Identifying Effects of Integrating Academic Makerspaces into Open Innovation Cooperations. A Research Framework

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Introduction

With the maker movement's rise, infrastructural resources for makers like fablabs, project spaces or fully equipped makerspaces – non-academic and academic – have also been created. Open innovation will play a key role in developed economies over the next decade [1], yet only little research is known dealing with the potential of (academic) makerspaces to support open innovation cooperations between makers, industrial companies, and research institutions. The existing knowledge often refers to specific industries or academic fields, e.g. Zakoth et al. [2] and Ponce et al. [3].

The Institute of Innovation and Industrial Management (IIM) at Graz University of Technology (TU Graz) is conducting an open innovation (OI) cooperation between students (=makers in this project), industrial companies, and academic research institutions called Product Innovation (PI / until 2018/2019 called Product Innovation Project) already back since the academic year 2006/2007. Within the last 16 years 30 industrial companies, 2 research institutions, and more than 530 students took part in 69 projects. Since the early beginning, the PI project was always supported with infrastructure as introduced by Herstätter et al. [4]. Referring to Culpepper [5] the different supporting infrastructures can be all classified as project spaces, community spaces, machine shops, or a combination of them [4].

With the preparation and the conduction of an OI cooperation, several barriers occur for the participating stakeholders. Some of them are describing organizational barriers and others are referring to legal problems [6]. In existing literature, a significant number of barriers to open innovation is mentioned, e.g. Chesbrough & Brunswicker [7] or Dziurski and Sopinska [8]. Despite no clear classification in the literature, the barriers can be somehow differentiated into barriers to participating in OI projects, barriers within the conduction of OI projects, and barriers to making use of OI project results.

This research aims to understand the value of the integration of academic makerspaces into OI cooperations. Thus, this research focuses on understanding how academic makerspaces can contribute to reducing OI barriers in different contexts and understanding the required framework for this kind of OI cooperation so that all participating stakeholders can gain valuable benefits from the cooperation results.

Case study research builds the methodical framework for this research study. The research process is based on case study research ref. to Eisenhardt [9]. The research data mainly consists of qualitative data collected via semi-structured interviews with the participating stakeholders. An embedded case study design [10] is used to distinguish between remarkable differences in the data sample of the PI.

Besides a detailed concept description of the research project, this paper also describes the status of ongoing research and some interim results.

Research Motivation & Research Question

To the current state of knowledge, only a few papers deal with academic makerspaces in the context of OI. For example, Zakoth et al. [2] investigated if and how makerspaces and makers could be involved in OI activities of specific industry branches. Ponce et al. [3] is describing the usage of academic makerspaces as so-called open innovation laboratories in electrical energy education, pointing out the importance of the implementation of those laboratories to improve the collaboration between universities and industrial companies. More general importance is described by Böhmer and Beckmann [11], who see makerspaces as an important element of an open innovation ecosystem, with significant meaning for physical product development and prototyping. Despite the interest in integrating (academic) makerspaces into OI projects and an expected value for the participating stakeholders, there is no literature known dealing with the potential of academic makerspaces to reduce barriers in the context of OI projects. The research questions were derived from the existing literature gap and the observations out of practical experience within the PI project:

RQ1: What is the contribution of academic makerspaces to avoid or reduce barriers to open innovation cooperations?

RQ2: How do industry supervisors need to be integrated into the PI cooperation to achieve valuable benefits for the participating stakeholders?

Data Sample

The fundament of the data sample was already introduced in [4]. Since the academic year 2006/2007, the IIM conducted 69 projects with 32 different PI partners. Table 1 gives an overview of the projects related to the academic years.

Table 1 Conducted Product Innovation Projects (Status: May 2022)

Academic Year	**Partici-pants**	**# of Projects**	**Project Partners**
2006/2007	11	1	A
2007/2008	13	2	A, B
2008/2009	20	2	A, C
2009/2010	22	2	A, D
2010/2011	10	1	A
2011/2012	12	1	A
2012/2013	19	2	A, E
2013/2014	36	3	A, F, G
2014/2015	67	6	F, H, I, J, K
2015/2016	62	7	C, L, M, N, O, P
2016/2017	60	8	C, F, P, Q, R, S, T, U
2017/2018	44	7	C, P, R, V, W, X, Y
2018/2019	54	9	C, I, Q, U, X, Y, Z, AA, AB
2019/2020	38	6	Q, R, V, W, X, AC
2020/2021	27	6	H, Q, S, X, AD, AE
2021/2022	39	6	S, V, X, AD, AE, AF
Overall	**536**	**69 Projects**	**32 PI Partners**

A to Z, AA to AF…different PI partners

Out of 32 PI partners, 24 were selected for the research study - the other 8 were sorted out due to limitation effects, e.g. the company is not existing anymore, the industry supervisor isn't available due to different reasons or the PI partner was rather a research institution instead of a company. The remaining 24 project partners are all industrial companies. The sample includes small and medium-sized enterprises as well as large enterprises (ref. to the definition by the Austrian Ministry of Digitalization and Economy [12]). The companies operate in different industrial branches which are structured in Table 2 in ref. to the Austrian classification of economic activities (ÖNACE) [13].

Table 2 Overview Economic Activities of PI Partners

Economic Activities PI Partners
Extraction of crude oil and natural gases
Coking plant and mineral oil processing
Metal production and processing
Manufacture of fabricated metal products
Manufacture of computers, electronic and optical products
Manufacture of electrical equipment
Mechanical Engineering
Manufacture of motorized vehicles and vehicle components
Other vehicle manufacturing
Manufacture of furniture
Energy supply
Research and development

All of the projects were supported by an infrastructure, which refers to the different flavors of academic makerspaces, as introduced in [5]. Table 3 shows the evolution of the used infrastructure related to the academic years of the PI. A detailed description of each infrastructure is already explained in [4].

Table 3 Evolution of Infrastructure

Academic Year	**Infrastructure**	**Flavor of Makerspace**
2006/2007	35 [sqm] Coworking Space	Project Space
2007/2008		
2008/2009		
2009/2010		
2010/2011		
2011/2012		
2012/2013		
2013/2014	177 [sqm] DesignLab + 130 [sqm] FabLab	Project Space / Community Space on 2nd Location Machine Shop
2014/2015		
2015/2016		
2016/2017		
2017/2018		
2018/2019	800 [sqm] Schumpeter Laboratory for Innovation	Project Space / Community Space / Machine Shop
2019/2020		
2020/2021		
2021/2022		

By working with such an extensive data sample many different parameters need to be considered, which led to an embedded case study design for this research. Further limiting factors for product innovation since the academic year 2019/2020 are repetitive lockdowns due to the COVID-19 pandemic which resulted in limited usage of the infrastructure and increased digital collaboration.

Research Methodology

Building up on an initial literature review on the research topic the state of existing knowledge was used to select an appropriate research approach. Since the state of knowledge is somewhere between nascent theory and intermediate theory, case research is a strong suggestion by Karlsson [14].

A. *Research Design*

The research design is structured in 4 subsequent phases (see Fig. 1)

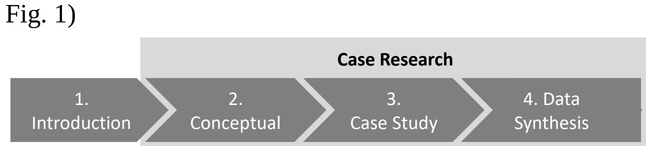

Fig.1 Research Design

Phase 1 (introduction) serves as the orientation phase to create an understanding of the research core topics and to identify missing literature and a research gap. A detailed literature review was conducted to identify the current state of knowledge concerning barriers to OI. In addition, this phase aims to define the goals of the research.

Within phase 2 (conceptual) preparation tasks for the case research were done. Documented data of the IIM archives were screened to identify participating stakeholders, like industry supervisors, academic supervisors, and students with available contact data. Furthermore, the different project tasks of the PI cooperations as well as changes in the process were identified and the structure of the database was created. Based on the already documented data the theoretical case sampling and an interview guideline for semi-structured interviews were developed.

In phase 3 (case study) the case study gets implemented. Besides a retrospective study about previous PI projects, the PI of the academic year 2021/2022 is investigated as the current study. Besides interviews with the industry supervisor, a second interview series is conducted with the academic supervisors of the different PI projects. This phase aims to build a deep understanding of the different cases with their units of analysis and to build a comprehensive database.

In phase 4 (data synthesis) qualitative data analysis ref. to Mayring [15] gets used to analyze the within-case data to search for cross-case patterns between the different units of analysis and the different cases. Based on the results a hypothesis will be derived and compared with potentially conflicting and similar literature. To further improve OI cooperations which integrates academic makerspaces recommendations for actions will be derived to:

1. further reduce barriers to OI
2. adapt academic makerspaces to optimize their fit for OI cooperations

B. *Research Process*

The case study research process in Table 4 was selected to match the research design and is embedded in phase 2 to phase 4 of it.

Table 4 Case Study Research Process [9]

Step #	Process Step	Activities
1	Getting Started	Definition of research question Possibly a priori constructs Neither theory nor hypotheses
2	Selecting Cases	Specified population Theoretical, not random, sampling
3	Crafting Instruments & Protocols	Multiple data collection methods Qualitative and quantitative data combined
4	Entering the Field	Overlap data collection and analysis including field notes Flexible and opportunistic data collection methods
5	Analyzing Data	Within-case analysis Cross-case pattern search using divergent techniques
6	Shaping Hypothesis	Iterative tabulation of evidence for each construct Replication, not sampling, logic across cases Search evidence for "why“ behind relationships
7	Enfolding Literature	Comparison with conflicting literature Comparison with similar literature
8	Reaching Closure	Theoretical saturation when possible

C. *Case Design*

Following the scientific guidelines of case study research, a theoretical sample was created by dividing the existing data sample into different cases. The main parameters for the case structure were the supporting infrastructure and the number of participations in the PI of the industrial companies. To identify further differences, PI projects with multiple participating industry partners were divided into 2 groups - experience of industry partner in one infrastructure and experience of industry partner in more than one infrastructure. In addition, the PI of 2021/2022 will be investigated as current case. An embedded case design referring to Yin [10] acts as theoretical base to structure the theoretic sampling.

Table 5 shows the theoretical case sampling divided into 4 cases based on the parameters described above. All 4 cases are subdivided into multiple units of analysis, each unit representing an industrial company as a partner of PI.

Table 5 Overview Case Design

Case	Time Frame	Case	PI Partners
A	Retro-spective	Multiple Participation / Different Infrastructure	A, C, H, Q, R, S, U, V, W, X, Y,
B	Retro-spective	Multiple Participation / Same Infrastructure	N, P
C	Retro-spective	Single Participation	D, E, I, M, T, Z, AB, AC,
D	Current	Product Innovation 2021/2022	S, V, X, AD, AE, AF

D. *Data Collection*

According to Edmondson & McManus [16], a qualitative approach is well-fitting to collect data in research studies with rather a nascent state of literature. Besides existing project data in the IIM archives (e.g. participant lists, project tasks, project descriptions, project reports, multimedia data of developed prototypes) the data collection mainly focuses on qualitative data collection via semi-structured interviews. The interview guideline was developed based on the procedure of Helfferich [17]. Research-related questions were collected and compared with predefined criteria. In the next step, 4 interview blocks were defined and leading questions were identified. By creating the interview guideline, special attention was paid to considering the three general requirements neutrality, clarity, and simplicity [18]. Table 6 shows the structure of the used interview guideline for industry partners.

Table 6 Structure Interview Guideline

Interview Block	Main Topic
1	General Data
2	Innovation inside the Industrial Company
3	Experience of the Industrial Company with Open Innovation in General
4	Experience within the PI Project

Ad 1) General Data

The first block includes general questions about the project, including information about the company, the project task, the department, and the responsibilities of the industry supervisor.

Ad 2) Innovation inside the Industrial Company

Within the second block questions about innovation inside the company are asked to better understand the firm's general mindset in terms of innovation. This includes questions about the innovation process, the organization, management, and implementation of innovation activities as well as the available resources for innovation activities.

Ad 3) Experience of the Industrial Company with Open Innovation in General

Moving on with the third block questions about the firm's general experience with open innovation are asked. Referring to previous OI experience of the company besides the PI this includes the types and partners of the projects, available resources, experiences during the implementation, and project results.

Ad 4) Experience within the PI Project

The fourth block deals with the particular cooperation within the PI. Detailed questions about the implementation of the project are asked including the process of working together, benefits in terms of available resources, potential problems within the project, the project outcome, effects of the used infrastructure, and effects of the project on the company partner in terms of their innovation activities.

By implementing the interview series with the industry supervisors the goals can be named as follows:

- Understanding the firm's general attitude towards innovation activities
- Learn about the firm's experience with OI projects
- Get a detailed overview of the specific PI cooperation, in particular the process, experiences, and results

Within an upcoming step, the guideline for semi-structured interviews with academic supervisors will be developed following the same procedure. Due to the fact, that interviews with industry partners sometimes only can take place with a significant time delay or in the worst case are not possible they are a potential bottleneck of this research. With ongoing research progress, the interview series with academic supervisors will be started.

E. *Data Analysis*

As introduced by Eisenhardt [9] the data analysis is divided into two main activities defined as within-case analysis and the search for cross-case patterns. The within-case analysis is used to analyze each unit of analysis (UoA) in detail with the target to identify unique patterns in these UoA. Applied to this research the outcome of the interviews is getting analyzed via qualitative data analysis referring to Mayring [15]. Therefore, a suitable coding scheme will be developed. To identify the relevance and contribution of academic makerspaces in terms of barriers to open innovation and in general the conduction of PI the interview data of interview block 3 "Experience of the Industrial Company with Open Innovation in General" and interview block 4 "Experience within the PI Project" will be compared. Initial findings are expected to appear after this step. By searching for cross-case patterns further findings are expected, in particular when comparing UoA with different industrial backgrounds, company sizes, and attitudes towards their innovation activities. In a follow-up step, the UoA with different experiences in terms of the used infrastructure (introduced in table 3) are expected to provide additional findings.

Expected Outcome

Focusing on the first research question, an important expectation is to understand where and how academic makerspaces can help to deal with barriers to OI, e.g. more general issues like missing infrastructure for the conduction of OI projects within the required framework or more detailed topics like availability of technical infrastructure for specific needs of specific PI project tasks. Referring to the second research question the expectation is to understand how the integration of industry partners into OI projects should look like to gain a high benefit of OI projects for all stakeholders. It is expected, that there are different parameters that could affect this topic, e.g. project task, the intensity of integration of the industry partner, the invested time, the position and tasks inside the company of the industry supervisor, and further parameters. The comprehensive data sample offers a promising opportunity to better understand OI projects with the participation of makers, industrial companies, and research institutions in academic makerspaces.

Study Progress & Interim Results

A. *Study Progress*

The research study, in particular, the qualitative data collection is still ongoing. Out of possible 39 interviews (considering that in some UoA the same industry supervisor was participating in several projects), 16 interviews were already conducted. Summed up this is roughly 14 hours of interview material at the present time. All interviews will be conducted until the end of September 2022.

B. *Case A: Unit of Analysis "Industry Partner C"*

Industry partner C is operating as TIER 1 supplier for the manufacturing of furniture with a company size of more than 330 employees (as of March 2021). Company C participated 5 times in the PI (2008/2009 and from 2015/2016 until 2018/2019 in a row) and experienced all three types of infrastructures. All project tasks were strongly related to the development of furniture and the controlling of moveable furniture.

In 2008/2009 the aim was to develop a safety feature for height-adjustable desks, which was rather a closed task. The industry supervisor for this PI project (supervisor C1) was to this time in a leading position in the middle management of the company. The interview is still pending.

The remaining four PI projects were all guided by supervisor C2, who was the innovation manager and acted as a staff position responsible for the innovation activities of the company.

In 2015/2016 & 2017/2018 the tasks were focused on the intuitive interaction/control with different types of furniture. In 2016/2017 it was a completely open task to identify the future of human-centered living and working. From 2015/2016 until 2017/2018 the supporting infrastructure was the 177 [sqm] project space/community space called DesignLab combined with the 130 [sqm] machine shop called FabLab. Due to multiple participation as supervisor, it's very difficult for C2 to distinguish how often he joined the students in the DesignLab in which project. At least 5 times within the three mentioned PI projects he was visiting the DesignLab.

2018/2019 the project task was related to the automated adjustment of furniture. For this project, the supporting infrastructure changed to the 800 [sqm] Schumpeter Laboratory for Innovation (SLFI), which combines a project space, community space, and machine shop in one facility. Approximately twice C2 joined the students in the SLFI during the PI project.

Initial Findings:

Industry partner C was strongly innovation-driven, had a staff position for innovation management, and operated an in-house corporate makerspace including extended prototyping capabilities. The company tried different approaches to integrate a standardized innovation process but the innovation activities were also high-level owner-driven, so the company owner decided mainly on the follow-up activities after initial ideas. Through further efforts over the years, they developed a so-called "Ideation Group" which reviewed interesting projects out of the predevelopment department or other innovation activities. The operation of the in-house makerspace caused several internal and legal barriers which hindered the use of the facility for the intended purpose. Problems like working time restrictions, IP concerns, and data security were named by C2.

In addition to the PI, the company made different experiences in other OI projects, e.g. 24h innovation sprints or collaboration with designers and artists were named. Besides the innovation sprints, where facilities in the context of project spaces were used, there was no supporting infrastructure available in the other OI projects. The importance of OI for the company was evaluated between medium and high importance.

With exception of the first PI participation where C1 was the supervisor, C2 was able to describe his experiences with the infrastructures used in the PI projects. The DesignLab combined with FabLab and the SLFI added beneficial effects to the PI projects. The open atmosphere, which is promoting a relaxed mood to generate ideas and an informal exchange and discussion of ideas was mentioned ref. to the DesignLab. In particular, the professional atmosphere of the SLFI was mentioned. According to the observation of C2, the professionally equipped infrastructure of the SLFI created a noticeable tension among the students and pushed their performance during the project. Depending on the respective project the results were partly usable for the company. The prototyping capabilities were useful as C2 stated, that several prototypes were of high quality.

The PI project results were never directly picked up to further develop them within the R&D department of the company, but different sub-results were used to integrate them into existing projects. The PI also lead to an intense dialogue and positive friction in terms of innovation activities between C2 and the company owner. As a negative aspect C2 described a very strong Not-Invented-Here syndrome (NIH) within the company, which occurred as a result of their strong innovation-oriented mindset inside the company. In general, it was very difficult to process OI project results from external sources, when the employees were not integrated into the project process. The same applies to the design thinking approach of PI, which didn't find further consideration inside the company. After the expiration of the partnership with the IIM, the cooperation wasn't extended.

C. *Case A: Unit of Analysis "Industry Partner U"*

Industry partner U is operating as a TIER 1 supplier in the automotive industry (manufacture of vehicle components). The company employs approx. 150 employees (as of March 2021) and participated 2 times in the PI (2016/2017 & 2018/2019). Since industry partner U is mainly developing and manufacturing valves, compressors, and system solutions both times the PI challenges were related to their core activities.

In the academic year 2016/2017 the PI challenge was to develop the next-generation valve technology. The challenge was formulated rather open and solution neutral. The industry supervisor (supervisor U1) was at this time the CTO of the company and was fully in charge of the R&D activities. In addition, the CTO was supported by an employee of the R&D department (supervisor U2), which later became his successor as CTO. The supporting infrastructure was the DesignLab combined with the FabLab. U1 himself visited the DesignLab 5-times to work together with the students on the challenge. Approx. 3 times he was accompanied by U2.

For the academic year 2018/2019 the challenge was to find suitable solutions for the digitalization of existing valve and compressor technology. Once again the challenge was rather open and solution neutral. U1 was no longer the CTO of the company and U2 as the new CTO was the industry supervisor. The supporting infrastructure changed to the SLFI for this project. U2 visited the SLFI several times during the PI. Despite U1 was no longer a supervisor, he was also familiar with the SLFI throughout other projects.

Initial Findings:

Industry partner U established an innovative mindset and operated a predevelopment and series development department. The series development department processed customer orders while the predevelopment department worked proactively on in-house developments with the goal to develop minimum viable products (MVPs) to demonstrate innovative technology applications to their customers for potential follow-up projects/orders. They structured the predevelopment activities by combining a stage-gate approach in the early phases with a scrum approach in later phases. The predevelopment department had adequate financial and personnel resources and infrastructural resources like 3D printers for rapid prototyping, an exhaustive test field environment, or capacities of the tool shop, which were also available.

To this point, the company had only limited experience in OI activities. Besides the cooperation with academic institutions in the form of academic theses, they maintained a relatively open relationship with their customers and suppliers in terms of intellectual property to gain early and fast feedback. They had no experience with makerspaces of any kind. In general, OI was of medium importance for the company at this time.

In both projects, the industry supervisors worked together several times with the teams in the related infrastructure. In this UoA the role of the infrastructure is strongly linked to the applied PI process. The main advantage of the DesignLab was the open, informal and comfortable atmosphere, which led in combination with the design thinking approach to the removal of thinking barriers of U1 and U2. U1 described their main problem in the application of the same solution approach for all innovation activities inside their company. The DesignLab contributed with the mentioned open atmosphere to support activities like tinkering and experimenting and supported creative thinking in the early stages of this PI project. For this UoA the rapid prototyping possibilities of the FabLab didn't play an important role because the in-house prototyping capabilities of the company could be used.

The results of the PI weren't followed up due to a lack of time caused by the prioritization of client projects. As a side effect, industry supervisor U1 tried to integrate the methodical approach of PI into the predevelopment department's innovation activities, but without consisting success. With U1 finally leaving the company the cooperation with the IIM wasn't extended.

D. *Notes to Initial Findings*

The initial findings should only provide a short outlook of possible results. The comprehensive data analysis will follow after the interview series is fully conducted.

What already can be seen is the immense importance of the companies' innovation mindset, the commitment of the supervisor to the PI project, and the supervisor's role inside the company to benefit from the PI project and its results.

It's interesting, that the apparently more innovative company C (strong innovation mindset, corporate makerspace, employed innovation manager) had heavy troubles with the NIH syndrome and several problems making use of their corporate makerspace in an intended way. For this UoA the used PI infrastructure was definitely important and built an easily accessible possibility for the PI participants to build prototypes. In comparison company U without a clearly defined innovation infrastructure but with the CTO as industry supervisor in charge the PI participants were able to make use of the company's prototyping capabilities. For this UoA the prototyping capabilities of the PI infrastructure weren't of high importance.

For the industry supervisors of both UoA the open and informal atmosphere of the Design Lab supported creative thinking, tinkering, and experimentation during the project, e.g. for the supervisors of company U, it helped to remove thinking barriers.

In both UoA the PI project results weren't directly picked-up to further develop them in specific projects or products. While company U didn't build up on the results due to a lack of time, company C had serious problems with the NIH syndrome. At least some sub-results found a way into projects of company C. Furthermore, company U also tried to apply the used methodical knowledge inside their predevelopment department.

With the complete conduction of the interview series, it is expected to gain more understanding of the different contributions of different types of infrastructure, correlating with the different project tasks and characteristics of the participating industrial companies.

Limitations of the Research

The limitations include obvious aspects raised out of the data sample, e.g. industrial partners which are operating and developing mainly in Austria as well as OI project-specific limitations, like the fact that only students are acting as makers in this type of OI project.

Furthermore, it needs to be considered, that there are tremendous differences in terms of responsibilities of the supervisors of the industry partners (position, department & decision-making ability). A further important aspect is the industry partner's knowledge about OI and innovation in general and their experience in OI projects. In a further advanced stage of this research, more limitations may appear.

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