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Improving knowledge transfers in student engineering teams through the application of the InKTI - Interdepartmental Knowledge Transfer Improvement method

Monika Klippert ✉, Robert Stolpmann and Albert Albers

Karlsruhe Institute of Technology, Germany

✉ monika.klippert@kit.edu

Abstract

Managing knowledge successfully is key for an organization to increase its innovative potential. The InKTI method supports the improvement of knowledge transfers in product and production engineering. To ensure acceptance, applicability, and contribution to success in practice, it is necessary to validate the InKTI method. This paper focuses on evaluating the contribution to success in a Live-Lab study with student engineering teams. Based on the results two consecutive field studies have been conducted to evaluate not only the success but also support, and applicability of the InKTI method.

Keywords: *knowledge management, knowledge sharing, product and production engineering, method, improvement*

1. Introduction

To increase a company's innovative potential, all stakeholders within the organization must work together effectively and efficiently (VDI 2221, 2019). Therefore, the interdisciplinary collaboration of several departments within an organization depends on the successful management of knowledge (Bas et al., 2015). Several approaches and models describe how to implement knowledge management in an organization (cf. VDI 5610, 2009) and they highlight the importance of knowledge transfer as part of knowledge management (Lee et al., 2013; Al-Sa'di et al., 2017; Montgomery et al., 2023). Some describe how to support the improvement of knowledge transfers in a product development context (Albers et al., 2019; Klippert, Stolpmann and Albers, 2023). Additionally, the InKTI – Interdepartmental Knowledge Transfer Improvement method was developed, which presents five activities, that support engineers in improving knowledge transfers in product and production engineering (Albers et al., 2023). To enable acceptance, applicability, and contribution to the success of the InKTI method in engineering practice, the method needs to be validated early and continuously. Therefore, this paper contributes to an initial validation of the InKTI method through a Live-Lab study (Albers, Walter et al., 2018). Engineers should develop competencies and skills in managing knowledge within their team. So, two Live-Labs have been analyzed according to their current state of knowledge transfer, one of which was selected for this research. A concept of validation was developed, which includes the initial process of the application and the data collection. The validation concept was implemented in the Live-Lab IP - Integrated Product Development with seven student engineering teams (Albers, Bursac et al., 2018). Lastly, the InKTI method is evaluated in terms of its success in improving the knowledge transfer within a student engineering team. The findings and improvement potentials have been considered in the further development of the method. Based on the results of the improvement of knowledge transfers within student engineering teams two consecutive field studies have been conducted to evaluate the InKTI method not only according to its success but also its support, and applicability (Klippert, Schäfer et al., 2023; Klippert, Siebert et al., 2023). Those field studies are not part of this paper.

2. State of research

2.1. Knowledge transfer as part of knowledge management in product and production engineering

Since innovation cycles are becoming shorter and shorter, and market demands as well as regulations are increasing, companies need to reconsider their way of working (VDI 5610 2009). Especially developing and manufacturing companies face challenges such as organizational or disciplinary silos, which need to be broken down to enable purposeful collaboration and knowledge exchange across disciplines and locations (Guertler et al., 2022). To do so, it is necessary to bring product and production engineers closer together to develop and produce products as well as production systems in an integrated manner (Albers et al., 2022). Hence, the approach of Product-Production-CoDesign highlights the importance of knowledge management (Albers et al., 2022). Knowledge management is essential, as it provides a method to organize the conversion of resources into capabilities within a company. When keeping in mind, that aging employees are retiring in the next couple of years, making their personal knowledge accessible is key. Hence, knowledge management should be understood as a socio-economic challenge (Albers and Gausemeier, 2012). It is necessary to understand the difference between tacit and explicit knowledge and how knowledge is being transformed through externalization, internalization, socialization, and combination (Nonaka and Takeuchi, 1995). A key aspect of knowledge management is knowledge transfer (Lee et al., 2013; Al-Sa'di et al., 2017; Montgomery et al., 2023). Knowledge transfer is defined as the identification of knowledge by the knowledge carrier (e.g., product engineer), its transmission, and the application of knowledge by the knowledge receiver (e.g., production engineer) (Grum et al., 2021). To ensure efficient and effective knowledge transfer it is necessary to understand the challenges and problems (Montgomery et al., 2023, Raudberget and Wlazlak, 2022) as well as its potential (Liyanage et al., 2009).

2.2. Improvement of knowledge transfers in product and production engineering

To support the improvement of knowledge transfers in product and production engineering, the InKTI method has been developed (Albers et al., 2023), which is shown in Figure 1. This method is the basis for this research and has been validated in two field studies (Klippert, Schäfer et al., 2023; Klippert, Siebert et al., 2023) after the Live-Lab study presented in this paper.

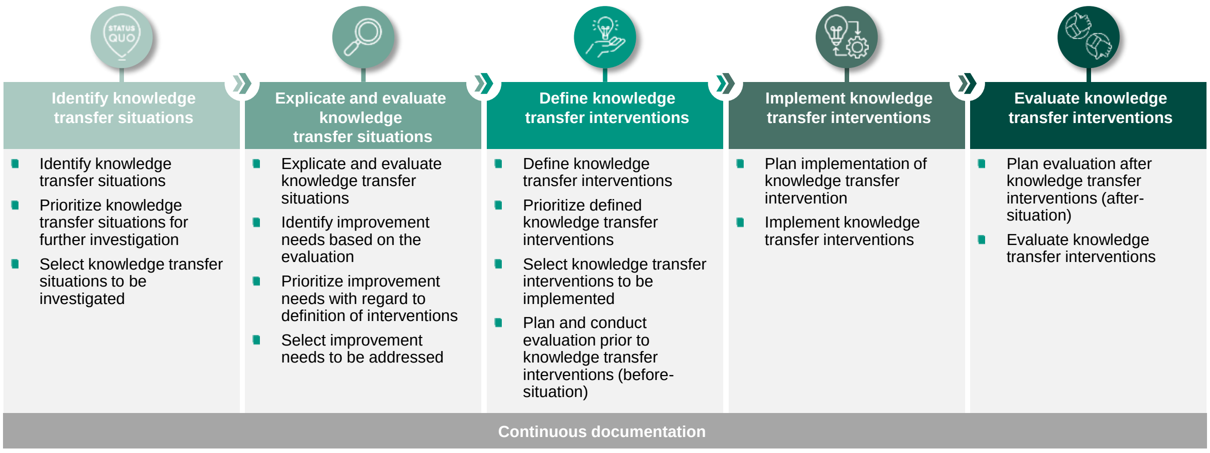

Figure 1. InKTI - Interdepartmental Knowledge Transfer Improvement Method (Albers et al., 2023)

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In the beginning knowledge transfer situations need to be identified, explicated, and evaluated (Albers et al., 2023; Klippert, Ebert et al., 2023). Based on the identified improvement needs so-called knowledge transfer interventions should be defined and implemented. The interventions to improve knowledge transfer in a specific situation can be very individual depending on either improving the quality (Klippert, Stolpmann and Albers, 2023) or speed (Albers et al., 2019) of knowledge transfers. For each intervention, there is an intervention template that characterizes the specific intervention (Grum et al., 2019; Klippert, Stolpmann, Grum et al., 2023). These templates include the title, a brief description of the before and after situation, the intervention, the theoretical background, the transfer type (cf. Sec. 2.1), and the practicability and feasibility of the intervention.
To evaluate knowledge transfer interventions, an objective measurement of the quality (Grum et al., 2021; Klippert, Stolpmann and Albers, 2023) or speed (Gronau and Grum, 2019; Albers et al., 2019) is needed using defined key performance indicators or requirements. To measure the quality of knowledge transfers, knowledge artifacts are evaluated according to an evaluation scheme proposed by Grum et al. (2021). Each of these requirements is rated according to the degree of fulfillment using the Likert scale (Likert, 1932). This scale allows an evaluation from "1: requirement not fulfilled" to "5: requirement fully fulfilled":

1. Requirement of correctness: knowledge artifacts need to represent the expectations of the knowledge carrier and receiver at least in essential features.
2. Requirement of relevance: knowledge artifacts do not need to be complete, but the facts relevant for the purposes must be represented.
3. Requirement of clarity: knowledge artifacts must be legible, understandable, and as clear as possible. They should be as simple as possible and only as complicated as necessary.
4. Requirement of systematic structure: knowledge artifacts must follow a systematic structure to reduce complexity.
5. Requirement of comparability: knowledge artifacts must follow the same guidelines and rules to be comparable.

Even though there are several approaches and methods described in the literature, it is always necessary to educate the users (e.g., product and production engineers) on the importance of knowledge transfer and how to improve it (Plappert et al., 2022). Therefore, the next section focuses on the validation of design processes, methods, and tools with a focus on collaboration with students.

2.3. Validation environments for design processes, methods, and tools

Live-Labs are situated between laboratory and field studies and enable the exploration of engineering processes, methods, and tools under real-life conditions while maintaining a high degree of controllability of the influencing factors. As a validation environment they combine the advantages and compensate for the disadvantages of laboratory and field studies (Albers, Walter et al., 2018). The Live-Labs developed at IPEK

- ProVIL - Product Development in the Virtual Idea Lab (Albers et al., 2016).
- IP - Integrated Product Development (Albers, Bursac et al., 2018)

consist of lectures, exercises, and project work with a special focus on project work with an engineering task from industrial practice.
One of the main goals of Live-Labs is to teach competencies and support students in building competencies through the use of various processes, methods, and tools in their engineering projects. According to Weinert (2002), competencies are the cognitive abilities and skills available in individuals or that can be learned by them to solve specific problems, as well as the associated motivational, volitional, and social readiness and skills to be able to use the problem solutions successfully and responsibly in variable situations. A distinction can be made between professional (e.g., physical, foreign language), interdisciplinary (e.g., problem-solving, teamwork), and action skills. Action skills can only be acquired in real-life situations such as project-oriented courses in the form of Live-Labs (Albers et al., 2013). In the case of this research knowledge transfer as part of knowledge management within a student engineering team should be supported.

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3. Aim of research and methodology

Looking at the current state of research it appears, that managing knowledge within an organization is key to ensuring efficient and effective collaboration between several departments. Even though knowledge management is investigated by many researchers, they rarely focus on knowledge transfer as part of knowledge management particularly between product and production engineers. Since successful interdepartmental knowledge transfers face different challenges and obstacles, the InKTI method (Albers et al., 2023) was developed to support engineers in improving knowledge transfers in product and production engineering. Hence, it is necessary to ensure acceptance, applicability as well a contribution to the success of the method in practice (Blessing and Chakrabarti, 2009). Since this research focuses on the latter, this study aims to support the improvement of knowledge transfers within student engineering teams by applying the InKTI method to gain knowledge for application in industrial practice. The following research questions (RQ) are addressed:

- RQ1. In which field of application can the InKTI method be applied in a Live-Lab? (Sec. 4)
- RQ2. How can the InKTI method be validated in the Live-Lab IP - Integrated Product Development in terms of its contribution to success? (Sec. 5)
- RQ3. Which measurable added value does the InKTI method offer in terms of improving knowledge transfers within a student engineering team in the Live-Lab IP? (Sec. 6)

To answer RQ1, the current state of knowledge transfer within a student engineering team in Live-Labs is analyzed. A suitable field of application shall be identified and the prerequisites for the application of the InKTI method shall be conducted to verify the chosen Live-Lab as a valid validation environment. Secondly, a validation concept should be designed, which includes an initial process of the application as well as the data collection format (answer to RQ2). To answer RQ3, the InKTI method is applied to the defined field of application, and the results of the application and evaluation are discussed. For the validation of the contribution to the success of the InKTI method the quality and speed of knowledge transfers are evaluated. Lastly, further improvement potentials of the InKTI method are presented.

4. Current state of knowledge transfer in live-labs and analysis of requirements for the validation environment

Albers, Bursac et al. (2017) compared the two Live-Labs ProVIL - Product Development in a Virtual Idea Laboraty and IP - Integrated Product Development based on success factors (see Table 1).

Table 1. Comparison of Live-Labs based on success factors; adapted representation from Albers, Bursac et al. (2018)

<table>
<tr><th colspan="2">Success factor</th><th>ProVIL - Product Development in a Virtual Idea Laboratory</th><th>IP - Integrated Product Development</th></tr>
<tr><td colspan="2">Focus</td><td>Application of methods</td><td>Selection and adaptation of methods</td></tr>
<tr><td colspan="2">Number of participants</td><td>Up to 48</td><td>Up to 42</td></tr>
<tr><td colspan="2">Duration</td><td>3,5 months</td><td>4,5 months</td></tr>
<tr><td colspan="2">ECTS</td><td>4 to 5</td><td>16 to 18</td></tr>
<tr><td colspan="2">Forms of collaboration</td><td>distributed, virtual</td><td>on-site, hybrid</td></tr>
<tr><td rowspan="5">Previous knowledge of students (based on lectures at KIT)</td><td>Specific competence</td><td>2 out of 5</td><td>4 out of 5</td></tr>
<tr><td>Method competence</td><td>0 out of 5</td><td>2 out of 5</td></tr>
<tr><td>Social competence</td><td>2 out of 5</td><td>2 out of 5</td></tr>
<tr><td>Creativity</td><td>0 out of 5</td><td>2 out of 5</td></tr>
<tr><td>Elaboration skills</td><td>1 out of 5</td><td>3 out of 5</td></tr>
</table>

In Live-Labs, students with different backgrounds (mainly mechanical engineering, mechatronics, and industrial engineering) develop product concepts with high innovation potential (Albers, Bursac et al., 2017). The students work intensively in interdisciplinary teams over several months on an engineering

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task. This task is set by a yearly changing industrial partner. The engineering process is divided into four to five phases, each of which begins with a kick-off and ends with a milestone.

In the Live-Lab IP, the students are taught relevant knowledge about processes, methods, and tools during the kick-offs and in process-accompanying lectures, workshops, and coaching. Each team works independently and self-responsibly and adapts processes, methods, and tools for their engineering process to achieve a desired outcome at the end of the phase. In doing so, they build up competencies, such as problem-solving skills, in addition to specialist knowledge. At the milestones, they present their results to the industrial partner, who evaluates their results (see Figure 2).

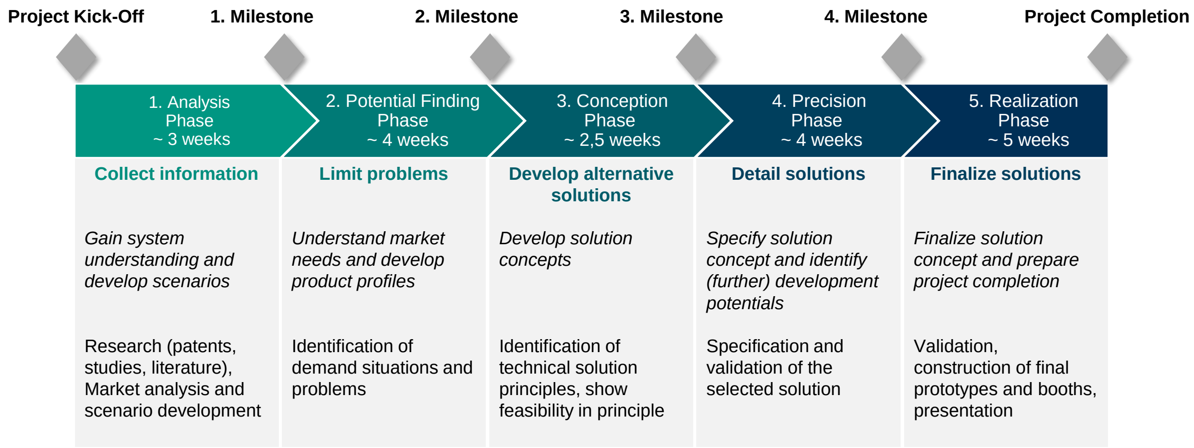

Figure 2. Phases, aims, and activities of the reference process in Live-Lab IP - Integrated Product Development; adapted representation from Albers, Bursac et al. (2018)

The Live-Lab IP provides a good basis for successful knowledge transfer, partly because the students work almost full-time on site (see Table 1). On the one hand, the students have good skills reagarding e.g. technical expertise in the field of product design or simulation. On the other hand they have potential for improvement in their method and social competencies, e.g. how to work in a interdisciplinary team, as well as creativity. At the beginning of each phase the students are taught the necessary knowledge for the upcoming phase in an kick-off event. Since each team designs its internal knowledge transfer differently, the focus of this study is on improving knowledge transfer within a team. To assess the suitability of Live-Lab IP in terms of using the InKTI method to support the improvement of knowledge transfer within a team, a survey was conducted with the study participants (here: IP students) (n=40 out of 42). In this survey, the students were asked if they faced challenges and problems with knowledge transfer within their team and if there was potential for improvement. The answer to this question was in the affirmative. Observations of different IP courses over the past years (cf. Klippert, Stolpmann and Albers, 2023) show, that challenges and problems with knowledge transfer occur throughout the entire engineering process. Examples include the unclear definition of responsibilities and tasks or the overabundance of tools used and the associated lack of knowledge of how to use them for their intended purpose. Furthermore, the IP students agree that they would like to improve their knowledge transfers and that methodological support, as well as a tool (e.g., action guide or training), would be helpful.

5. Concept for the validation of the InKTI method in the Live-Lab IP

For the validation of the InKTI method, a concept is developed, which includes the application and evaluation of the method. Figure 3 shows the five activities of the method as well as the target and actual process for the validation in the Live-Lab IP over 5 months. The application of the InKTI method accompanied the five phases of the IP project. The seven student engineering teams with six students each were divided into four test groups and three control groups. Both groups participated in the accompanying surveys, but only the test groups participated in the activities of the InKTI method.

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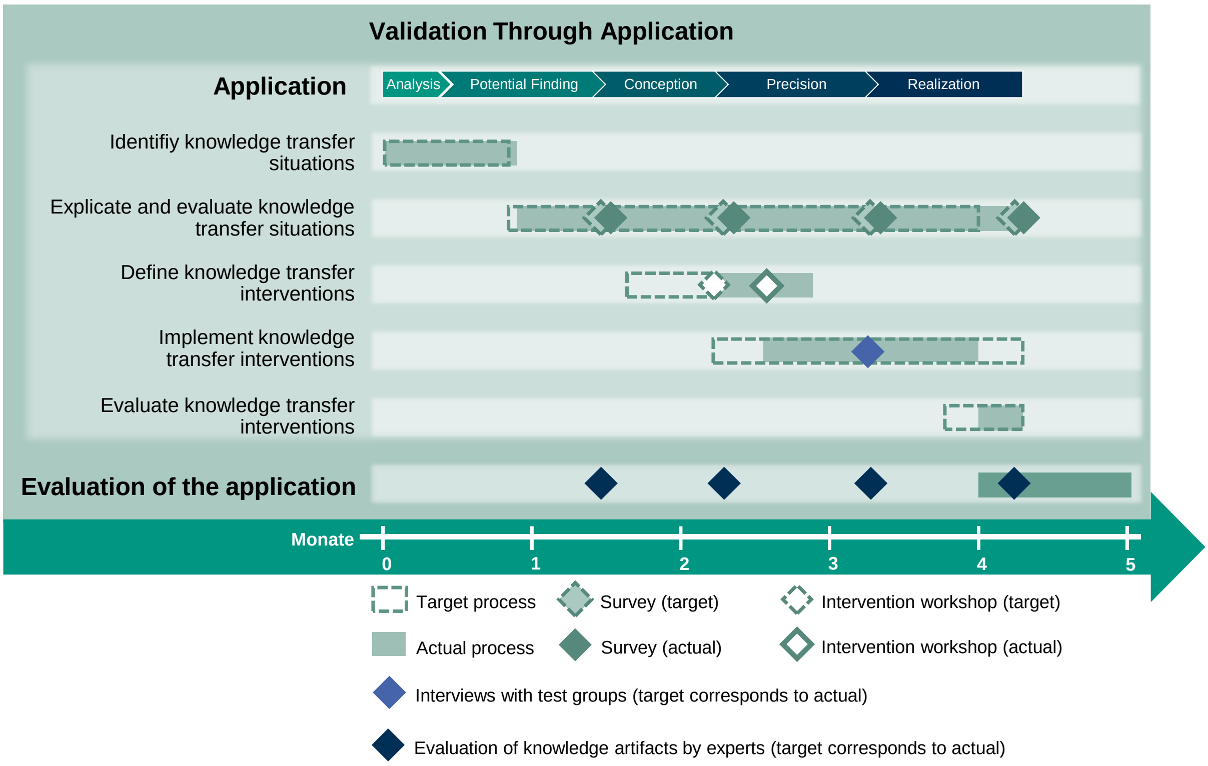

Figure 3. Comparison of the target and actual process of the application and validation of the InKTI method in the Live-Lab IP - Integrated Product Development

The following types of data collection have been used (see Table 2).

Table 2. Types of data collection in the Live-Lab IP - Integrated Product Development

	qualitative	**quantitative**
subjective	Interviews with study participants (test groups) and observations	Surveys with study participants (test and control groups)
objective	Process and document analysis	Evaluation of knowledge artifacts by experts

The potential finding and conception phases of the IP process were used to analyze the current knowledge transfer within all student engineering teams (control phases). At the beginning of the fourth phase (precision phase), the test groups identified potential for improvement in the knowledge transfer within their student engineering teams and defined knowledge transfer interventions as part of a workshop. They then implemented these independently in their engineering process. The last two phases of the IP process are also referred to as test phases, where the added value of the InKTI method should be apparent. The control phases help to better evaluate the results later, as it cannot be guaranteed that all teams have exactly the same set of skills.

After applying the InKTI method, its *contribution to success* is evaluated (cf. Albers et al., 2023). To determine the *quality of knowledge transfers* (E1), four knowledge artifacts (product profiles, product ideas, specified product ideas, and finalized product ideas) were evaluated by experts from the company partner at the milestones. Templates were provided to the students in advance for the development of the knowledge artifacts, hence, only the following evaluation criteria according to Grum et al. (2021) were used (see Sec. 2.2): requirement of correctness, relevance, and clarity. The use of these criteria allows an objective evaluation and comparability between the results. To determine the *speed of knowledge transfer* (E2), surveys were conducted with the test and control groups. The survey included questions regarding the duration, structure, and productivity of meetings within their student engineering team. For this purpose, the duration of meetings in minutes (approx. 15, 30, 60, 90, >90 minutes) and their structure (structured, rather structured, unstructured, not structured at all) were collected. In

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addition, the study participants were asked how they perceived the meetings concerning their duration (definitely too long, rather too long, appropriate, rather too short, or definitely too short) and productivity (very productive, productive, moderately productive, rather unproductive, very unproductive). This enables a subjective assessment of the speed of knowledge transfer.

6. Implementation of the validation concept of the InKTI method in the Live-Lab IP

In the following, the application as well as evaluation of the InKTI method in the Live-Lab IP is described.

Identify knowledge transfer situations: First, it is necessary to identify situations in which knowledge is transferred within a student engineering team. By analyzing the IP development process, observing and conducting surveys, various knowledge transfer situations were identified. An excerpt of these is shown in Table 3.

Table 3. Excerpt from the identified knowledge transfer situations in the Live Lab IP - Integrated Product Development

Name	Daily Meetings	Planning and distribution of tasks	Project documentation
Why?	Situation analysis and status update	Implementation	Preservation of knowledge
What?	Organizational topics	Project management topics	Topics related to process, product, and production
How?	Formal meeting	Formal/ informal meeting	Documentation of knowledge
Who?	Bilateral knowledge transfer of all team members	Bilateral knowledge transfer of all team members	Bilateral knowledge transfer of all team members
Where?	In-person, hybrid	In-person, hybrid, online/ digital	online/ digital
When?	Regularly	Regularly	irregularly

Explicate and evaluate knowledge transfer situations: Through surveys and observations, the identified knowledge transfer situations were explicated and evaluated both for the test and control groups. The categories of knowledge transfer, *conditions of the transfer situation*, *communication, technology and tools*, and *properties of knowledge* introduced in Klippert, Ebert et al. (2023) were analyzed. To give an example, meetings lasted up to 90 minutes, even though most of them were scheduled for 15 to 60 minutes. Whereas the test groups mostly plan and formalize their meetings, the control groups tend towards more unplanned and informalized meetings. The comparison between the test and control groups shows that knowledge transfer in the control phase (potential identification and conception phase) is very similar and that there is thus a similar need for improvement regarding *structured and documented communication***,** *continuous knowledge documentation*, or *uniform use of tools*.

Define knowledge transfer interventions: Based on the improvement needs, a workshop was held with each of the test groups to define knowledge transfer interventions (n=24 out of 24). First, the current state of knowledge transfer (based on the first two activities) was discussed to create a common understanding within the team. On this basis, the desired future state was formalized. To close the gap between the actual and target states, knowledge transfer interventions were defined. A total of 23 knowledge transfer interventions were defined across all test groups. These relate to the *communication*, *structure*, and *retrievability of knowledge*. To select the most suitable interventions for implementation, the defined interventions were then initially ranked in terms of effort and benefit by the team members of each test group. For each test group, two to four interventions were selected for implementation, some of which were composed of up to two thematically related interventions.

Implement knowledge transfer interventions: After the intervention workshop, the test groups concretized their selected knowledge transfer interventions. 10 out of the 23 knowledge transfer interventions have been implemented. Reasons against implementation include a lower effort-benefit

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ratio than initially assessed or addressing multiple characteristics through one intervention. As shown in the as-is process in Figure 3, an interview took place with each test group, each of which was conducted with a representative of the team and the author of this paper. This interview served to determine the current status as well as existing challenges and problems in implementing the knowledge transfer interventions. One test group, for example, addressed the knowledge transfer situation *project documentation* by developing a checklist for the creation of a new working directory. The introduced checklist and the new format of the work directory should increase the retrievability of knowledge and thus reduce queries. In addition, the structured filing and linking to further relevant content should speed up the search for relevant information.

Evaluate knowledge transfer interventions: To examine the extent to which the intervention workshop and the implemented knowledge transfer interventions contributed to an improvement of knowledge transfers in student engineering teams, a survey was conducted with the test groups. 14 out of 24 students who participated in the workshop took part in the survey. Thereby, 13 persons perceived the intervention workshop as helpful to very helpful, and only one person perceived the workshop as not helpful. For the evaluation of the knowledge transfer interventions, questions were asked about the degree of and the effort required for implementation as well as the benefits. In addition, specific questions were asked for each of the implemented knowledge transfer interventions regarding the improvement of knowledge transfer in the previously identified improvement needs (cf. method activity explicate and evaluate knowledge transfer situations). Overall, the effort-benefit ratio of the implemented knowledge transfer interventions was mostly appropriate, only a few interventions seem not have a positive effect according to the students. Improvements were perveived in the following:

- Test group 1: Clarity about communication processes and the tools used, as well as the structure, transparency, and retrievability of knowledge
- Test group 2: Loss of information, the structure, and retrievability of knowledge
- Test group 3: Transparency about the current project status and involvement in decision-making
- Test group 4: Good clarity, structure, and networking of information and documents, thus quick retrieval and avoidance of frequent queries

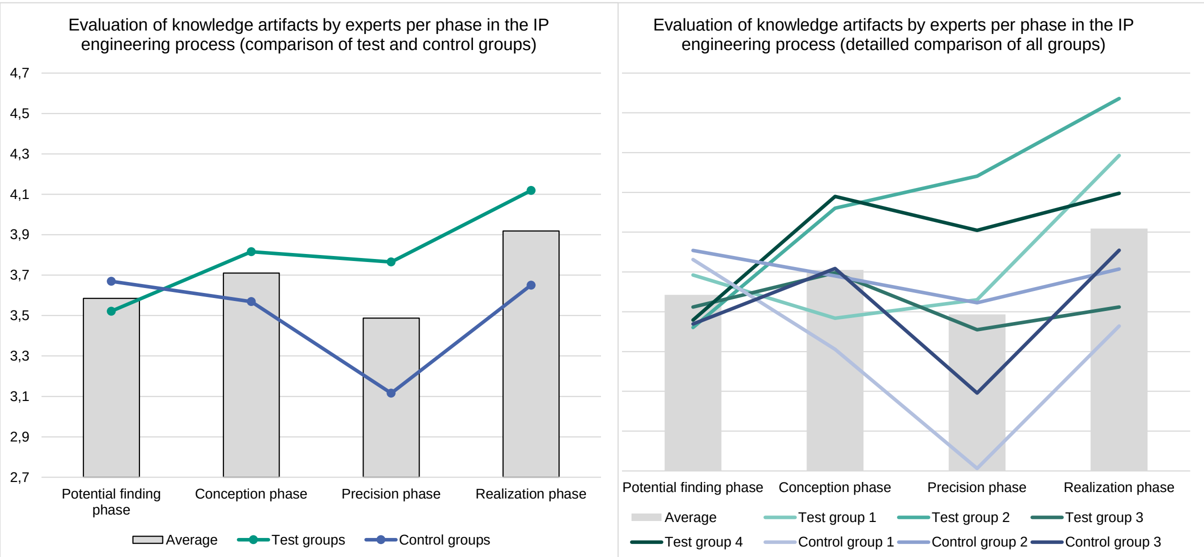

Figure 4. Comparison of the test and control groups based on the results of the evaluation of the knowledge artifacts by experts per phase in the IP engineering process (1 requirements not met to 5 requirements completely met (cf. Grum et al., 2021))

A comparison of the test and control groups is shown in Figure 4. During the control phases (phase 2 and 3), the quality of the knowledge artefacts was quite similar for all teams and the control groups even tended to have the better results. After applying the InKTI method, a clear trend can be seen. In phases 3 and 4 (test phases), the test groups almost all received better ratings than the control groups and the difference between the teams increased. The slightly lower rating of all teams in phase 3 could be due

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to the difficulty of this phase, e.g. the short time to develop three different product concepts. However, it can still be seen that the test groups performed better in this phase. Another finding is, that the improvement of knowledge transfer is highly dependent on the people involved in knowledge transfer, e.g. the motivation of the study participants and the time invested in deliberate knowledge transfer. In addition, it was found that for the implementation and continuous evaluation of the knowledge transfer interventions, it is important to have a facilitator from the team who ensures long-term implementation.

7. Conclusion and outlook

To address the existing research gap and research need, it has been investigated, whether the InKTI method supports the improvement of knowledge transfers within student engineering teams. To answer the first research question, two Live-Labs were compared regarding their suitability as a research environment for this study. Hence, a concept for the validation has been developed (answer to RQ2) and applied (answer to RQ3) in the Live-Lab IP, which has been chosen as a suitable validation environment. The results show, that the test groups applying the InKTI method were able to improve the quality and speed of knowledge transfers within their teams and achieve a better quality of project results (here: knowledge artifacts) in comparison to the control groups. In conclusion, by applying the InKTI method, an improvement of knowledge transfer within student engineering teams could be achieved in a realistic and partially controllable research environment, which already provides a basis for successful knowledge transfer. As a limitation it is necceray to consider the lower response rates from the participants towards the end of the IP project. Therefore, the results and findings of this Live-Lab study serve as an initial basis for the validation and application of the InKTI method in field environments. Due to the relatively small number of teams in this study, it is necessary to further confirm these results in a larger-scale study. This would reduce the influence of individual participants or other factors and allow a clearer statement to be made. Further insights and development potentials such as developing an action guide or training for an easier application have been identified, which need to be considered in the continuous improvement of the InKTI method.

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