrepreneurial university* and *business* within this process and describe how this interaction could help technology transfer, while assisting in social welfare. In this paper the government helix will not be addressed, since the study focuses in the relationships between universities and businesses.

Entrepreneurial university

Some authors discuss the university's role toward society as well as toward the economic and social development of a region or country, other than educating professionals. In order to analyze this subject, some indicators are necessary, such as the integration to innovative research projects, the participation in modern and high technology start-up companies, and the participation in competitive companies (Carayannis, Rogers, Kurihara, & Allbritton, 1998).

According to Etzkowitz (2003), the new mission of the university is the capitalization of knowledge, by being connected to the creators and users of knowledge in order to establish itself as participant that deserves the role. In other words, it is necessary to produce and provide economic development for it to be recognized by society. Therefore, Guerrero and Urbano (2014, 2016) argue that universities must do more than just generating and transferring knowledge and technology; they must be a source of opportunities for the university community, by fostering leadership for the creation of entrepreneurial thinking and by providing a suitable structure for transforming knowledge into new ventures which can make people's life easier.

Massachusetts Institute of Technology (MIT) identified the importance level of their students' production in innovative research, which affected the local, state and even overseas economy. The survey found that if they only considered the companies created by MIT students and researchers, they would become the 24th world economy, which means more than 1 million jobs generated by about 4000 companies with annual revenues of over US$ 230 billion. All of these companies are high-level technological and innovative companies (Carayannis et al., 1998).

Accordingly, we must pay attention to the quality of the university's faculty, as this quality is positively related to the faculty's involvement in patenting and to the students' entrepreneurial capacity. In this context, professors who have

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greater involvement with entrepreneurship are those who transmit this ability and motivation inside the classroom, thus training young people committed to the economic development of a country (Perkmann, King, & Pavelin, 2011).

In addition to qualified faculty, the interaction between companies and universities may be driven by researchers' individual desire in relation to the income that new technology can generate. Although this is a motivating factor, it is not the most mentioned one. Scholars see the interaction between companies and universities as a tool for technology transfer, innovation generation, and development generation within a country, which are listed as the main motivations for the interaction with industries or companies (Franco & Haase, 2015).

Not all universities have an entrepreneurial bias, not focusing on the commercialization of knowledge and innovations generated by its faculty and students, but in teaching. However, there is a global trend popularizing and transforming institutions in entrepreneurial universities, making them different from those universities from the Middle Ages considered isolated communities of scholars (Etzkowitz, Andrew, & Peter, 1998).

In 1984, in Brazil, the activities started on the Support Program for Scientific and Technological Development (PADCT), which is linked to Brazil's Ministry of Science, Technology and Innovation. This program comprised various areas for the nation's development, including the Industrial Property (IP) (Lima, 2010).

In 1998, a discussion started regarding the importance of IP for Brazil's economic development, particularly in relation to the internationalization of the economy. In that decade, the lack of national legislation contemplating and guiding the actions of this developing area was evident, as the Technological Innovation Centers (TICs) received different names and diverged on actions, which were totally unfocused. This situation was crucial to the creation of Brazil's National Innovation Act in 2004 (Lima, 2010).

The Innovation Act, n. 10.793, of December 2, 2004, defines TIC as a Technological Innovation Center or another entity consisting of one or more institutions whose objective is to manage their innovation policy. TICs are also responsible for monitoring the development processes from research to innovation and promoting partnerships between universities and companies.

The activities linked to the TICs within the universities are related to the attention on the institutional policy and the incentive with respect to innovation culture through the protection of intellectual property, patent licensing, management of technology transfer agreements, interaction between universities and companies, organization of events that promote and create an enabling environment for the dissemination of innovation at the university, assistance to researchers in fundraising for innovation, among other activities. TICs are responsible for compliance with the legislation in accordance with each specific country. In the United States, the law that initiated all related legislation was the Bayh-Dole Act, in 1980, which inspired the Innovation Act of 2004 in Brazil (Franco & Haase, 2015).

Business

The transition from industrial companies to knowledge companies has happened since the nineteenth century, hence the ideas and objectives have been changing. From the moment that knowledge becomes part of the production and commercialization of goods, products and services, organizations aim to develop partnerships and agreements with other areas (Etzkowitz & Leydesdorff, 2000b).

According to Schumpeter (1942), the first attitude of a modern company is to establish a research department, considering the organization's subsistence depends on this department's success and improvements.

Over the years, organizations are developing partnerships with others in a similar field. After that, they tend to develop partnerships with larger companies, start-up companies, research centers or universities. Nowadays, we notice that companies have transferred units to the so-called technology parks or science parks installed within universities and research centers. Doing so, they are able to carry out agreements and are closer to the knowledge produced by basic and applied research, which are developed in academic research groups aiming at licensing new products with market potential (Etzkowitz, 2003).

For Arocena and Sutz (2000), the private sector should have the responsibility to develop innovative products and services, promote interaction within the scientific community and lead in change processes. However, the limitations are noticeable, such as the low investment capacity for new technology development and the lack of academic and technological preparation to conduct research.

Since each organization has its own beliefs, culture and ideals, it is necessary to be careful when dealing with private funding investments for technological research. This is essential so that the cooperation with universities takes place in an ethical and moral way. If the organization really has that in its culture, society will absorb the proposal, therefore the cooperation can promote the company before its stakeholders as well as improve its image not only for an economic development, but also for a social development, arising from the cooperation and involvement of the parties in favor of a common goal for society (Quetglás & Grau, 2002).

The contribution that organizations may provide to developing communities occurs by investing in applied research for these economies, mainly through the interaction and qualification of research centers, which lead to the development of that particular region throughout technology transfer (Velasquez, 2010).

In order for this ideal situation to occur, an ethical behavior is necessary at all levels of the process, such as, the organization, the university, the researcher, the investor. In other words, the only right answer for solving ethical problems is to increase the ethical behavior at all levels (Fassin, 2000).

Schumpeterian Trilogy approach

The components of the Schumpeterian Trilogy are: invention, innovation and diffusion. This trilogy, highlighted by

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Joseph Schumpeter (1961), is composed by authors from the Neo-Schumpeterian current, who determined the following theoretical approaches: firm approach and technological standards approach, thus defining the techno-economic paradigm. These authors are: Richard Nelson, Sidney Winter and Giovanni Dosi, Christopher Freeman, Carlota Perez and Luc Soete (Pérez & Sánchez, 2003).

Among these authors, those who intend to emphasize the invention move between science and technology and have a technical character. Those focused on innovation built a link between the development phase and the interaction between technological standards and infrastructure. Finally, those engaged in diffusion studies are the most recent, focusing on R&D (research and development) policies and national innovation systems (Pérez & Sánchez, 2003).

In the next sections of the paper, we present the concepts of the proposed trilogy, so that they can be understood.

Invention

For the Brazilian National Institute of Industrial Property (INPI) (2013), invention is seen as something that needs to be covered by novelty, is not an obvious result of technique, is not purely theoretical and has applicability in the industry.

Other authors, like Roman and Puett Junior (1983), define invention by using the verb "conceive", because they see the inventive activity as the act of conceiving an idea in order to use it later, transforming it into innovation. Even though both are part of the Innovation Trilogy proposed by Joseph Schumpeter (1961), it is important not to confuse invention and innovation, which are conceptually different.

Stoneman and Diederen (1994, p. 918) explain that invention may be defined as the generation of new ideas. According to OECD (2002), invention is more than creating ideas, since it has to be viewed as an inventive activity and, especially, it must have an industrial application.

The invention represents an idea, an outline, or a model of a new device, product or even process, which may not always become an innovation. It is only defined as innovation when there are commercial transactions and economic drive based on such invention, that is, when it directly involves the diffusion principle generating the expected financial return (Song, 1998).

Innovation

In 1942, Schumpeter defended the idea that capitalist economies were supported through the impact of technological innovations, in which new technologies would replace the old ones, an idea that opposes the neoclassical theory. According to neo-Schumpeterians, technical progress can be considered an important variable for the evolutionary process both for firm and market (Freeman & Perez, 1988). Nelson and Winter (1982) suggest that the technological issue should be incorporated into theories, such as the firm theory, for example. This evolutionary approach has raised the idea that firms seek to introduce changes in their products and processes, which results in a dynamic process.

Schumpeter proposed a list of innovations, such as products, production methods, new markets, new market structures in an industry, and new sources of raw materials (Schumpeter, 1961).

Economic progress driven by technological advances and the innovation growth directly affects the evolution of nations. In this sense, in 1963 the Organization for Economic Co-Operation and Development (OECD) organized the Frascati Manual with the objective of creating a standard system for evaluating research and development. This manual interprets innovation as the transformation of an idea into a salable, new or improved product, a production process, or, finally, a new method of social service. For Peter Drucker (1985), innovation must lead to dedication so that useful improvements, which can leverage the financial and social potential of a company, are created.

In 1992, following these studies, the first version of Oslo Manual was made available in order to guide the collection of data on technological innovation. This manual describes innovation as a dynamic process in which knowledge is accumulated through learning and interaction (OECD, 2005).

In 2004, in Brazil, the Law of incentives for innovation and scientific and technological research was published. In article 2, section IV, innovation is defined as "the introduction of a novelty for enhancing the productive or social environment that results in new products, processes, or services".

In this research, we focused on product technological innovation, which leads to a university–industry interaction through technology transfer. In this sense, it is possible to highlight the various stages composing the technological innovation process that involves the generation of new ideas, its practical applications and the technology transfer, which aims to transform the knowledge generated into new competitive technologies (Quetglás & Grau, 2002).

According to OECD (2005), product or process innovations may be considered technological innovations. Therefore, we can assume that technological innovation occurs when there are significant changes in products, goods and services, or when a new product is introduced in the national or international market. Within this context, it is possible to understand changes in quality and productivity, while making the product or service somehow closer to the real market desire.

Technological innovation can be defined as an idea transformed into a new or improved product that is marketable, and the technological innovation in process is related to a new process performed in the industry or even in sales. It can be considered a transforming agent, guiding countries on economic progress and highlighting the role of universities and companies, which hold the scientific and techno-scientific knowledge. The knowledge transferred by the university to the company is, consequently, widespread and incorporated into products and services that get into the market (OECD, 2002).

Technology diffusion and transfer

OECD (2005) introduces diffusion as the way in which innovations disseminate among consumers as well as businesses, markets, sectors and even countries. Without diffusion,

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innovation cannot generate economic results. According to Carayol (2003), without invention there would not be innovation, and without innovation, there would not be diffusion, since they are interconnected. Rogers (1971) explains that diffusion is a theory composed by a set of generalizations or channels that propagate the innovation within social systems over the time.

There are some mechanisms that can assist technology diffusion, such as mass media; however, the diffusion theory highlights the importance of influential leaders. The difference between these mechanisms is that media can disseminate ideas to a greater number of people in a short time, while leaders have a direct and closer positioning facilitating the understanding of innovation and mainly generating greater confidence for persuasion (Bray & Lee, 2000; Rogers, Takegami, & Yin, 2001).

In order to analyze the diffusion of a given innovation, some variables and the relationship among them are important. These variables are: dimensions of innovation (product, process, marketing and management innovation, which can be radical or incremental); characteristics of innovation producers (researchers, independent inventors or professional); characteristics of potential customers (people who may be interested in using the new technology) (OECD, 2005).

Cribb (2009, p. 91) reports that technology transfer can be considered a technological management activity and the author describes such transfer as the "displacement of technological knowledge from one place to another". This displacement can be performed either in a commercial or a non-commercial way depending on the type of technology to be transferred and if patented or not. Nonetheless, one cannot compare technology transfer to buying and selling new tools, machines, plants, materials or methods, because it goes beyond this, mobilizing individuals and organizations (Gonçalves, 2012; Hanna, Guy, & Arnold, 1995; Trajtenberg & Yitzhaki, 1989).

Financially, technology transfer that does not result in successful trading has little added value. Thus, it is necessary to be careful so that the technology transfer assists the technological progress and increases competitiveness in the national economic scenario (Quetglás & Grau, 2002).

In order to have success on technological knowledge transfer, there are some forms of efforts which can be made, through technology transfer offices allocated in universities or even spin-off companies, which are kinds of businesses built within universities among researchers and students who, along with labor mobility, form the motivators of the advancement of knowledge trading and of the building capacity for the growth or evolution of a given geographical area or scientific and theoretical field of an institution (Borges & Filion, 2013; Bozeman, Rimes, & Youtie, 2015).

The development of institutions that go beyond article publishing, by promoting the commercialization of technologies, goes through the management of scientific development, which is almost always carried out by the institution's management. This may happen in the infrastructure of the institute or university, in the creation of internal policies that support such commercialization, or even in the creation of accounting, legal and administrative advisory offices for new products or projects (Chang, Yang, Martin, Chi, & Lin, 2016).

Method

This research studies two cases. According to Yin (2013), studying more than one case validates the research and makes it more reliable; therefore, this is essential to have good results. For investigations of contemporary phenomena, case study is the most appropriate methodology, as opposed to how it was seen, as a methodology that was not strict and scientific enough (Yin, 2013).

As for the research classification, this is a descriptive study with a qualitative approach (Denzin & Lincoln, 2008). According to Yin (2013), in qualitative studies, it is recommended to work along with a small group of people, who should be chosen due to their mastery of the issue addressed.

Due to the cultural level of the respondents and their understanding of the subjects addressed, the data collection technique used was the semi-structured interview, so that the interviewees could speak freely about the subject. In this case, the researcher only intervenes if necessary, to maintain the focus. In addition, the data analysis technique used was the content analysis, with the support of NVivo® software, version 11.0 (Denzin & Lincoln, 2008; Wolcott, 1994).

The two cases studied in this research were University of Campinas (UNICAMP) and the University of Vale do Rio dos Sinos (UNISINOS). In each of these institutions, our study sought to investigate three issues: how the university–industry interaction happens, how the technology transfer process is developed, and lastly, what means are used by both institutions to make it possible to understand the methodology used for technology transfer between universities and companies. Respondents were defined based on the technologies studied, one from each university. We interviewed those responsible for the transfer process: the inventor (researcher), the TIC (which is responsible for the transfer process), and the company for which the technology was transferred (the one responsible for negotiating with the TIC), hence adding up to six interviews.

Therefore, this research can be classified as descriptive, qualitative, based on the study of two cases, with data collected from semi-structured face to face interviews (primary data source) and institutional documents, such as reports and universities websites (secondary data source). The analysis were performed through content analysis, by using the NVivo® software, and document analysis (Denzin & Lincoln, 2008).

The Research Ethics Committee approved this article as per Consolidated Opinion no. 479.743. In order to receive this approval, we created a Free and Clarified Consent Term (FCCT), presented to all participants of the survey, who signed it, thus confirming their participation in the research.

After the approval of the Research Ethics Committee, the coordinators of the technology transfer offices/innovation agency of the two objects of study were contacted for the initial definition of the transferred technologies which would be studied by the researchers. The following criteria were applied:

a) both studied technologies should be considered technological innovations;

Occupation	Area of Concentration	Institution	Research Execution
Communication manager of the TIC	Innovation	UNICAMP	Yes
Manager of the TIC	Innovation	UNISINOS	Yes
Co-owner	Health	Spin-off	Yes
Environmental engineer	Environmental engineering	Company	Yes
Researcher	Chemistry	UNISINOS	Yes
Researcher	Nursing	UNICAMP	Yes

Fig. 1. Interviewees' details.
Source: Developed from research data.

b) technologies should have been transferred, so that the whole process could be evaluated;
c) both UNICAMP and UNISINOS should agree with the transfer process analysis of the chosen technology.

The interviews were conducted in person, which means that the researchers went to the institution after prior appointment with the interviewees, and were recorded for later transcription and data analysis. Each interview's average duration was 45 minutes. Fig. 1 shows the interviewees' details as well as the institutions to which they belong.

After the two technologies were chosen, one for each university, a brief description of each one was elaborated, following information available in the TICs, through documents and data collected during the interviews and published in papers.

Studied cases

It is a company founded in 2010 at UNICAMP, which focuses on the development and manufacture of pharmaceutical, biotechnological and medical products. This company also provides services in the areas of R&D+i, and scientific, regulatory and quality management technique for companies that produce medicine (activity report – INOVA UNICAMP, 2012).

In 2011, the company entered the business pre-incubation program of INCAMP, which is UNICAMP's business incubator of companies with technological base, maintaining its focus on innovative pharmacological tools, biomarkers and application and development methods of basic research in drugs and medicines (activity report – INOVA UNICAMP, 2012).

The founders of the spin-off were doctoral students at the time of its foundation. They were in contact with the technology that originated the company since their master's degree course. With a professor, researcher and mentor, they developed the product and created the spin-off so that the technology could be licensed and marketed. All this articulation of discovering the technology, its commercial value, patenting and creating the spin-off were activities carried out constantly supported by UNICAMP's innovation agency, Inova UNICAMP (activity report – INOVA UNICAMP, 2012).

The first studies about technology started in 2002. Some researchers from the research group of UNICAMP studied insulin in different tissues and found that it would also affect the skin (activity report – INOVA UNICAMP, 2012).

Consequently, there was a long period of studies and testing, and in 2007 the idea of the product, a scar treatment for diabetic people, became real, leading to the first patent of the product. All the patent claiming, registration and submission were carried out by Inova's office staff, who noticed the market capability of the product, which was only being considered as an initial stage research, according to the researchers (activity report – INOVA UNICAMP, 2012).

Since then, tests have been performed, first on diabetic animals, in which a wound would take up to 15 days to heal. On non-diabetic rats, the same wound would heal in 9 days at most. With the help of the scar cream, the healing time on diabetic animals reached 9 days, such as the healing period in non-diabetic rats (activity report – INOVA UNICAMP, 2012).

In the current stage of studies and technology testing, partnerships with other companies will be necessary to overcome some stages until the product is ready to be launched to market. In this context, the current contact network at the university is essential for the research in order to build partnerships, according to one of the co-owners of the spin-off.

The company studied at UNISINOS was founded in 1902, in England, and belongs to an international group which is present in more than 30 countries. In Brazil, it operates in two manufacturing areas – Porto Alegre and Charqueadas – both in the state of Rio Grande do Sul. It also has a sales office in São Paulo, in the state of São Paulo (Chiaradia, 2004).

The company's initiative deals with the correct disposal of Phosphatization Sludge (PS) generated from the treatment of liquid effluents from companies' steel phosphate coating processes. This residue's disposal used to be made in industrial landfill sites, and after the research conducted in partnership between the university and a brickyard, the residue started being used to produce ceramic blocks (Interview data, 2013).

During laboratory stage, tests were performed with blocks with 2.5%, 5% and 7.5% of phosphate sludge being used to replace clay, and with one block used for reference, without the addition of sludge. There were physical, mechanical and environmental characterization tests. The test results showed that the addition of up to 5% of the sludge in the ceramic material meets the standard requirements and also the testing conditions (Reckziegel et al., 2013).

Industrial pilot tests were carried out with the addition of 2.5% of PS in order to maintain the safety of the product if it reached industrial scale. These tests proved that the addition of PS to the blocks did not compromise the physical, mechanical or environmental properties of the product. After all these technical and environmental verifications, the release of the operational license for the product's manufacturing and scale of production was still necessary (Reckziegel et al., 2013).

The decision was made based on technical, mechanical and environmental evidence sent to the City's Environment Department, therefore the blocks could be produced on industrial scale if the following requirements were met: phosphate sludge should be stored in a weatherproof container and the blocks should have their own identification so that they could be monitored (Reckziegel et al., 2013).

Thus, the brickyard interested in producing the blocks with addition of PS as well as the company providing the raw material would have to meet these requirements. Therefore, there was an

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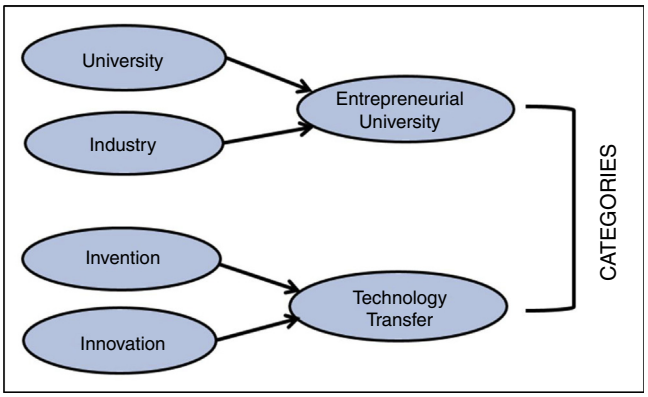

Fig. 2. Analysis categories.
Source: Created by the authors.

adaptation period for the two companies, and the university also needed to develop the product's own identification (Reckziegel et al., 2013).

The brand BIOBLOCK, present in all the blocks produced with 2.5% of PS, was registered at INPI. Along with the blocks, a technical file with explanations on the production of the block is sent to the consumers of the product (Reckziegel et al., 2013).

The project was developed with the participation of the university, the company that produced the raw material and the recycling company. The results evidence the use of phosphate sludge recycling in construction industry. From this, both the company which generates the sludge and the recycler reduced their costs, one in the availability of its waste and the other in raw material, thus generating a co-product that could contribute to the preservation of non-renewable natural resources (Reckziegel et al., 2013).

The analysis and discussion of survey data will be presented with the help of NVivo® software. Categorization (Denzin & Lincoln, 2008) is based on the definition of Entrepreneurial University by Etzkowitz (2003) and of Technological Diffusion by Rogers (1971), as shown in Fig. 2, which was the basis for the analysis presented in sequence.

Data presentation and analysis

Entrepreneurial university

It is possible to notice the importance of the entrepreneurial university to the respondents, since all of them cited it in their interviews. By running the software tool called Text Search Query, we were able to find out that the expression was used 110 times. Its frequency was higher in interviews of the TICs, followed by the companies and, finally, in the researchers' interviews.

Another interesting fact is that the interviewed companies can notice the difference between traditional universities, totally focused on education, and entrepreneurial universities, as transcribed below:

> [...] the difference is the level and the volume of applied research which reflects the availability of technology and infrastructure for society, thus creating more propitious conditions for the development of companies. (Company linked to UNICAMP).

> Yes, it is possible to notice the difference between the traditional and the entrepreneurial one, as they perform together research projects, innovations, certifications. (Company linked to UNISINOS).

However, for the interviewees, the community does not understand this difference so easily. According to UNICAMP's TIC, although the university has a slightly different stance than the others, since its creation, this is still not clear to the outside community. According to a researcher from UNISINOS: "people are quite amazed when they get to know that I developed, along with two companies, a product that is now on the market. They still believe that the university educates people, only that. This culture is still not common".

According to Etzkowitz (2003), an entrepreneurial university should look for research conducted within the academia that could be considered technological potentials and be put into practice. This concept clearly shows the understanding that the respondents had on the issue.

For both respondents from TICs, the interaction with the company can start in different ways. According to the UNICAMP's TIC, there is a portfolio mentioning the companies with which Inova UNICAMP works more often, and gives preference to offer a product for licensing. For UNISINOS's TIC, the interaction can start based the needs of the industry or university. These situations prove what is mentioned in the theory by Sankat et al. (2007), who state that the interaction process between university and industry starts when the productive sector needs a new technology, or even when the scientific sector produces or creates new knowledge that has practical applications, thus an interaction emerges between these sectors for the promotion of technological innovation.

After, the respondents were asked whether the university is prepared for this interaction. Below we can see some extracts from the interviews:

> Firstly, there must be a time adjustment. We cannot give the result to the company after four years; they cannot depend on a result of a dissertation or thesis. Depending on the area, we are able to give an answer to the company in a timely manner, yet establishing reliable relationships and a very well planned schedule (UNICAMP'S TIC).

> We must reduce bureaucracy and be careful about the negotiation, because the amounts requested on the contracts are high and they often do not include the risk of investing in embryonic technology taken by small businesses (Company linked to UNICAMP).

> Therefore, I see that those who develop research with companies are always on the market and have experience with what happens on the factory during manufacturing. Students like professors who are in contact with companies, and through research with companies, I can be connected. We notice how valuable this is for students. (Researcher from UNISINOS).

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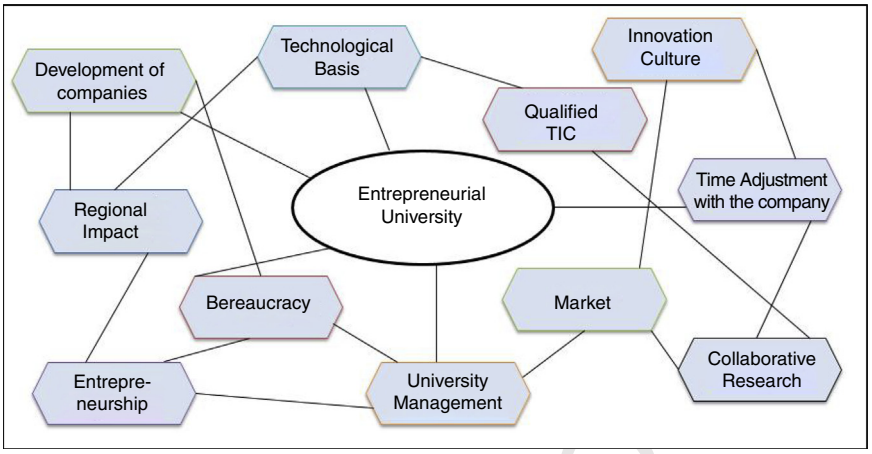

Fig. 3. Main aspects related to the Entrepreneurial University.
Source: Created with NVivo® software.

Through the universities' opinion, we can observe their concern on balancing university time with company time. This concern can be identified in one of the companies, when it comes to bureaucracy. Another comment from one of the companies interviewed was regarding the diffusion of patents that the university has. According to the interviewee, the universities need to publicize their projects, so that companies are able to invest in the university-generated research.

Regarding the opinion of the researchers interviewed, they were clear in emphasizing the importance of the TIC for their research with companies. One of them described TIC's services as first-world services, while emphasizing the little time the researchers have to devote themselves to the bureaucracy emerging from the interaction between the entities, which proves the demand for the Innovation Law and the generation of Innovation and Technology Transfer Centers in the Science and Technology Institutions.

Another important aspect observed during the interview with one of the TICs is related to university management. The institution must decide whether to follow the path of an entrepreneurial university or not. If the answer is "yes", it is necessary to act with the professionalism that the area requires.

Fig. 3 displays a summary of the aspects mentioned during the interviews concerning the entrepreneurial university by all respondents, as per analysis.

Based on Fig. 3, we can observe that several factors mentioned in the interviews are essential to characterize a university as entrepreneurial. The university management must support and encourage innovation culture, collaborative research, entrepreneurship, as well as assisting the TIC in reducing bureaucracy, paying attention to the market, developing technology-based research for the generation of companies, thus leading to a regional impact via the technology transfer to the productive sector. Besides, Fig. 3 shows that these activities could not be isolated, since one depends on the other to be successful. If there is the culture of innovation in a university, but there is also bureaucracy, the regional impact of innovative actions may be compromised. This logic is true to all the links represented in Fig. 3, since all of them support an entrepreneurial university.

Technology transfer

As mentioned by a UNICAMP's researcher, it was not even the researchers' intention to protect that technology; however, it happened through the TIC as described: "Actually, when we started, we did not think about patenting the product. With that, the university embraced the cause, because they saw the potential in technology". According to UNICAMP's TIC, actions which aim to diffuse TIC's work, the culture of innovation and entrepreneurship are essential for researchers to understand why the protection is necessary, how this should be done, and to whom the researcher must report at this time, as seen in the following excerpt:

> [...] when students start studying at the university, a material about the TIC [is given] to them. Every semester we have lectures in the units that talk about what TIC is, what the role of the post-graduation student is, and this involves the entire TIC – the team involved in planning and organizing the content, IP team to deliver the lecture, in other words, everybody is involved for the cause.

UNICAMP has demonstrated a concern about keeping their researchers and students aware, which is important, especially when considering a statement from a UNISINOS' researcher, who experienced this lack of clarification. According to her, since she was not aware of the patenting process, she eventually published her article, which presented data from the technology generated between the university and the company, prior to its registration with INPI. Because of that, they were not able to issue the patent, as the technology was already in the public domain. In the excerpt below, we can see the professor's declaration:

> We do not have a patent for this specific product, because we published the article before. We did not know the importance

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of the patent before publishing and, then, we lost the patent. The only thing we have is the trademark registration of the created product with INPI.

In such cases, the importance of a TIC in the university becomes evident, by mediating negotiations between researchers and companies and, especially, the level of professionalism demanded in these situations. Protecting the technology created is the first step toward the generation of innovation, which should be carried out according to current legislation in the area in Brazil, Law no. 9.279, of May 14, 1996, that regulates rights and obligations related to IP, thus avoiding the damage of losing the patent.

After the interview, there was a question about how the technology transfer process occurs in each of the universities. Through that, we could see that there is not an established process or model used. The description of the excerpts from the interviews that report these situations are presented below:

> We do not have a defined operational process, despite having the inventor's manual with some basic steps to protect the technology and the items researchers should care about. We have a policy of contracts and agreements available to guide our transfer agreements as well as agreements with companies (UNICAMP's TIC).

> This is something new for us. Everything will be about learning. We have some processes that are defined, but as we are practicing now, we do not exactly the steps. Sometimes we think that everything is going to be solved in a meeting, but we actually need five, and so on. Everything is really new. Today we have no patent granted (UNISINOS's TIC).

According to UNICAMP's TIC, some initial steps work for all technologies, such as registration with INPI, the pursuit for interested companies, the negotiation with companies and the meetings involving researchers and companies. From this moment on, each stage is composed by different activities including negotiation, which may result in different possibilities, as there is no mapping. The terms of the contract are an example of this, which, in some cases, foresee the payment of royalties. A clause stipulates the estimated time the company has to make the technology available in the market, but it depends on the stage in which the technology is. If the companies do not comply with this term, they will start paying some minimum royalties for the university.

According to the TIC, the objective that guides UNICAMP's actions is having the technology on the market, available for trading. Therefore, there are punitive clauses for the company that does not produce the technology. Similarly, special attention has not been given to the technology valuation stage of UNICAMP yet, since their focus is to conduct the entire process and make the technology available, learn how the process should be done so it can be discussed, adapted and improved. Some excerpts from the interviews are presented below:

> This negotiation stage is always difficult, because there is not a definite method for the valuation of a technology yet. Nowadays, it happens through tacit knowledge, as the available analysts do that. There is no formal procedure. Our expectation is that within two years we will have mapped this process of how the valuation of technology happens (UNICAMP's TIC).

> The staff responsible for agreements does the writing, and then the going back and forth begins. It is an exhausting stage which ends when the contract is closed and, then, we move to the signatures step. Both in the unit and in the dean's office, which sums up to two signatures internally, without considering the signatures of the company. This step alone can take up to 4 months. Nowadays, there is an evaluation of the contract at the time, made by a committee for contracts, because once the contract would be sent to the council of deans, and that would risk the university's position toward the company (UNISINOS's TIC).

Considering the comments above, we can notice that the image of UNICAMP perceived by the companies is a matter of concern, so much that the delay of signing contracts and agreements were detected as a risk for their relationship with the companies.

At the interview with the company that was created with the technology developed by UNICAMP's researchers, the bureaucracy was also highlighted. This fact shows that both parties realize that this type of process deserves a differentiated service by TICs, reported by the interviewed company as follows: "there is some concern from the customers regarding the bureaucracy, delays and excessive preciousness of little applied (basic) research of the academia".

The next question discussed with the company linked to UNICAMP was about the structure designed for research within the company, the presence of a definite flow to the TT process, and the way the company was interested in registering the patent. The answers were transcribed as follows:

> The company was generated from the patent available for licensing, because we are partners and students of the postgraduate course offered by the patent's inventor, and we have closely followed the entire history of the technology, as researchers. We do not have a specialized team in technology transfer. Negotiations are initially made with the inventors and, after, we move to the transfer bureaucracy in accordance with the university. Nonetheless, here in the company we do not have a standard procedure. We have specialized researchers who are fully dedicated to R&D.

When we asked the same question to the company linked to UNISINOS and the answer obtained was the following:

> The technology was developed here in the company with the university's participation in the testing and a greater number of researchers were involved. It was not possible to register the patent because a scientific article had been published before the registration request. In our company, we have a specific sector for product research and development and for continuous improvement, but we do not have staff for the technology transfer, and do not have a defined process.

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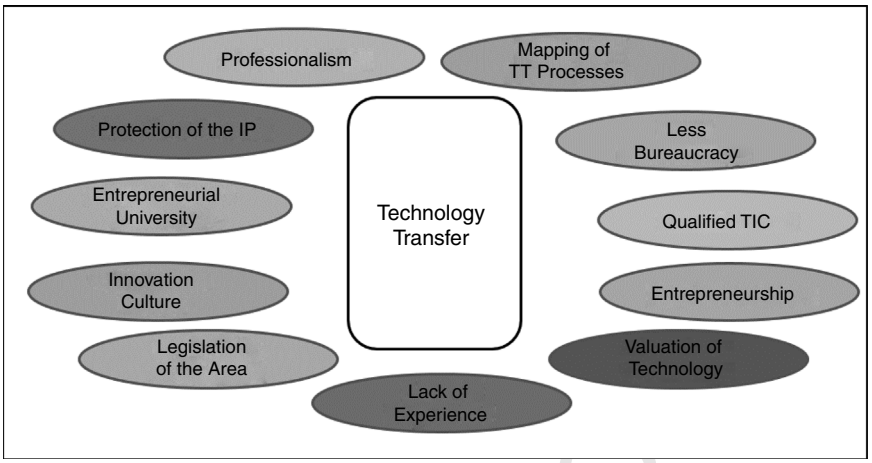

Fig. 4. Main aspects related to the TT.
Source: Created with NVivo® software.

In both answers, we can notice that there is not an established process for the TT within the interviewed companies. The universities that participated in this research are starting their mapping processes for defining the roles and the flow for the transfer. A positive aspect that was found in both companies is the fact that they have a specific R&D sector that maintains a direct contact with the mentioned universities.

Fig. 4 shows a summary of the information outlined in the analysis about technology transfer.

As seen in Fig. 4, some factors surround the technology transfer in the cases studied. For those surveyed, the central issue is in the entrepreneurial university, from which the following actions stem from: dissemination of innovation culture and entrepreneurship, training and investment on the TIC and its professionals.

Furthermore, the lack of experience of the TICs with the transfer process can be identified. One of which did not perform the transfer through licensing, while the other did not map the processes in order to have a specific analysis with knowledge about its obstacles (Fig. 4).

As shown in Fig. 4, the valuation of technology, transfer phase that is still done by means of tacit knowledge by the respondents, is another naive aspect. It is worth mentioning the bureaucracy as well, a factor that leaves both companies and universities fearful in relation to the good interaction of both parties.

A positive aspect listed, which can be seen in Fig. 4, is the legislation of the area, which provide the professionals an informed and consistent performance. In this regard, we can refer to the Innovation Law No. 10.973, the Industrial Property Law No. 9.279, both national laws, as well as state laws, such as São Paulo State Innovation Law No. 54.690 and Rio Grande do Sul State Innovation Law No. 13.196.

We could also add to these laws, the policies of each of the institutions studied, such as the Intellectual Property Policy from UNICAMP CONSU-A 016/2010, which guides the actions of the TIC in this area. In the case of UNISINOS, there is no approval of internal policies related to Intellectual Property and, in this sense, the TIC's coordinator states that there is a proposal being drafted which will be forwarded for the approval of the University Dean's Office.

Final remarks

Through this research, we were able to identify that there are weaknesses and strengths both in the university–industry interaction processes and in the technology transfer processes of the studied cases. As shortcomings, we point out the bureaucracy, the lack of innovation and entrepreneurship culture, and the university's lack of experience on working in collaborative research as well as the company's lack of experience on working with the university. As strengths of this relationship, there is the importance of combining theory with practice, achieved through collaborative research, the possibility of generating new technologies, and the regional impact that these technologies may achieve. These findings are corroborated by other studies conducted in Brazil, which allows a view that is not restricted to the cases pointed out in this study (Closs, Ferreira, Sampaio, & Perin, 2012; Cysne, 2005).

The university categorized as entrepreneurial has the possibility to interact with companies, since it seeks to approximate the activities developed in their laboratories or even in research studies, targeting them for the market. In this sense, an entrepreneurial university is the one supporting and encouraging innovation and entrepreneurship culture, helping TICs to reduce the bureaucracy within their activities, paying attention to the market and developing research based on technology, helping to generate new companies and, consequently, leading to technological impact. It is important to highlight that this interaction is in a consolidation phase.

An interesting fact easily noticed based on our research is that the interviewed universities and their researchers realize that the outside community has not yet understood the function of research, which starts as a project design at the university and goes to the final consumer as a product through the company. For them, the outside community understands and sees the university only as responsible for educating professionals. Therefore,

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announcing these collaborative projects is necessary so that this culture of innovation can complete the Schumpeterian Trilogy in the perspective of technology diffusion.

Another issue worth mentioning is how much it is gained by the professor inside the classroom when being in contact with the market through the companies. For a research professor, such contact is difficult to occur when having a 40-hour contract with the university and not having a research workload. The university–industry interaction forces this researcher to maintain a relationship with the market, making the professional more dynamic and differentiated classroom.

According to the survey results, entrepreneurial universities have some related aspects, either positive or negative. An entrepreneurial university needs to have a management body that understands and is willing to behave as an entrepreneur, conducting collaborative and technology-based research focused on the market, needs to have a skilled TIC, foster the development of new companies as well as the university entrepreneurship, worry about setting time schedules considering market and university and, lastly, reduce bureaucracy and rework in the activities.

There have been some uncertainties for the technology transfer process between university and industry, since some success cases are unable to be studied due to confidential contractual formalities. This shows that universities and companies need to improve this interaction, thus generating more transfer cases, increasing the rate of inventions that become innovations, which can serve as reference for scientific analysis that contribute to the advancement of science in this field of knowledge.

Universities are creating their TICs with skilled professionals in order to work in the areas necessary for the transfer to take place, such as the protection of intellectual property. Currently, these institutions already have a portfolio of patents available to companies that seek licensing for commercial use; however, it does not happen often. This path is slow, and it is a matter of adapting and diffusing the innovation culture, since companies also need to have access to these new technologies so that they can acknowledge them and offer them to the market.

Regarding technology transfer, the processes are not established at the institutions studied yet. There is not a clear and defined process. Currently, these processes are carried out through the existing tacit knowledge in the TICs. Similarly, one of the transfer stages that does not have a valid methodology for its execution is the valuation of new technologies.

The main aspects related to technology transfer discovered by this research study were: the need to professionalize and train the TICs, the need to protect the intellectual property generated in universities, the university needs to be entrepreneurial in order to foster the innovation culture, creating internal policies in the innovation area and mapping transfer processes to reduce bureaucracy in these activities.

From this, we consider that this study has achieved the proposed objectives, describing the process of university–industry interaction, featuring the technology transfer process and analyzing each of the cases proposed by the institutions studied.

With this research, we were able to conclude that the university–industry interaction process has been improving, but it still needs to advance in organizational aspects. Some of the aspects to be considered are: the adjustments for the institutions' internal policies, the existing negotiations, the researchers' behavior regarding the dissemination of the innovation culture, and the performance of the TICs, which gradually are being trained to work in the market as well as in the university.

It is necessary that primarily companies and universities understand that they must join efforts in collaborative technological research, so that the financial resources invested are not only accepted as published articles in qualified journals, but also turn into technological innovations accepted by the market. All this investment must return as new products, services and technologies that generate local, regional, national and even international impact, implementing new types of businesses, new markets and yielding an economic impact in the country, thus generating innovation and social well-being (Fig. 5).

Fig. 5 shows the scientific contribution of this research. This figure focuses on the Schumpeterian Trilogy approach along with the presented theoretical framework about the interaction university–business. Here the entity Government is shown representing the financial resources that encourage innovation through public notices and economic subsidies, and also the end point of diffusion that is the economic impact generated by innovation.

Although the Government has an important role mainly in regulating laws and guidelines for innovation in the country, financial supporting does not always take place, especially in moments of crisis. Consequently, the interaction of university and business is relevant so that innovations continue to take place, not only in the research stage, but in a mutual act of financial and economic assistance. Universities need an entrepreneurial and proactive attitude, managing these activities and being the protagonists of this scenario, so that this interaction happens.

Thus, it is concluded that financial resources, basic research and knowledge provided by the university allow the generation of the bench top prototypes and the so-called inventions. All this combined with the company's ability to receive these products or services and transform them through the production on an industrial scale combined with the diffusion of this technology, generates an innovation of local, regional, national or international economic impact, made possible through new products, new services or new markets, hence contributing to society's welfare.

The research's limitations were the unfeasibility of studying the government helix, the lack of clear and established processes within universities so that a comparison between the cases would be possible, and the lack of access to technology contracts, since they are considered confidential. In addition, the use of two cases is considered a limitation, since it is not possible to generalize the conclusions pointed out by the study. Besides, some interviews were conducted through internet, which may have compromised the final analysis. Therefore, for future studies we suggest the validation of tools for the valuation of technologies, a hindrance presented by the two studied institutions, studies about technology transfer processes, aiming to speed up and reduce bureaucracy, as well as studies that analyze the entrepreneurial

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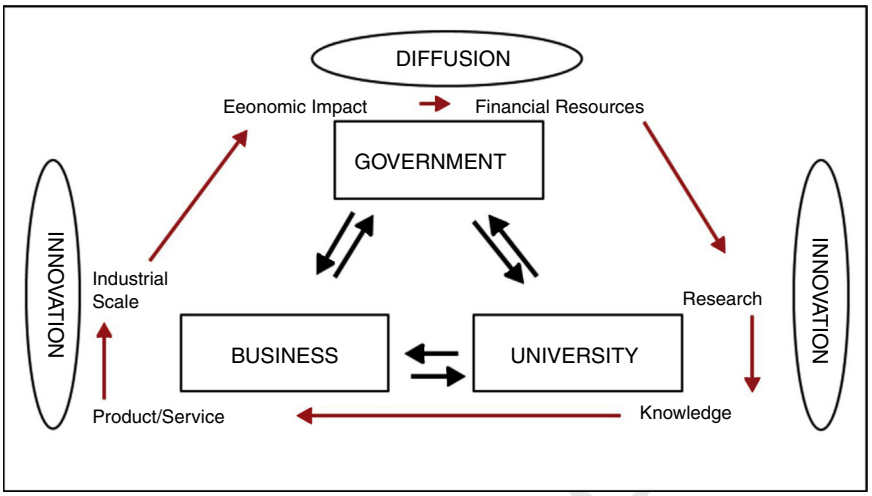

Fig. 5. Process of technology transfer.
Source: Created by the authors.

university and its innovation environments in the contribution to regional development.

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Lei (1996, 2004), Brasil (2012), INPI (2015a, 2015b), Universidade Estadual de Campinas (2015, 2016a, 2016b) and Universidade do Vale do Rio dos Sinos (2016).

Conflicts of interest

The authors declare no conflicts of interest.

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