From Concept to Market: Integrating Organizational Knowledge Creation to Bridge Technology and Business Gaps

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Abstract: This study explores the intersection of project development and organizational knowledge creation within the context of industry-academia collaboration, applying Nonaka and Takeuchi's organizational knowledge creation model as the theoretical framework. Conducted at the Manufacturing Laboratory (Manulab) at the Norwegian University of Science and Technology in Aalesund, the research investigates how integrating academic research into industrial applications can be optimized through effective knowledge management and the use of practical tools. The findings emphasize the critical role of knowledge workers, including researchers, engineers, sales managers, and decision-makers from the industry, in every project phase. A significant focus is placed on the Manulab-industry competence-building process, which progresses in parallel with the Technology Readiness Level and Business Readiness Level axes. This dual advancement strategy ensures that technological innovations meet both technical standards and market needs, enhancing their commercial viability. The study demonstrates that adopting a structured framework incorporating TRL and BRL helps overcome common challenges such as the creation of technically sound but commercially unviable technologies. Additionally, the integration of simulation platforms has facilitated the active involvement of diverse stakeholders throughout the development process, improving the practical application of Nonaka and Takeuchi's model. Specifically, the research tests two hypotheses: (1) that the use of TRL and BRL frameworks for tracking and verifying project progress is a practical tool for applying Nonaka and Takeuchi's model, and (2) that the use of simulation platforms in the product development process, by involving diverse stakeholders, significantly improves the alignment and synchronization of technology and business concept development. The research concludes that successful implementation of academic research in industrial settings requires a comprehensive understanding of organizational knowledge creation, strategic collaboration, and the use of practical tools like TRL and BRL. These findings advocate for a systematic approach to project development that emphasizes both theoretical knowledge and actionable insights for effective industry-academia collaboration.

Keywords: Organizational Knowledge Creation, Industry-Academia, Technology Readiness Level, Business Readiness Level, Collaboration, Innovation

1. Introduction

The interplay between academia and industry is a cornerstone for pushing the boundaries of technological innovation. Yet, the path from academic research to tangible industrial applications often encounters numerous hurdles. Recent research conducted at the Manufacturing Laboratory (Manulab) within the Norwegian University of Science and Technology in Aalesund highlights these challenges and illuminates the crucial role that knowledge workers play in every phase of organizational knowledge creation to ensure the success of projects (Hansen *et al.*, 2023). These knowledge workers include a diverse group of individuals, from researchers and students at Manulab to engineers at technology integration firms and various stakeholders within industrial companies such as operators, engineers, sales managers, and decision-makers.

Drawing upon the Manulab-industry competence-building process, which is inspired by Nonaka and Takeuchi's seminal model of organizational knowledge creation, this research explores the vital elements required to synchronize all participants into a unified, collaborative effort (Hansen, Mork and Welo, 2019; Nonaka and Takeuchi, 1995). A key element of this framework is the strategic use of virtual and physical prototypes, which provide a tangible medium for both industry and academic stakeholders to collaborate effectively.

The aim of this article is to evaluate the effectiveness of integrating Technology Readiness Level (TRL) and Business Readiness Level (BRL) frameworks, along with simulation platforms, in enhancing the practical application of Nonaka and Takeuchi's knowledge creation model in industry-academia collaborations. Specifically, this study tests two hypotheses: (1) that the use of TRL and BRL frameworks for tracking and verifying project progress is a practical tool for applying Nonaka and Takeuchi's model, and (2) that the use of simulation platforms in the product development process, by involving diverse stakeholders, significantly improves the alignment and synchronization of technology and business concept development.

This article delves into a comprehensive case study involving Manulab and the FishMech company to dissect the factors that contribute to successful research implementation. This partnership not only resulted in immediate project successes but also set the stage for a strategic, long-term competence-building initiative that continues to benefit both the university and the company. Moreover, the paper advocates for the implementation of TRL and BRL as critical tools to monitor and guide project development from its inception in the lab to its full-scale implementation in the industrial arena.

The forthcoming sections of this article explore the theoretical background, methodology, case study, and findings. Section 2 outlines the theoretical premises and hypotheses tested. Section 3 describes Manulab-industry competence-building process and details the TRL and BRL frameworks. Section 4 elaborates on the methodology, including the case study approach and workshops for data collection. Section 5 details the collaboration between Manulab and FishMech, highlighting key stages and outcomes. Section 6 presents findings from the case study and workshops, showing the impact of TRL, BRL, and simulation platforms. Section 7 discusses the verification of hypotheses and supporting evidence. Finally, Section 8 summarizes the findings, discusses practical implications, outlines limitations, and suggests future research directions.

2. Theoretical Background and Hypotheses

The need for an effective knowledge management (KM) approach in industry-academia collaboration projects is critical for facilitating technological advancement and innovation. Studies by Hermansand and Castiaux (2007) and Johnson and Johnston (2004) highlight the significance of knowledge conversion processes and enabling conditions, which are positively associated with technological achievements. This underscores the necessity of a structured KM approach to achieve successful outcomes.

In the context of Norwegian marine and maritime industries collaborating with academia through Manulab, the organizational KM model developed by Nonaka and Takeuchi has been adapted to suit the local context (Hansen, Mork and Welo, 2019). This model has proven valuable in fostering knowledge creation and innovation across several projects. However, there remains a pressing need to develop more practical tools for the effective implementation of this model.

Several other studies underscore this need for practical applications of the organizational knowledge creation model by Nonaka and Takeuchi. Researchers like Balde, Stoyanov, and Cabana advocate for tools that better address practical KM aspects. Balde (2018) and Stoyanov (2018) build on the SECI model, focusing on team trust, intrinsic motivation, and the conversion of tacit and explicit knowledge. Cabana (2021) emphasizes the role of wise leadership in balancing knowledge types and prioritizing long-term sustainability.

Additional studies explore KM dynamics in industry-academia collaborations. Marijan and Gotlieb (2021) proposes a participative knowledge creation model with active stakeholder involvement to meet both academic and industrial objectives. Gómez-Marín et al (2022) suggest a comprehensive KM model tailored for academics and business stakeholders, highlighting systematic management of knowledge flows. Hansen et al (2022) and Talab et al (2020) emphasize the critical role of universities in fostering innovation through agile principles and extensive knowledge collaboration.

While the Nonaka and Takeuchi model provides a solid foundation, there is a clear demand for the development of practical tools to enhance its application in organizational knowledge creation. Addressing team dynamics, leadership, and the balance between tacit and explicit knowledge is essential to drive innovation and achieve successful industry-academia collaborative outcomes.

Researchers working in Norway with Manulab observed that using simulation platforms in product development significantly increases the implementation of research results in real industrial settings. These platforms enable the involvement of operators, engineers, sales personnel, and decision-makers throughout the entire development process. This integration connects technology development with the evolution of business concepts. Consequently, the Manulab-industry competence-building process, derived from Nonaka and Takeuchi's organizational knowledge creation model, advances simultaneously along both the TRL and BRL axes. Building on these observations, the following hypotheses are proposed to explore the potential benefits of integrating TRL and BRL frameworks with simulation platforms:

Hypothesis 1: The use of Technology Readiness Level and Business Readiness Level frameworks for tracking and verifying project progress is a practical tool for applying Nonaka and Takeuchi's organizational knowledge creation model in industry-academia collaborations.

Hypothesis 2: The use of simulation platforms in the product development process, by involving diverse stakeholders (operators, engineers, sales personnel, and decision-makers), significantly improves the alignment and synchronization of technology and business concept development.

These hypotheses aim to evaluate the effectiveness of TRL and BRL frameworks, along with simulation platforms, in facilitating the practical application of knowledge management principles and improving collaboration outcomes between academia and industry.

3. Manulab-Industry Competence Building Process, TRL, and BRL

Drawing on the framework developed by Nonaka and Takeuchi, Manulab researchers have outlined a comprehensive six-stage process for competence development in Manulab- industry projects, as illustrated in Figure 1 (Nonaka and Takeuchi, 1995; Hansen *et al.*, 2023). This framework reflects the model of organizational knowledge creation by Nonaka and Takeuchi but also introduces specific stages tailored to Manulab.

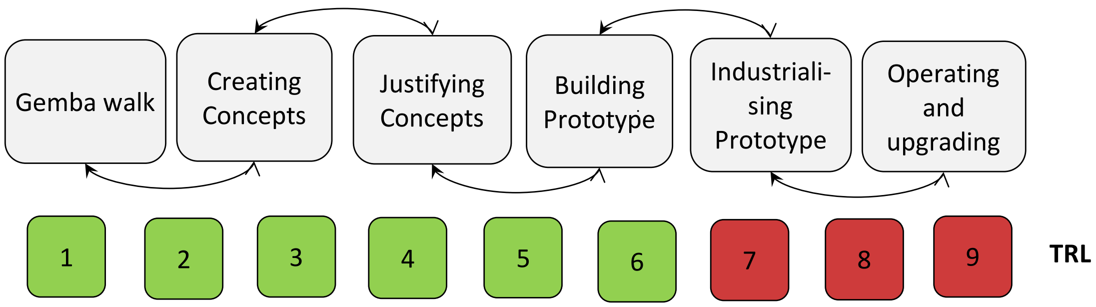

Figure 1: Manulab-industry competence building process in relation to TRL – when the research results are not implemented in industry

The process begins with a Gemba-walk, which promotes interaction between the corporate team and Manulab personnel (Womack, Jones and Roos, 2007). These Gemba-walks initiate cooperation through visits to manufacturing sites and Manulab, enhancing mutual understanding of methods, fostering connections, and identifying industrial challenges.

Following phases include "creating concepts" and "justifying concepts," as well as "building prototype." These phases are deeply connected and involve repeated adjustments between the conceptualization and prototyping stages.

The “industrialising prototype” stage signifies the deployment of the technological solution at the industrial facility. Typically managed by a system integrator, this stage requires detailed planning and may disrupt ongoing production. The system integrator is also charged with training staff and ensuring that the technology integrates smoothly into the current production environment.

The concluding stage, "operating and upgrading," involves industrial personnel and engineers who maintain and improve the system, while the system integrator focuses on maintenance and upgrades. Through collaborations between Manulab and industry, the Manulab-industry competence building process aims to close the gap between technological innovation and its practical implementation in industry. The technological innovation develops alongside the competence building process. As Figure 1 shows, the Technology Readiness Level rises together with the projects’ development. TRL is a metric used to assess the maturity of a specific technology, progressing from conceptualization to deployment. Here is a brief overview of the TRL stages according to Innovation Norway (2023):

1. *Basic principles observed***:** Initial scientific research translates into applied research. Phenomena are recognized, and potential applications are understood.
2. *Technology concept formulated:* Practical applications are formulated based on observed principles. The concept is speculative, lacking proof or detailed analysis.
3. *Experimental proof of concept:* Research and design efforts, including analytical and lab studies, validate predictions of separate technology elements.
4. *Technology validated in lab:* Technology is refined and validated through controlled experimentation.
5. *Technology validated in relevant environment:* Technological components are tested in a simulated environment, reflecting operational conditions.

6. *Technology demonstrated in relevant environment***:** A representative model or prototype is tested in a relevant environment to assess performance.
7. *System prototype demonstration in operational environment:* A near-final prototype is tested in the intended environment under expected conditions.
8. *Technology proven to work in its final form and under expected conditions:* The technology is completed and qualified through tests and demonstrations.
9. *Actual technology proven through successful deployment in operational environment:* The technology is fully developed and proven to work in its final form and under expected conditions.

These levels are essential for assessing technology maturity, managing developmental risks, and guiding technology from conceptualization to commercial deployment. Integrating TRL with the Manulab-industry model is crucial. Prior research on various collaborative projects between industry and Manulab revealed that, although project outcomes were satisfactory for the industry, they were not implemented in industrial settings. Figure 1 highlights this issue with TRL 7-9 in red, indicating project shortcomings at these levels. Previous studies using the Manulab-industry competence-building process investigated why these final phases were unsuccessful (Hansen *et al.*, 2023). A significant problem is the minimal involvement of decision-makers, system integrators, and sales leaders in the early stages, which hampers the integration of Manulab innovations into production environments. Additionally, excluding the Manulab team from later industrial stages reduces their potential to enhance operational technology.

To address the need for commercialization of research results, Manulab researchers decided to assess their projects in parallel with the Business Readiness Level framework. BRL measures the readiness of a new technology or product for successful commercialization (Innovation Norway, 2023). Since Manulab's projects success are evaluated by the commercial deployment of technology solutions, the BRL metric was crucial in the workshops. The BRL framework assesses commercial maturity across nine levels:

1. *Basic Principle Observed:* The core idea or principle behind the business initiative is identified, recognizing the potential opportunity.
2. *Technology Concept Formulated:* The concept is structured into a basic business model, outlining potential markets and preliminary value propositions.
3. *Proof of Concept:* The business concept is experimentally tested for feasibility through small-scale experiments or pilot studies.
4. *Business Model Validated in Lab***:** The model undergoes rigorous testing in a controlled environment to validate its functionality and effectiveness.
5. *Fidelity of Business Model Validated:* The model is tested in a simulated environment to assess its performance under near-real conditions.
6. *Prototype Model Tested:* A working prototype is developed and tested in a relevant environment, encountering real-world variables.
7. *Business Model Demonstrated in Operational Environment:* The model is fully implemented on a limited scale, including all aspects of operations and market engagement.
8. *Actual System Completed and Qualified:* The model is finalized and integrated into the operational framework, ready to meet specified performance standards.
9. *Business Model Proven and Ready for Full Deployment:* The model has been successfully proven through full-scale operations and is ready for widespread deployment, fully viable and sustainable in the market.

4. Methodology: Case Study and Workshops

Recently, Manulab has seen an increasing number of projects that not only reach industrial realization but also spawn subsequent initiatives with the same partners, often extending to include additional companies. To understand the drivers behind these successful outcomes, several workshops were conducted. Workshops serve as an effective research tool for gathering accurate and insightful data on advanced strategies (Ørngreen and Levinsen, 2017). The workshops aimed to identify the key factors contributing to project success and to determine how best to leverage these insights across other projects.

Three researchers and two engineers working in Manulab, and one the researcher and the chief of the research and development team in the industrial company participated in these workshops.

Alongside these workshops, the research team reviewed various project documents, including applications, meeting summaries, and final reports. The focus of the total four workshops was to examine industry-collaborative projects within the framework of Manulab-industry competence building process, as well as to promote the advancement of projects in terms of Technology Readiness Levels and Business Readiness Levels.

Four projects were selected as case studies for the workshops: one collaborated with a company that specializes in air filters, while the other three were associated with enterprises in the fish industry. The sizes of the companies involved vary significantly. The air filter company employs approximately 90 people. Two of the fish industry cases involved the same company, which has around 200 employees. The third case relates to a smaller fish company with about 40 employees. The case study focusing on this smaller company, which we will refer to as "FishMech" for the purposes of this article (this is not the company's real name), is detailed in the next section.

5. Case Study Fishmech-Manulab

FishMech, a company specializing in fish processing equipment, approached Manulab for expertise in camera vision and machine learning to enhance their market competitiveness. In addition to creating new devices, FishMech also upgrades and refurbishes existing equipment for resale.

The collaboration followed the structured phases of the Manulab-industry competence building process, starting with the Gemba work phase, which included multiple meetings at Manulab. During these sessions, researchers and engineers showcased their equipment, software, and case studies, emphasizing the importance of active participation from FishMech.

Attendees from FishMech included decision-makers, sales managers, engineers, and operators. Manulab also visited FishMech's facilities to understand their operations, equipment, production methods, market dynamics, and customer interactions.

After several discussions, Manulab and FishMech agreed to focus on integrating camera and machine learning technologies into a fish cutting machine, with an interested customer already identified. The technology integrator, familiar with both organizations, had previously collaborated with them, completing the initial Gemba work.

The project team included two engineers and three researchers from Manulab, one engineer, two operators, a sales manager, and a decision-maker from FishMech, and three engineers from the technology integrator. The project progressed through phases: "creating concepts," "justifying concepts," and "building a prototype," advancing from TRL 1 to 5. Figure 2 shows the project meeting where Manulab, FishMech, and the technology integrator discuss the virtual prototype.

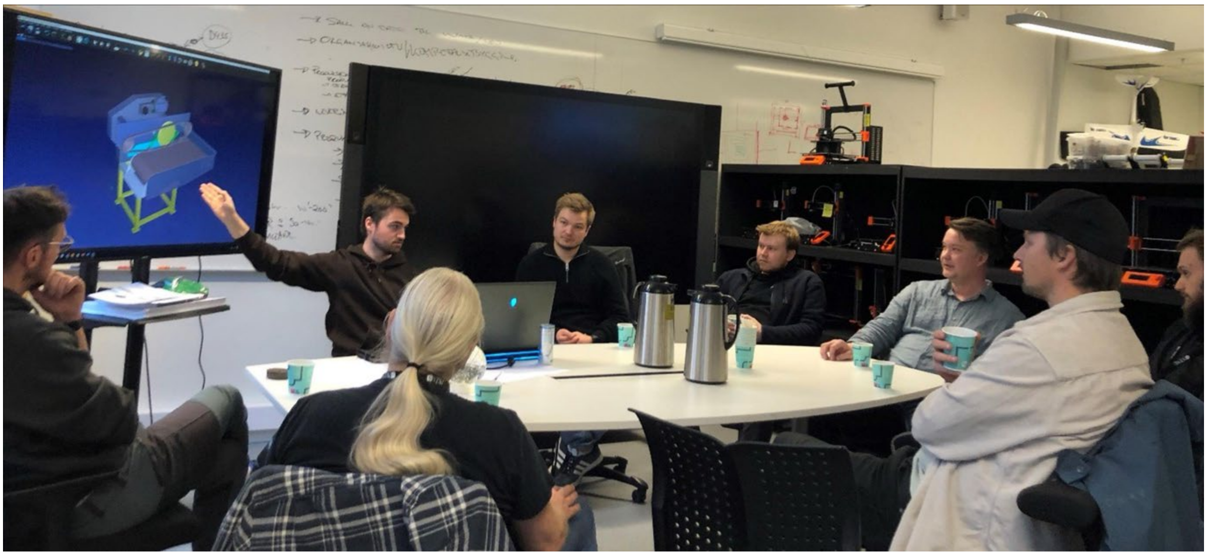

Figure 2: Project meeting FishMech, Manulab and technology integrator company

Several concepts were developed and justified by testing the virtual prototypes in simulation programs before the physical prototypes was first built in the Manulab facility as Figure 3 illustrates. This corresponds to the TRL 6.

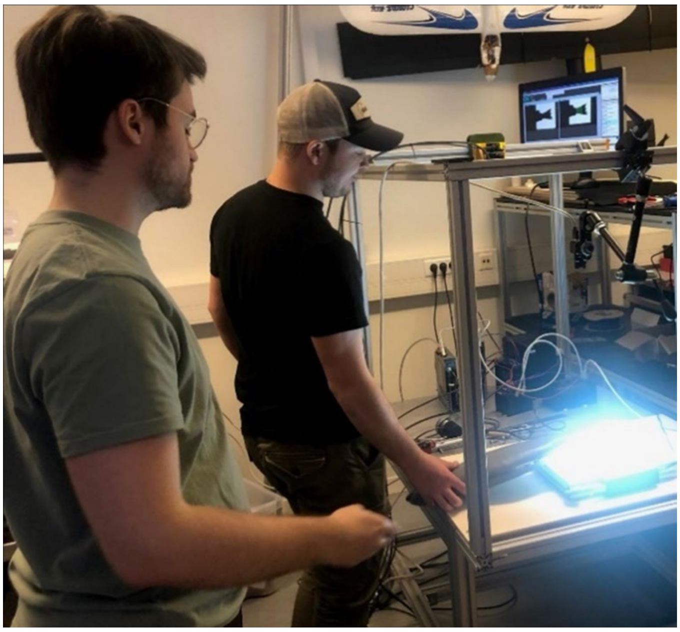

Figure 3: Building physical ptototype in Manulab

When this prototype was verified by the company and the technology integrator, it was transported in the manufacturing facilities of FishMech and integrated in the fish processing machine to test if the system was working as intended in the operational environment, which corresponds to the TRL 7. This is shown in Figure 4.

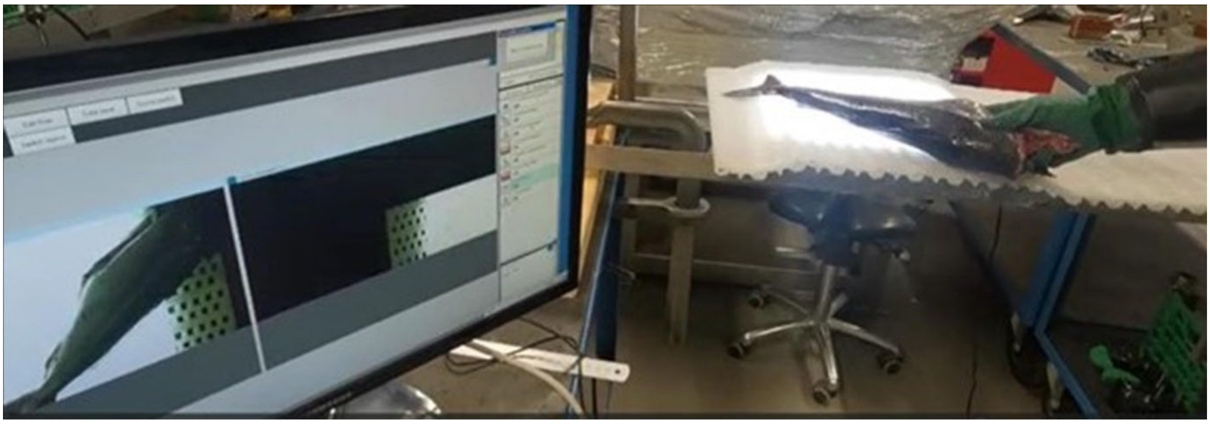

Figure 4: Test of the prototype in the FishMech facilities

Throughout the project, the partners actively collaborated in knowledge exchange and creation. A skilled operator from FishMech, with a professional diploma in automation, dedicated one day each week to develop a prototype in the university lab. Working closely with Manulab engineers, the operator gained significant insights into equipment design and simulation programs, while the Manulab team learned practical aspects of fish processing. This mutual exchange greatly influenced the design of fish processing equipment, especially in understanding the unique behaviors and anatomical features of fish.

The technology integrator company contributed their expertise in vision technology throughout the project. Numerous formal and informal meetings ensured consistent involvement and rich knowledge exchange among project members.

The developed solution has been successfully integrated into FishMech's machinery, demonstrating efficacy and reliability under operational conditions, achieving TRL 8. This milestone showcases the technology's readiness for broader application. FishMech has already attracted interest from customers, indicating market receptivity and a shift toward advanced methodologies in fish processing.

Manulab's expertise in advanced manufacturing and prototyping was instrumental in transitioning the concept into a viable product. Their optimization of machine learning algorithms and vision systems ensured the solution met industry standards. The technology integrator played a crucial role in seamlessly incorporating new systems into existing processes, addressing deployment challenges and ensuring a smooth transition.

The enthusiastic customer response brings the project closer to commercial deployment, aligning with BRL 8. This level involves not only launching the product but also expanding and optimizing business operations. For FishMech, this means refining their go-to-market strategy, enhancing customer support, and potentially scaling production to meet demand. With the combined efforts of FishMech, Manulab, and the technology integrator, the project is set to revolutionize fish processing operations, improving efficiency and sustainability in the industry.

6. Findings

This section elaborates on the results derived from the workshops evaluating four distinct projects, focusing on their progression through key developmental metrics and stakeholder engagement. Figure 5 shows Manulab-industry competence building process alongside TRL and BRL development.

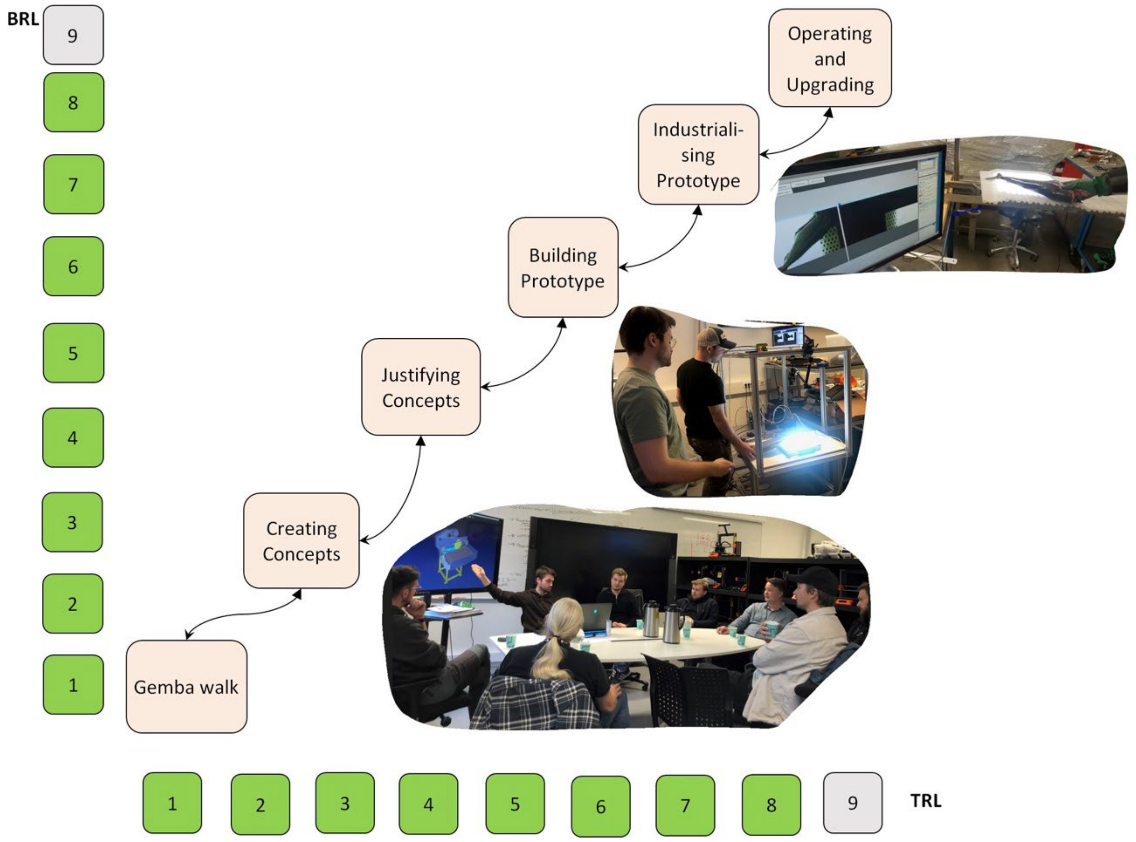

Figure 5: Manulab-industry competence building process alongside TRL and BRL

7. Utilization of TRL and BRL as Project Development and Competence Building Indicators

The projects, including the collaboration between Manulab and FishMech, successfully progressed through the Manulab-industry competence building process by simultaneously advancing along both TRL and BRL metrics, as depicted in Figure 5 . This concurrent advancement is crucial as it ensures that research outcomes are not only technically feasible but also economically viable and ready for real-life implementation. The findings suggest that the TRL and BRL metrics are effective tools for mapping the journey of a project from concept to execution, providing a clear framework for tracking progress in both technological development and market readiness. By understanding and utilizing these metrics, organizations can better navigate the complex landscape of collaborative project development, ensuring that each phase aligns with both technical specifications and business objectives.

7.1 Enhancing Project Effectiveness Through Inclusive Engagement of Stakeholders, and all Organisational Levels in the Industrial Company

The analysis underscored the significance of inclusive engagement, involving a diverse range of personnel- from ground-level operators and engineers to upper management and decision-makers within the industrial company. This comprehensive involvement ensures that strategic decisions, such as finalization of production strategies, small-scale operations, and marketing tactics for the technological solutions, are well-informed and broadly supported. Moreover, engaging technical staff like operators and engineers in the process facilitates a smoother transition of innovations from the laboratory to real-world applications. This strategy not only maximizes the effectiveness of the projects but also expands their impact by incorporating diverse perspectives and expertise, which is essential for addressing real-world challenges effectively.

7.2 Strategic Commitment to Knowledge and Business Development

For the partnership between a company and a university to be fruitful, both parties must recognize and commit to filling a specific knowledge gap that promises long-term competitive advantages. When such a need is identified, the company is more likely to dedicate necessary organizational and financial resources, fostering an environment conducive to effective collaboration. This strategic alignment between the partners' goals and the project’s objectives ensures that both parties are equally invested in the project's success and can reap substantial benefits from their joint efforts. This commitment is crucial for the seamless translation of laboratory research into practical, industrial applications, enhancing the overall value and impact of the collaborative project.

7.3 Important Role of Simulation Platforms in the Competence Building Process

The use of simulation platforms is instrumental in bridging the gap between diverse stakeholder groups, such as engineers, financial analysts, and decision-makers. These platforms serve as critical tools for knowledge exchange and co-creation, allowing for iterative testing and refinement of project designs in a virtual environment. They enable stakeholders to provide direct feedback on both the technical and business aspects of a project, thus enhancing the design and functionality of the solutions. By demonstrating technological effectiveness and market viability, simulation platforms play a pivotal role in attracting investment and ensuring alignment with broader business strategies. This iterative, inclusive approach to simulation-based development and evaluation not only fine-tunes the project outcomes but also significantly contributes to the robustness and readiness of the technology for market introduction.

8. Discussion: Verification of Hypothesis

Hypothesis 1: The use of Technology Readiness Level and Business Readiness Level frameworks for tracking and verifying project progress is a practical tool for applying Nonaka and Takeuchi's organizational knowledge creation model in industry-academia collaborations.

The case studies from Manulab provide robust evidence supporting this hypothesis. Projects that incorporated TRL and BRL frameworks demonstrated a more systematic and structured approach to development. These frameworks facilitated a clear progression from conceptualization to commercialization, ensuring that technological innovations were both technically mature and market ready. For instance, the FishMech project showed that by systematically advancing through the TRL stages, the team could effectively validate technological components and integrate them into operational settings. Similarly, the use of BRL helped align the project's business objectives with market needs, ensuring commercial viability. This dual tracking of technological and business readiness enhanced the overall effectiveness and implementation of research outcomes in industrial settings, confirming the practical utility of TRL and BRL frameworks in applying Nonaka and Takeuchi's model.

Hypothesis 2: The use of simulation platforms in the product development process, by involving diverse stakeholders (operators, engineers, sales personnel, and decision-makers), significantly improves the alignment and synchronization of technology and business concept development.

The FishMech project highlighted the critical role of simulation platforms in fostering effective stakeholder collaboration. By providing a virtual environment for testing and feedback, these platforms allowed for continuous interaction among operators, engineers, sales personnel, and decision-makers. This inclusive approach ensured that diverse perspectives were integrated into the development process, leading to more comprehensive and aligned technological and business strategies. The iterative nature of simulation platforms facilitated real-time adjustments and improvements, which enhanced both the technical robustness and market readiness of the final product. The active involvement of all stakeholders not only improved the project's outcomes but also strengthened the collaboration between academic and industrial partners, thereby validating the second hypothesis.

9. Conclusion

This study confirms that integrating TRL and BRL frameworks with simulation platforms effectively applies Nonaka and Takeuchi's knowledge creation model in industry-academia collaborations. The use of these practical tools enhances the systematic development of projects, ensuring that innovations are both technically sound and commercially viable. The case studies from Manulab demonstrate that such an approach leads to better alignment and synchronization of technological and business developments, fostering more successful project outcomes.

For organizations seeking to enhance their collaborative projects, adopting TRL and BRL frameworks and utilizing simulation platforms are critical steps. These tools not only help track project progress but also ensure that both technological and business objectives are met. Engaging diverse stakeholders throughout the development process is essential for achieving comprehensive and effective project outcomes. The structured approach demonstrated in this study provides a practical roadmap for organizations to follow, facilitating better alignment between research and real-world application.

While the study provides valuable insights, it is based on a limited number of case studies, which may not fully capture the diversity of industry-academia collaborations. Additionally, potential biases in project selection and participant involvement may influence the results. The specific context of Manulab and the Norwegian industrial environment may also limit the generalizability of the findings. Further research with a broader range of case studies and more diverse participant groups is needed to validate and expand upon these findings.

Future studies should explore the long-term impacts of integrating TRL and BRL frameworks on project success across various sectors. Additional research is needed to refine the role of simulation platforms at different stages of project development and across different industries. Understanding how these tools can be tailored to specific contexts will provide deeper insights into their effectiveness and broader applicability. Furthermore, investigating the role of power dynamics, tensions, and stakeholder differences in the use of these tools can offer a more nuanced understanding of their impact on collaboration outcomes.

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