RESULTS PRODUCED BY INTERACTIVE RESEARCH: EXAMPLES AND DISCUSSION

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ABSTRACT

This paper presents results produced in research projects using an interactive research approach. The results are categorised into three basic types: i) organisation/process-related results, ii) method/tools-related results, and iii) academic results. Some of the results suggest that an interactive research approach, where researchers and practitioners engage to co-produce knowledge, might lead to long-term effects in the companies that are involved. It is also shown that interactive research lead to academic outcomes in terms of publications and teaching materials.

INTRODUCTION

Various types of investigations and methods can be used in the research activity and all have different pros and cons. This paper is descriptive in its character and concentrates on collaborative research, where academics and practitioners co-produce knowledge. More precisely, the idea of this paper is to shed some light on outcomes originating from one type of collaborative research, i.e. interactive research. The paper presents different results produced using an interactive research approach. Such an approach refers to activities performed collaboratively by researchers and company representatives during all research phases including initiation and problem formulation, data collection, analysis and conclusion drawing (c.f. Svensson *et al*., 2007).

The paper rests upon results produced in six research projects carried out during 2005-2017. The projects involved several manufacturing companies. All projects followed an interactive research design. In the projects, product or production innovation were studied, but also integration between the two areas.

The paper is organised as follows. Next, a theoretical exposition is presented followed by an overview of six research projects carried with an interactive research approach. Thereafter, results from those research projects are presented and categorised. The paper ends with a discussion and final remarks section.

THEORETICAL EXPOSITION

A challenge for research in applied fields of research such as engineering and operations management is to create value for both academia and practice (Karlsson, 2016). It has been indicted that practitioners fail to adopt findings from research, and several top journals have highlighted that academic research tends to be less useful for solving practical problems (Van de Ven, 2007). In the literature, this is referred to as the theory-practice gap, which can be addressed in at least three different ways (Van de Ven, 2007). First, the limited use of scientific knowledge in practice is framed as a knowledge transfer problem. The underlying assumption here is that if an idea is good enough, it will be used. However, as pointed out by Van de Ven (2007), there is evidence that despite sound scientific knowledge might have been created, it is not used among the intended users. This means that the problem is related to translating and diffusing scientific knowledge in to practice, i.e. it is an issue of knowledge dissemination. Secondly, the theory-practice gap can be addressed by viewing scientific knowledge and practical knowledge as distinct kinds of knowledge (Van de Ven, 2007). This distinction was made already by Aristoteles, making a distinction between techne (knowledge for

action/know how), episteme (theoretical, scientific knowledge/know why) and phronesis (practical wisdom) (Hansson, 2007). Later, additional dimensions have been added, such as tacit practical knowledge and explicit epistemic scientific knowledge (Nonaka, 1994).

The insight that these different kinds of knowledge is complementary leads to the third way of addressing the theory-practice gap, i.e. as a knowledge production problem (Van de Ven, 2007). Already more than 20 years ago, a shift from research on industry to research together with the industry was advocated. It was argued that there was a shift from the traditional paradigm of scientific discovery denoted Mode 1 to a new paradigm of knowledge production described as Mode 2 (Gibbons *et al*., 1994). In Mode 1 research, the problems and solutions were governed by the academic agenda. According to the Mode 1 view on knowledge production, it follows a cycle, starting with development of knowledge, followed by dissemination, and later knowledge is applied on a real-world problem (Anderson, Herriot, & Hodgkinson, 2001). Mode 2 research is considered as a more reflexive approach, which involves a wider set of researchers and practitioners to address a specific problem (Gibbons *et al*., 1994) and within a context of application (Nowotny *et al,* 2001). There is, however, a risk to use such dichotomies because it simplifies reality where complexity and uncertainty of knowledge production processes call for various types of processes (Pettigrew, 2001).

During the years, several different ways of conducting research characterised by collaboration between researchers and practitioners have evolved, including action research, collaborative management research, interactive research, and participatory research, among others (Adler *et al*., 2004; Pasmore *et al*., 2008, Ellström, 2007; Coghlan and Coughlan, 2010). In this paper, we focus specifically on interactive research which: *"[…] is seen as a development of the action research tradition"* (Svensson *et al*., 2007 p. 233). Interactive research has received increasing attention in Sweden and the other Nordic countries and compared to action research, "*the interactive research approach focuses less on the researcher's role in, and responsibility for, the development work, but more on the joint learning process with the participants and the theoretical outcome of this joint learning" (*Svensson *et al.,* 2007 p. 238*)*.One fundamental point is that interactive research is expected to produce a common conceptualization and interpretation of the research object, which is fed back to the next cycle of problem solving activities (Ellström, 2007). The research approach advocates a need to engage *with* practice, rather than *for* practice (Svensson *et al*., 2007). The requires extensive efforts from both researchers and practitioners during the entire research process. Although the interactive research approach implies close collaboration and joint learning between researchers and practitioners, it is relevant to point out that researchers and practitioners enter the research process with different roles, interests and expectations on the results. As illustrated in the figure 1, the interactive research approach aims at producing both academic results and usefulness. Another word for usefulness, or practical applicability, is relevance (www.merriam-webster.com/dictionary/relevance). Relevance can be defined as the ability achieve results that satisfies the needs of the user

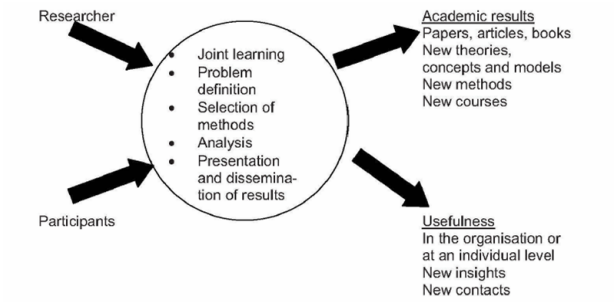

Figure 1: Different roles and interest in collaborative research process (Svensson *et al*., 2007).

However, whether the research is relevant or not depends on how the user appreciates the research results. Relevance must be viewed in the context of the stakeholders of the research carried out. Academic researchers and practitioners are acting with different stakeholders, which emphasises different requirements on the result. For researchers, academic results such as papers, new theories, concepts, models and methods are relevant, whereas practitioners often consider the usefulness, new insights and new contacts more relevant to be used for change processes (Svensson *et al*., 2007). Still, relevance is required both from the academic and the industrial perspective.

SIX INTERACTIVE RESEARCH PROJECTS

The main criteria for presenting results from the six research projects in this paper were that 1) all focused on either product innovation, production innovation, or both, 2) all were all based on an interactive research design and they were all carried out in industrial settings. In this paper, the projects are used as descriptive examples of projects carried out by an interactive approach. The idea of including all six projects is to present an array of potential results originating from an interactive approach and to show potential practical use of such results as well as their academic relevance and rigour. Table 1 summarises some key features of the six projects.

Four research projects (KNOP, STRATEGO, LEAP, INDUS) were carried out according to a similar four-phase logic. This logic was specified to ensure frequent interaction between the companies and the researchers. It was also defined to emphasise the responsibilities of the companies to engage in internal development

activities and hence knowledge production. The two other research projects (INTERFACE, DINO) followed a slightly different pattern. INTERFACE was based on a two-phase logic, where the first phase was based on an exploratory study followed by phase of close researcher-practitioner collaboration to develop a method for use in practice. However, this two-phase logic shows strong resemblance with the four-phase logic of the research projects KNOP, STRATEGO, LEAP, and INDUS. That is, the exploratory study involved a survey and diagnosis of the current state as well as feedback of the findings to the companies. Moreover, the second phase involved collaborative development of the method as well as testing and evaluation of the method. The DINO project, which was carried out as a real-time, longitudinal study of a single product development project, deviated more from the four-phase logic. It did not involve such explicit phases, but relied more on frequent data collection, constant dialogue, and interaction between the researchers and the practitioners throughout the entire project. The reason was due to the character of the research project, where a real-time study was carried out.

RESULTS PRODUCED

The results produced in the research projects presented in this paper can be categorised into three basic types: *i) organisation/process-related results, ii) method/tools-related results, iii) academic results*.

Organisation/process-related results refer to research outcomes that have an impact on how work is organised Method/tools-related results refer to research outcomes that are transformed into a method, tool or technique that support analysis or improvement of a specific task or situation. Academic results refer to publications or

Table 1: Overview of the research projects.

Project INTERFACE (Interfaces in Industrial Innovation Processes)
Aim: contributing with knowledge on how the interfaces between technology development and product development as well as between product development and production could be effectively managed *Industrial partners:* five medium-sized manufacturing companies *Study logic:* a two-phase logic with an initial exploratory phase, in which ten development projects were studied in-depth. Followed by a phase were a method was developed collaboratively between researchers and industrial partners.
Project DINO (Distributed innovation projects: Management of technological and organisational challenges in distributed settings)
Aim: develop a support tool that describes challenges that an industrial product development project must manage when product development and production are organizationally and geographically separated *Industrial partners:* a company that produces a wide variety of products for outdoor use and acts on a global market *Study logic:* a real-time, longitudinal study of a single product development project with extensive and frequent company-researcher interaction
Project KNOP (Learning and competence driven product introduction for the Swedish manufacturing industry)
Aim: contribute with knowledge on how a workplace develop competences and relations that support efficient product introductions *Industrial partners:* three manufacturing companies represented by two manufacturing sites and one R&D site. *Study logic:* four main phases, carried out iteratively: 1) survey and diagnosis, 2) feedback of results, 3) development initiatives, and 4) follow-up/evaluation.

Project STRATEGO (Manufacturing strategies supporting competitiveness in small and medium-sized manufacturing companies)
Aim: to increase the ability for small- and medium-sized manufacturing companies (SME) to use manufacturing strategies *Industrial partners:* initially five manufacturing companies in Sweden and subsequently four companies in Sweden and two in Singapore *Study logic:* four main phases in an iterative manner: 1) survey and diagnosis, 2) feedback of results, 3) development initiatives, and 4) follow-up/evaluation
Project LEAP (Long-term learning for improved innovation capability in global project-based development organisations)
Aim: to develop methods which support long-term learning, continuous improvement and enhanced innovation capabilities by making local knowledge globally accessible and utilized in the organization *Industrial partners:* three companies *Study logic:* four phases in an iterative manner. 1) Present-state analysis of existing lessons learned-methods and routines in the product development organizations at the companies, 2) Development, implementation and test of new methods, 3) Feedback from implementation and test activities, 4) Synthesis of results.
Project INDUS (Efficient industrialisation supporting successful production ramp-up in supply chains)
Aim: to support successful production ramp-up in a supply chain through efficient management of supplier involvement during industrialization process *Industrial partners:* four manufacturing companies *Study logic:* four phases in an iterative manner. 1) Problem-finding and diagnosis, 2) Feedback of results, 3) Development initiatives, and 4) Follow-up/evaluation

Table 2: Results from research projects based on an interactive research approach.

Organisation/process-related results	Project(s)
New work procedure	LEAP, KNOP
Method/tools-related results	
Handbook	STRATEGO
Analysis tool	INTERFACE, STRATEGO, DINO
Template for information/data collection	INTERFACE, LEAP
Academic results	
Journal articles, conference papers, case reports for teaching, thesis reports	INTERFACE, DINO, KNOP, STRATEGO, LEAP, INDUS

teaching material produced based on the research projects. These three types of results from the research projects are presented and discussed in the following sections. An overview of the types of results is shown in table 2.

ORGANISATION/PROCESS-RELATED RESULTS

Three of the research projects, LEAP, KNOP, and INDUS generated results that can be categorised as organisation/process-related results. In the LEAP project, it was identified that the companies had no structured or consistent way to collect and distribute learnings from former projects. Following this finding, a totally new work procedure for collecting, documenting, sharing and using lessons learned was defined for one of the participating companies. This new procedure was denoted: ”a lessons learned work flow”, and described how the company was supposed to ensure that experiences from earlier projects were captured and shared within the organisation. Both lessons learned in terms of ‘best-practices’ and improvement potentials were part of this new work procedure. A follow-up interview one year after the LEAP project was completed showed that the company had developed the work procedure even further and started to define an agenda for implementing the procedure on a global scale within the company. Figure 2 illustrates schematically the work procedure developed in the LEAP project.

The KNOP project lead to that the involved companies implemented a more structured way to work on product introductions. During the research project several changes were made, including establishment of a cross-functional meeting forum and definition of a product introduction coordinating role. Another change involved stronger emphasis on forums and activities to ease joint discussions between different organisational functions regarding product introduction. Furthermore, during the study an internal education effort was introduced regarding work procedures for product introduction.

Figure 2: Lessons learned work flow implemented in one company.

The INDUS project also produced results that can be described as organisation/process-related. In this project, the way of working implied that several development activities were identified and implemented. Many of the development activities were carried out jointly by several companies. Among these activities, communication of work processes, education in project management, and regular and more reliable information, can be mentioned. These activities might not be seen as direct effects on the organisation or processes, but led to more implicit effects. For example, the education in project management were not affecting the project management models, but were nonetheless essential for increasing the understanding and relevance of the models and their use. There were also activities carried out solely by one of the participating companies, aiming at improving their own way of working such as implementation of different lean-tools, including a summary sign-off and plan for every part.

METHOD/TOOLS-RELATED RESULTS

Several of the research projects produced results in the format of methods/tools. The INTERFACE project produced an analysis tool based related to six challenges for product development projects. The analysis tool includes statement for the challenges and each statement indicates a risk that might affect the project negatively. The user of the tool shall rank each statement on a scale from 1 to 6, where 1 indicates “completely disagree” and 6 indicates “completely agree” with the statement as it applies to the project. The total score for a specific challenge highlights a risk in the project and that preventive actions need to be implemented to manage the challenge before it becomes disruptive. The assessment tool is shown in figure 3. In addition, a checklist

Challenge	Total score	Challenge	Total score
A. Market uncertainty		D. Production complexity and/or degree of change in production	
B. Technological uncertainty		E. Dispersion between technology- and product development	
C. Product complexity and/or degree of change in the product		F. Dispersion between product development and production	

Figure 3: Analysis tool developed in the INTERFACE study (Lakemond *et al*, 2013; Johansson and Säfsten, 2015).

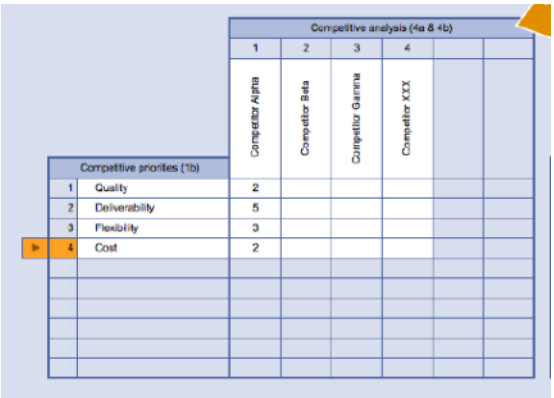

Figure 4: Analysis tool developed in the STRATEGO study (Säfsten *et al*, 2014).

was developed with ideas for how to deal with challenges that are potentially disruptive. The analysis tool produced in the INTERFACE project was operationalised as an Excel-tool to simplify the use of it. Follow-ups of the use of the INTERFACE tool a couple of years after the research project was completed showed that three of the companies that participated in the research project still used the tool in their product development activities.

The STRATEGO research project resulted in a handbook aimed at supporting SMEs to define their production strategies. The handbook included an analysis tool and a set of guidelines for strengthening of competitive factors. Figure 4 illustrates a section of the analysis tool and figure 5 shows some guidelines.

Quality

Guidelines - quality		Comments
1	Can change in level of automation contribute to improved quality?	Automation does not in itself solve problems with undeveloped processes. High level of automation will in that case lead to increased complexity, higher cost, and more quality problems.
2	Can set-up times be reduced?	Short set-ups enable smaller batches and earlier detection of quality problems.
3	Can quality be improved through change in product or process?	The base for right quality is stable processes. Robust design may also make the product more insusceptible of a not entirely stable process.

Figure 5: Guidelines developed in the STRATEGO study (Säfsten *et al*, 2014).

In addition to the work procedure developed in the LEAP research project, it also delivered a tool for collecting and classifying lessons learned for one of the companies. This tool was developed by the company, in a dialogue with the researchers, and is illustrated in figure 6. Like the INTERFACE research project, the DINO project also delivered a tool in the format of an Excel-tool as illustrated in figure 7. The tool included an extensive set of challenges related to integration between product development and production, and indicated the potential severity of the challenge based on ratings by the user. Furthermore, the tool provided the user with ideas for suitable integration mechanisms to manage the challenge. The tool was developed in close collaboration between the company and the researchers; in fact, a project manager at the company

	Experience	Comments	Impact on generic development	Project unique	Process	Technical	Test	Documentation	Customer	Other	Responsible
Budget											

Figure 6: Tool for collecting and classifying lessons learned.

specified the requirements to be set on the tool: it should 1) be easy to use, 2) capture earlier experiences, 3) be related to the company's project model, 4) include generic challenges relevant for many projects, etc. When the project ended, the tool was in a format of an advanced prototype which was handed over to the company. Interestingly, five years after the DINO project was completed, the company contacted the researchers to discuss whether a new collaborative activity could be defined to further develop the tool for possible implementation in the company. It should be noted that the company participating in the DINO project also participated in the LEAP project, and it saw synergies between the results from the research projects. That is, the tool developed in the DINO project was considered to potentially be used as part of lessons learned work procedure developed in the LEAP project.

The INDUS project also resulted in method/tools-related results. However, it differed from the types described for the other research projects. Even though the INDUS project expected to deliver a method/tool it was found, half-way through the project, that participating companies preferred to develop already existing work routines and procedures rather than developing a new, separate method/tool for the specific purpose of integrating suppliers into product development. Therefore, existing guidelines concerning, for example, ramp-up plans, plan for every part, summary sign-off were developed.

RISK	PROBLEM / UTMANING	TYP
3	Avoidance of design changes	T
	Mutual understanding of developent task	T
3	Project focus and discipline	T
2	Comunication with Chineese supplier	E
3	Be aware of the problems at EP and MP	E
1	Shanghai organisation not used to use SmarTeam	E
3	Tool changes not done between Eng. pilot 1 and 2	E
1	Too many project SOP at same time slot in Shanghai	E
2	Clear definition of Technical OK	E
2	Shanghai and R&D didn't have common dev. process	E

ACTION / ÅTGÄRD	TYP
Relocate employees	T
Applications for DFA method	T
Appoint liaison employees	T
Daily communication between the team leader and individual team members	T
Define roles and responsibilities for each team member	T
Define standards, protocols and rules	T
Seminars on cultural differences	T
Empower project team members as equals	T
Jointly define plans and schedules	T
Language training	T
Utilize product data management system (PDMS)	T
Internal Drawing Review was done with supplier by Shanghai factory	E
Feed back from choosen supplier on 3D data before tooling order	E
R&D Shanghai have to translate between R&D Sweden and supplier	E
Persons from R&D Swe represented at EP and MP	E
Manual handling of ECO's in TeamRoom	E
Feed back documents from R&D Swe were complemented with pictures after EP2	E
Picture with text and color that clearly shows changes in the ECO's as a complement to 3D and 2D	E
SQA resourses from Changzhou during the PPAP process	E
Four different TOK templates (categories) were defined	E
Working model was set how to handel ECR/ECO	E

Figure 7: Excel-tool produced in the DINO project.

ACADEMIC RESULTS

In addition to the outcome from the research projects in terms of results for practitioners (i.e. organisation/process-related results and method/tools-related results) as shown in table 2 and presented in the previous sections, academic results in terms of scientific publications were also produced. Even though the number of publications produced in each project has varied quite substantially, both journal articles and conference papers have been produced. Although even more rarely, case reports to be used in teaching have also been produced as well as thesis reports done by students that were engaged in the projects.

DISCUSSION AND FINAL REMARKS

The short-term effects in the companies that were involved in the research projects were quite immediate and led to attention to the questions and issues addressed in the research projects. The research projects and researchers acted as "moderators" for the companies to devote resources and to engage in a specific area represented by the questions and issues addressed. The research projects also lead to more long-term effects in the some of the companies. As was described earlier, the INTERFACE tool was still in use in three of the companies when follow-ups were done a couple of years after the research project was completed. Furthermore, one year after the LEAP project was completed one of the companies had developed the work procedure for lessons learned even further and started to define an agenda for implementing the procedure on a global scale. It should be noted, though, that all projects have not been followed-up in terms of long-term effects. Still, the examples from the INTERFACE and LEAP projects suggest that an interactive research approach, where researchers and practitioners engage to co-produce knowledge (c.f. Gibbons *et al*., 1994; Van de Ven, 2007), might lead to long-term effects in the companies that are involved.

The examples and categorisation of results presented in this paper, which all rest upon an interactive research approach, show that co-production of knowledge also result in academic outcomes in terms of publications and teaching materials. The interactive research approach (Svensson *et al.,* 2007) therefore provide opportunities to overcome the theory-practice gap (Van de Ven, 2007). The joint learning that is emphasised in the interactive research approach (Svensson *et al*., 2007) provides a basis for collaborative activities as shown in the examples from the research projects. The operationalisation of the joint learning efforts, through the collaborative activities, is an essential ingredient in the interactive research approach. In the research projects presented in this paper, the operationalisation was carried out via a four-phase logic where the phases followed an iterative procedure (with minor deviations between the projects): 1) Problem-finding and diagnosis, 2) Feedback of results, 3) Development initiatives, and 4) Follow-up/evaluation. Even though two of the projects did not follow this four-phase logic, they still included similar elements and involved extensive and frequent interaction between the researchers and the practitioners. The operationalisation therefore fit well with the fundamental idea of interactive research to produce a common conceptualization and interpretation of the research object, and to use this in cycles of problem solving activities which co-produces new knowledge that can be used for re-conceptualization and re-interpretation (Ellström, 2007). Despite the interactive research approach is based on joint learning and co-production of knowledge, the experiences from the research projects presented in this paper show that the researchers have a key role to play when defining the setup and plan for the research projects. As was mentioned earlier, the researchers acted as "moderators" for the companies to devote resources and to engage in development, implementation, tests, and evaluation of organisat-ion/process-related results as well as method/tools-related results. The interactive research approach is therefore quite demanding not only for the companies and practitioners involved, but also for the researchers. It is time-consuming and calls for exhaustive and frequent communication with the companies. Companies involved often need guidance regarding the collaboration. Therefore, it is essential to define roles and responsibilities early in the research project, but also to constantly monitor roles and responsibilities depending on the progress of the project.

This paper shows that a fairly large proportion of the outcome from the interactive research projects were in the format of different method/tools. This is not surprising, because many of the research projects aimed at producing such type of results. However, a central ingredient of interactive research approach is to involve the practitioners when the research project is defined, initiated and planned (c.f. Svensson *et al*, 2007). That is, it is critical to jointly define the aim and the research questions of the project to ensure both practical and scientific relevance. The companies involved in the research projects were engineering-driven organisations, in which the use of methods/tools is a natural ingredient in their business activities. Engineers are by education and training often taught to use different kinds of methods/tools and therefore the companies' expectations when setting up the research projects might reflect that results in the formats of methods/tools were considered positive outcomes. However, methods/tools are also a convenient way to codify knowledge (Hansen *et al,* 1999) and to make knowledge explicit for others, referred to as externalization (Nonaka, 1994). Methods/tools are not only a means to codify knowledge, but also a means to facilitate knowledge transfer. Results in terms of methods/tools can potentially be adapted for, and shared with companies beyond the ones involved in the research projects.

Still, in all research projects presented in this paper the type and format of the methods/tools were not specified in advance. The ideas of the methods/tools gradually developed during the research projects based on the findings from the early present-state analysis and the joint analysis of the findings as well as the extensive and frequent dialogue between company representatives and the researchers. The specific format of the methods/tools produced in the research projects presented in this paper are simple and often operationalised in an Excel-tool or as guidelines. A major reason why the methods/tools developed were simple is indicated by the DINO project. In the project, a practitioner from the company (a project manager) specified the requirements for tool. One of the most important criterion was that the tool must be easy to use. Time-consuming and complex tools were considered to be of less value, compared to a simple tool that could be used easily in the product development projects. As research projects based on an interactive research approach implies close collaboration and joint learning between researchers and practitioners (Svensson *et al*, 2007), such input from the practitioners regarding format and complexity of the methods/tools to be developed are therefore of key importance. If the practitioners are involved in specifying the method/tool requirements, the experiences from the research projects show that it increases the likelihood of implementation and long-term effects in the companies.

Emphasis in this paper has been on results from interactive research. The results have been categorised into three basic types: i) organisation/process-related results, ii) method/tools-related results, iii) academic results. As was noted earlier, experiences from the research projects show, that the interactive research approach is quite time-consuming for the researchers which might affect the potential to publish results during the project. This needs to be considered when engaging in interactive research. Still, the detailed and rich data collected especially during the initial phase of the project creates potentials for publications during the later phases of the project or after it is completed.

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