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Artificial intelligence (AI) in strategic collaborations for product development: A case study in the biotechnology and pharmaceuticals industry.

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Patras, Greece, May 2026

“Artificial intelligence (AI) in strategic collaborations for product development: A case study in the biotechnology and pharmaceuticals industry.”

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"To Christine and Dimitra;
my driving force throughout this journey"

Abstract

The aim of this dissertation is to explore the role of Artificial Intelligence (AI) in collaborative product development within strategic partnerships in the Life Sciences. The selected case study focuses on Symbeeosis ELIXIRS, a brand offering a wide range of organic functional supplements using a combination of bee ingredients and botanicals. The existing literature has studied AI either in the context of a single firm, or in the field of pharmaceutical drug development. Very few studies focus on how AI operates across partners in nutraceutical and consumer health product innovations. This study aims to address that gap.

This research adopted a qualitative, single-case-study approach. Ultimately, seven role-based interviews were conducted, which were subsequently supplemented by a collection of relevant project materials. The analysis identified aspects of AI use, areas that required human judgement, and how partners organized their knowledge and evidence as well as their respective documentation and decisions.

The research revealed that AI operates as a governed support system. Rather than replacing specialists, it provides support to partners in the fields of market analysis, literature background development, evidence synthesis, drafting, claims preparation and communication, and the translation of a broad wellness vision to the ELIXIRS product category of IMMUNE, ENERGY, BRAIN and RELAX. Overall, there was an improvement to the workflow and the system enhanced the alignment of partners.

This dissertation provides insight into theories of resources, capabilities, knowledge integration, open innovation, and socio-technical governance and their interconnections. The findings demonstrate that AI can support collaborative product innovation. This can be achieved when enough high-quality data is available. Clear decision rights are also essential. AI use must also be guided and governed. Finally, specialists need to identify value in the system.

Keywords

Symbeeosis ELIXIRS
Artificial Intelligence (AI)
Strategic Alliances
Nutraceutical Innovation
Collaborative Product Development
Knowledge Integration

Περίληψη

Στόχος της παρούσας διπλωματικής εργασίας είναι η διερεύνηση του ρόλου της Τεχνητής Νοημοσύνης (AI) στη συνεργατική ανάπτυξη προϊόντων, στο πλαίσιο στρατηγικών συνεργασιών στον τομέα των Βιοεπιστημών. Επικεντρώνεται στην περίπτωση των Symbeeosis ELIXIRS, μιας σειράς βιολογικών λειτουργικών συμπληρωμάτων διατροφής, που συνδυάζουν συστατικά των μελισσών και φυτικά εκχυλίσματα.

Το υπάρχον βιβλιογραφικό υπόβαθρο εξετάζει κυρίως τη χρήση AI, είτε στο πλαίσιο μιας μεμονωμένης επιχείρησης, είτε στον τομέα της ανάπτυξης φαρμακευτικών προϊόντων. Ελάχιστες μελέτες έχουν εστιάσει στον τρόπο με τον οποίον η χρήση AI αξιοποιείται μεταξύ συνεργαζόμενων εταίρων· ιδίως στον τομέα της καινοτομίας συμπληρωμάτων διατροφής και προϊόντων υγείας. Η παρούσα έρευνα επιδιώκει να καλύψει αυτό το κενό.

Η έρευνα υιοθέτησε μια ποιοτική μεθοδολογία, μιας μεμονωμένης περίπτωσης. Συνολικά πραγματοποιήθηκαν επτά συνεντεύξεις με στελέχη διαφορετικών ρόλων, συλλέγοντας ταυτόχρονα άλλο σχετικό υλικό από τα λοιπά έργα της σύμπραξης. Η ανάλυση ανέδειξε τα πεδία αξιοποίησης της AI και τους τομείς που απαιτούσαν ανθρώπινη κρίση. Εξέτασε τον τρόπο με τον οποίον οι εταίροι οργάνωσαν τη γνώση, τα δεδομένα τους, την αντίστοιχη τεκμηρίωση, καθώς και τις αποφάσεις τους.

Τα ευρήματα δείχνουν ότι η χρήση AI λειτούργησε ως ένα ελεγχόμενο σύστημα υποστήριξης, χωρίς να αντικαθιστά τους ειδικούς. Συνέβαλε ουσιαστικά στην ανάλυση της αγοράς, στις βιβλιογραφικές ανασκοπήσεις, στη σύνθεση επιστημονικών τεκμηρίων, στη σύνταξη κειμένων, στην προετοιμασία ισχυρισμών και στην επικοινωνία. Παράλληλα διευκολύνει τη μετάφραση ενός ευρύτερου οράματος ευεξίας στην κατηγορία των ELIXIRS προϊόντων, IMMUNE, ENERGY, BRAIN και RELAX. Αξιοσημείωτη ήταν και η βελτίωση της ροής εργασίας και της ευθυγραμμισμένης δράσης των εταίρων.

Η μελέτη συνδέει τα ευρήματα με θεωρίες πόρων και ικανοτήτων, ενσωμάτωσης γνώσης, ανοιχτής καινοτομίας, απορροφητικής ικανότητας και εταιρικής διακυβέρνησης. Τα ευρήματα καταδεικνύουν ότι η χρήση AI δύναται να στηρίξει αποτελεσματικά τη συνεργατική καινοτομία προϊόντων, υπό την προϋπόθεση ύπαρξης υψηλής ποιότητας δεδομένων, σαφώς καθορισμένων δικαιωμάτων λήψης αποφάσεων και κατάλληλης καθοδήγησης και διακυβέρνησης. Τέλος, καθίσταται απαραίτητη η αναγνώριση της αξίας του συστήματος από τους ειδικούς.

Λέξεις – Κλειδιά

Symbeeosis ELIXIRS
Τεχνητή Νοημοσύνη (AI)
Στρατηγικές Συνεργασίες
Καινοτομία Λειτουργικών Τροφίμων
Συνεργατική Ανάπτυξη Προϊόντων
Ενσωμάτωση Γνώσης

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1. Introduction

1.1 Background and Context

AI transforms competitive advantage and innovation in knowledge-intensive industries, including biotechnology and pharmaceuticals. Certain sectors present more challenges than others. Some industries have extended R&D cycles. Development decisions for health and wellness products and services are governed by more stringent evidence, quality, and reliability requirements. Development decisions also need to address practical health and wellness considerations, particularly in terms of prevention, nutrition, and wellness (Bagchi & Nair, 2016; Mak & Pichika, 2019; Vamathevan et al., 2019).

At the same time, life sciences innovation has moved toward collaboration with the aim of making new products. Pharmaceutical corporations, biotechnology firms, functional and nutraceutical businesses, and academic institutions are increasingly forming strategic alliances to utilize complementary knowledge, mitigate risk, and accelerate the progression from discovery to commercialization. Alliances like these bring together a wide range of skills, such as formulation science, regulatory relations, and specialized research. At the same time, they impede coordination and control across organizational borders.

Multiple AI technologies can assist in knowledge-intensive tasks in varied stages of the development process. For example, these tools can help development teams in the process of engaging with pertinent literature and evidence, drafting and/or designing, preparing for upcoming meetings, structuring tasks and evidence related to said meetings. AI can also provide assistance with computational screening and other associated in silico work in the context of life-science applications. However, even advanced AI systems require formal assessment and/or independent regulatory judgment by experts (Huang and Rust, 2021; Müller, 2020; FDA, 2025).

Collaborations in product and service development can utilize support from many types of AI, including, but not limited to, tools to help with literature searching, evidence synthesis, drafting, coordination of workflows, initial in-silico evaluations and various types of creative support.

Other tools are included only as contextual illustrations of related AI capabilities, and in the ELIXIRS case, they are not considered implemented tools. Microsoft Copilot Studio and OpenAI agent workflows are examples of frameworks that connect information sources and help coordinate and execute multi-step tasks. Of the mentioned tools, UiPath's RPA is a more specialized tool that can help automate the transfer of data or help perform tasks related to documents. In the life-science activity, an example is the AlphaFold Server, which is a specialized scientific AI system for biomolecular analysis (Microsoft, 2026; OpenAI, 2026b; UiPath, 2026; Google DeepMind, 2026).

In this dissertation, “Agentic AI” refers to AI that is able to plan and execute tasks which require multiple steps, all while remaining under the supervision of humans and their defined constraints. This does not imply that the system owns or replaces decision making authority. Within the ELIXIRS, evidence mostly indicates that generative and analytical tools function as supplementary support as opposed to autonomous AI replacing scientific, regulatory, creative, or managerial judgement.

This is an important distinction. When it comes to the value of AI in the context of cross-organizational product development, said value is less about the name of the tool, and more about its governance. The key question is not whether AI exists, but how it is governedThe advent of these LLMs allow. The point is to identify the areas where the presence of AI is beneficial and those where it is potentially dangerous, as well as the fields where the realm of human accountability must be clearly defined.

In this dissertation, these questionnaire constructs will be explored in the context of the SYMBEEOSIS ELIXIR collaboration. The collaboration aims at producing a functional/nutraceutical dietary supplement made of bee-based ingredients and extracts from specific botanic or plant-based sources.

This collaboration involves a functional/nutraceutical company, a pharmaceutical and commercial partner, research partners, manufacturing and creative support. AI technologies are used in the scientific, organizational, and documentation support activities, while final accountability rests with human partners and decision makers.

1.2 Problem Statement

While the adoption of AI within the context of research and development as well as strategic partnerships is beginning to gain traction, this research problem is not limited to the Symbeeosis example. The overarching issue refers to the responsible use of AI in collaborative, multi-partner, product-oriented, knowledge-intensive partnerships dealing with the retention of confidential information, the management and coordination of tasks, and the preservation of human accountability for the scientific and business decisions.

As yet, most of existing literature background adopts the following path:

- examines AI adoption in the context of a single organization rather than a network of partners (Davenport & Mittal, 2023; Trunk et al., 2020);
- addresses AI from the perspective of a technical dominance challenge rather than a relational and governance challenge; and
- tends to focus on drug discovery and clinical development rather than cross-sector functional/nutraceutical innovation (Brynjolfsson and McAfee, 2014).

Managers, therefore, have limited understanding of how the governance of AI across partners' boundaries is dealt with, and they have an even more limited understanding of how AI affects coordination, knowledge sharing, documentation, trust, data governance, and confidentiality and IP protection.

The challenge of Responsible AI makes this even more relevant. Although AI outputs may be inaccurate, weakly justified, contestable, or insufficient for validating health, quality and partner-assurance claims (Müller, 2020; Porter and Heppelmann, 2014).

This dissertation regards the Symbeeosis ELIXIRS project as a qualitative case study to investigate this broader challenge. The research challenge is not limited in the case study alone. Rather, the case study provides the empirical structure for understanding the AI-supported collaboration and the analytic scope for the insights offered.

1.3 Research Aim and Objectives

The aim of this study is to examine how AI supports and constrains strategic collaboration in biotechnology/pharmaceutical and functional/nutraceutical product development, using Symbeeosis ELIXIRS as a single qualitative case study.

The study pursues the following aspects:

- Describe how generative, analytical and agentic AI tools can support operational and managerial routines in collaborative product development.
- Evaluate the role of AI in managing knowledge processes, including the generation of ideas, integration of literature, and validation of hypotheses.
- Assess the function of AI in computation screening, initial identification of variables, planning, and logistic assistance. Differentiate these tasks from the last phase of lab work and regulatory validation.
- Assess the role of AI in enhancing communication, knowledge integration, and collaborative decision-making through documented workflows and handoff protocols.
- Assess various stakeholder positions on AI and how it may influence development outcomes in terms of processes to expedite time-to-market, innovation quality, efficiency, reliability, and readiness for regulatory approval.
- Assess the impact of skills, tech adoption, trust, data access/privacy, governance frameworks, and IPR issues on the use of AI.
- Provide strategic and managerial guidance on how to employ AI for collaboration in biosciences.

1.4 Questionnaire Constructs and Interview Protocol

The study is guided by four questionnaire constructs. Compared to the interview prompts, those items are broader. The prompts operationalize the questionnaire constructs for the seven-role participants. They are deliberately formulated at a general analytical level and are examined through the Symbeeosis ELIXIRS case.
The nineteen (19) case-specific interview prompts that follow operationalize these items and provide the empirical evidence used in the analysis. For consistency, the four constructs are labelled **QI.1-QI.4** throughout the dissertation.

QI.1. In what ways does AI enable and/or limit cross-organizations collaborative product development in knowledge-intensive and highly regulated life-science and nutraceutical domains?
QI.2. In what ways can AI impact the integration of knowledge and the processes of communications, coordination and decision making among the partner organizations?
QI.3. How do stakeholders expect AI to influence project outcomes in terms of speed, efficiency, quality, reliability, and launch readiness?
QI.4. What organizational, technological, relational and governance conditions enable or constrain the ethical application of AI in these alliances?

The nineteen (19) following interview prompts are grouped into six (6) thematic sections to support a clear and natural interview flow and are aligned with the four (4) questionnaire constructs (QI.1-QI.4). The thematic sections organize data collection, while the questionnaire constructs provide the framework for analysis, discussion and conclusions.

General Understanding of AI and Collaboration

1. In the ELIXIRS project specifically, where did AI actually get used (and where did work stay fully manual)?
2. Which partner(s) pushed AI adoption the most - and why (speed, cost, compliance, documentation, forecasting)?
3. What 2-3 collaboration tasks would you classify as "AI-supported" today (e.g., evidence review for ingredients/claims, supplier assessment, QC trend monitoring, document drafting)?

Impact on Product Development

4. Give one specific example where AI changed a product decision (formula, ingredient spec, packaging format, dosage, claims, supplier choice). What was the before/after?
5. Where did AI reduce development cycles or rework (e.g., fewer reformulations, fewer label revisions, fewer QC deviations)?
6. Looking at the full timeline (from concept to first sellable batch), what were the top 3 time drivers - and which of them were improved by AI (if any)?
7. Did AI influence key targets like shelf-life confidence, quality consistency, or launch readiness? How was that assessed internally?

Collaboration Dynamics

8. How did AI change how partners coordinated day-to-day (fewer meetings, faster approvals, clearer responsibilities, or new friction)?
9. In this collaboration, who had final decision rights when there was disagreement (Symbeeosis, manufacturer, QA, R&D partner)? Did AI outputs affect that power balance?
10. What were the biggest collaboration "failure points" (handoffs, misunderstanding of specs, documentation gaps, delays)? Which ones were most fixable with better AI?
11. What change management issues did you face (skills, trust in outputs, workflow adoption), and what actions worked best to overcome them?

Knowledge Sharing and Data Management

12. What information had to be shared across partners to make ELIXIRS work (specs/CoAs, batch records, test results, allergens, traceability, labeling/claims evidence) - and what was hardest to share?

13. What were your minimum standards for data quality before using AI (format, completeness, validation, audit trail)?

14. How did you handle data access and confidentiality between partners (who could see what), and did IP/privacy constraints limit AI use?

Future Consequences

15. Over the next 3–5 years, which ELIXIRS-type activities are most likely to become AI-assisted at scale (regulatory documentation, QC release analytics, supplier risk scoring, demand forecasting, formulation screening)?

16. What is the biggest blocker to that future (data readiness, validation/compliance, cost, talent, integration with partner systems, trust)?

17. If you could invest in one capability next year to accelerate AI-enabled collaboration (platform, governance, skills, external vendor), what would deliver the highest ROI?

Evaluation of AI's Effectiveness

18. What metrics do you use (or would you use) to judge AI’s value in collaborative product development - pick your top 5 (e.g., time-to-market, cost per iteration, right-first-time batch rate, deviation rate, documentation cycle time, QC lead time, forecast accuracy, margin impact)?

19. Comparing ELIXIRS to a similar project without AI support: what measurable differences did you observe (or expect) in speed, cost, quality, compliance effort, and partner coordination?

Table 1.1 Breakdown of Interview Prompts by Interviewee

No.	Interviewee	Organization / Role	Interview Prompts
1	Founder & CEO	Symbeeosis	Q1, Q2, Q4, Q6, Q8, Q9, Q10, Q12, Q15, Q16, Q17, Q18, Q19
2	R&D Director	Symbeeosis	Q1, Q3, Q4, Q5, Q6, Q7, Q10, Q12, Q13, Q14, Q18, Q19
3	Market Director	SARL LEBEAU LABORATOIRES - Manufacturer	Q1, Q4, Q6, Q8, Q10, Q12, Q13, Q18, Q19
4	General Manager	VIAN - Commercial / Partner Leadership	Q1, Q2, Q6, Q8, Q9, Q10, Q12, Q15, Q16, Q17, Q18, Q19
5	Creative Department Manager	Beetroot - Branding / Packaging / Communications	Q1, Q4, Q6, Q8, Q10, Q11, Q12, Q15, Q18, Q19
6	Associate Professor	Laboratory of Food Chemistry and Biochemistry, Department of Food Science and Technology, Faculty of Agriculture - ARISTOTLE UNIVERSITY OF THESSALONIKI - R&D Collaboration	Q1, Q3, Q4, Q7, Q12, Q13, Q14, Q15, Q16, Q18, Q19
7	Professor	HELLENIC PHARMACEUTICAL UNIVERSITY OF ATHENS - R&D Collaboration	Q1, Q4, Q7, Q10, Q12, Q13, Q14, Q15, Q17, Q18

Source: Author's case study data (2026)

1.5 Scope and Delimitations of the Study

This study is based on one qualitative case study and focuses on the collaboration of SYMBEEOSIS ELIXIR. Boundaries of this study are as follows:

Sector Boundaries: Biopharmaceutical and functional/nutraceutical product development. Findings may not have direct relevance to other sectors which have different innovation cycles or regulatory frameworks.

Lifecycle Boundaries: Development of concepts or product formulations, scientific and/or analytical, support and coordination/documentation. Other phases, particularly the evaluation of the commercial activity post launch, are explicitly out of the study.

AI Boundaries: Use, governance and perceived value/risks of AI as collaboration and development support. Model validation or AI output as scientific truths are beyond the scope of this study.

Boundaries of analysis units: collaboration as a unit of analysis is a primary focus as opposed to a partner organization as a unit of analysis.

Boundaries of research methods: Interviews and secondary/documentary sources, as available. A large-scale quantitative study or experimental study is not being conducted.

Due to limitations on access to confidential proprietary data, this is a reflection of the current governance situational context in which this study has been undertaken. These boundaries ensure research depth, to a reasonable extent, in MBA dissertations.

1.6 Significance of the Study (Academic and Practical)

This study examines the significant effects of Artificial Intelligence technology in the life sciences industry. It continues to build research on how to manage strategic partnerships by examining the implementation of Artificial Intelligence in collaborative frameworks and decision-making. It also focuses on the socio-technical aspects of digital transformation through the understanding of cross-industry technology integration. (Müller, 2020; Brynjolfsson & McAfee, 2014).

Practical Implications

This research shows the key findings for managers in the life sciences industry, including biotechnology, pharmaceutical, and functional/nutraceutical products. This offers strategies on how to use Artificial Intelligence in collaborative activities and decision-making effectively.

Potential Benefits

- Accelerated Knowledge Creation: Rapid dissemination of knowledge through Artificial Intelligence.
- Better Decision-Making: Artificial Intelligence tools lead to better decisions.
- Better Coordination: Advanced Artificial Intelligence facilitates coordination of stakeholders.
- Practical Concerns.

Several major obstacles exist.

- Capability Gaps: Most companies cannot use Artificial Intelligence effectively due to the different levels of capabilities and readiness.
- Lack of Trust and Accountability: Trust in AI systems was essential for effective collaboration.
- Data Access and Confidentiality: Confidentiality of data in the context of data-sharing agreements remains a challenge.
- Documentation: Documentation of Artificial Intelligence systems and decisions made should be well documented.
- Control of Intellectual Property: Patents should be well controlled in partnerships.

The study provides direction on how partnerships augmented by AI can comply with ethical, legal, and regulatory requirements by means of the following:

- Ensuring privacy protections.
- Recognizing AI-related bias.
- Guaranteeing proper human oversight of decisions.

The findings of this study integrate theory and practice. It demonstrates that AI bolsters collaboration when integrated into well-defined workflows, trusted data, as well as defined roles and supervision (Porter and Heppelmann, 2014; Kaplan and Haenlein, 2019).

1.7 Structure of the Dissertation

Chapter 1 - Introduction. The background and contextual framework will be outlined in this section. The problem statement will identify what prompted this research. The research aim and objectives will be described in detail. The design of the study including some of the delimitations will be included. The relevance of the research will be described, followed by outlining the structure of the dissertation.

Chapter 2 - Literature Background. The literature background that focuses on strategic collaborations in biotechnology/pharmaceuticals, product development, and AI-supported inter-organizational collaboration will be reviewed. This chapter will also present the conceptual framework and the gaps in the literature.

Chapter 3 - Research Methods. The qualitative case-study design, methods of data collection, interviewee selection, analytical framework, and ethical considerations, will be described and defended.

Chapter 4 - Results and Analysis. Empirical data will be collected and analyzed in relation to the four (4) questionnaire constructs and aspects of the conceptual framework.

Chapter 5 - Discussion. The findings will be discussed in relation to the four (4) questionnaire constructs and the literature background, before theoretical contributions and managerial implications are presented.

Chapter 6 - Summary, Conclusions and Recommendations. In this chapter, the principal findings will be presented, and conclusions drawn around the four (4) questionnaire constructs will be given. It will also provide practical recommendations, address the policy implications, identify limitations, and provide directions for future research.

2. Literature Background

2.1 Introduction to the Literature Background

AI is permeating more stringently regulated sectors, including pharmaceuticals, biotechnology, and adjacent functional and nutraceutical markets. The lengthy, evidence-based, and quality-sensitive nature of product development in these industries leads to significant changes in the employment by such organizations of AI to identify and seize opportunities; select partners; share information; mitigate risks; and manage the complex, multidimensional aspects of development (Davenport and Mittal, 2023; Iansiti and Lakhani, 2020).

This investigation examines relevant literature background spanning four domains. Strategic alliances research shows that companies tend to join forces to promote innovation when they are in need of resources and capabilities that lie outside the reach of one company alone (Gomes-Casseres, 2015; Nevin, 2016). Studies in pharmaceuticals and biotechnology indicate that external collaboration is even more crucial in science-based industries, given that discovery, clinical development, regulation, manufacturing, and commercialization employ different types of expertise and involve different kinds of risk (Pisano, 2006; Schuhmacher et al., 2016).

Additionally, studies in product development point to a sequential order of the development process that can be either rigid or flexible (Ulrich et al., 2020). Finally, recent AI studies propose methods of predictive, searching, and design assistance, as well as communication and decision-making. They also highlight emerging issues regarding data quality, governance, ethics, and the accountability void (Agrawal et al., 2022; Mollick, 2024; NIST, 2023, 2024).

Building on these streams, this chapter reviews strategic collaborations and alliances in business, biotechnology, and pharmaceuticals.

As a result, this chapter situates the dissertation at the convergence of innovation theory, autonomous product creation, strategic partnerships, and the regulatory environment of regulated innovation. The focus is on literature traceable to reliable, established, and academically credible sources, including authoritative books, official regulatory texts, and, where absolutely needed to reinforce an argument, peer-reviewed, foundational literature.

2.2 United We Stand - Strategic Collaborations & Alliances in Business

Strategic alliances allow organizations to achieve common goals while retaining their legal and strategic independence. Academic literature framing strategic alliances suggests that these collaborative arrangements are the best compromise between fully transactional agreements and fully integrative alliances.

Consequently, participants can gain access to other members' resources, capabilities, intellectual resources, and community legitimacy, all the while avoiding the organizations' political merger (Gomes-Casseres, 2015; Nevin, 2016).

The literature background on competitive advantage identifies the role of combined capabilities. Increased emphasis is placed upon the integration of firm assets and how firms leverage both their internal strengths and those of their external partners. In the context of strategic alliances, the combined resources, knowledge and routines of partner firms become an essential requirement, as firms need partners to complement, adapt and expand their current capabilities (Barney and Hesterly, 2021; Grant, 2021).

There are various types of strategic alliances, including R&D agreements, co-development partnerships, and licensing and supplier agreements. These alliances can take the form of equity partnerships, data-sharing partnerships, platform alliances, and joint ventures.

The configuration of these types of partnerships is linked to the assessment of uncertainty, control, the sensitivity of knowledge assets, the collaboration's anticipated longevity , and the trade-off between stability and commitment (Nevin, 2016).

Motivations for establishing Strategic Alliances

Companies use strategic alliances to combine efforts with others to reduce risk, increase speed, and extend their reach to resources that are challenging to acquire internally.

Innovation results from collaboration among various players who possess specialized scientific, technical, regulatory, and market knowledge. This is especially common in technology-intensive industries. Alliances therefore enable firms to pool complementary assets, accelerate learning, enter new markets, share development costs, and improve the probability of commercial success (Gomes-Casseres, 2015; Grant, 2021).

Another motive is learning. An organization can utilize alliances to watch partner activities, internalize outside skills, and create new proficiencies if the organization has the needed precursory awareness and the ability to be receptive to recognize, digest, rearrange, and utilize what it learns (Zahra and George, 2002). This is especially important in AI-enabled collaborations, where partners may contribute different forms of expertise, such as proprietary data, domain science, computational infrastructure, regulatory experience, and commercialization channels. This flexibility is valuable in uncertain environments where technologies, standards, regulations, and market expectations change quickly (Nevin, 2016; Whittington et al., 2023).

Building & Missions of Strategic Alliances

Strategic alliances have several steps: identification of partners, evaluation of partners, negotiations, designing of the alliance, governance of the alliance, execution, and modifications. Regarding partner selection, several factors must be addressed, some of them include the strategic fit, availability of complementary resources, partner culture, partner's absorption capacity, the trust and transparency levels, data readiness, and the readiness to meet the established milestones (Nevin, 2016).

While reducing uncertainty and vagueness, formal contracts cannot substitute for relational governance, which encompasses trust, communication, reciprocity, and fairness, and can be important in times of uncertainty (Nevin, 2016; Poppo and Zenger, 2002).

The design of partnership rules and roles for data and models, along with validation and security control steps, establishes the groundwork for accountability for AI-supplemented recommendations. AI, in this case, influences not just the rapidity of evidence review, but also the trust and intervention rights and the defensibility of the regulations (NIST, 2023, 2024).[1]

Benefits of Strategic Collaborations

Strategic collaborations generate several benefits. They allow firms to share costs and risks, especially in projects where scientific uncertainty and commercialization uncertainty are high. They foster scope for improvement and learning as partners engage in their own collaborative world of constant interaction, routine, and joint problem-solving.

Improved innovation is facilitated when multiple elements of distinct reasoning types come together. One example of such collaboration may involve a technology firm providing digital platforms and analytics, a pharmaceutical firm, regulatory, and clinical expertise, a biotech start-up, certain novel scientific assets, and university, early-stage research. The alliance's value comes from the ease of these partners providing solutions that no other firm can produce. (Gomes-Casseres, 2015).

However, alliances also create risks. Partners may disagree over objectives, deadlines, input requirements, data ownership, publication rights, and/or distribution and realization of profits. For these reasons, the ability to manage strategic fit, operational collaboration, relational trust, and governance discipline will jointly determine the success of the alliance (Nevin, 2016; Poppo and Zenger, 2002).

Interest in Strategic Collaborations

More interconnected, digital, and knowledge intensive Innovation ecosystems have increased interest in strategic collaboration. Companies that compete based on their internal capabilities now also compete on the basis of quality of the ecosystems and partnerships they can mobilize (Adner, 2021; Jacobides et al., 2018).

The same applies for AI, where value is determined by data, cloud infrastructure, algorithms, domain expertise, responsible deployment and more, all distributed among multiple entities.

Examples of Strategic Collaborations

Multiple successful examples underscore the significance of collaboration across diverse sectors. The collaboration between ***Apple and IBM*** in the technology sector has resulted in significant advances through the integration of their hardware and software capabilities.

Microsoft and OpenAI are incorporating OpenAI models into Microsoft Azure and Microsoft products to accelerate AI research and provide developers and enterprises with extensive AI capabilities (Microsoft, 2023). Google and Adobe are merging Google Cloud systems with Adobe's creative and marketing tools to create a customer experience platform with deeper product integrations, AI co-innovation, and collaborative go-to-market tactics. These examples show how alliances can combine complementary assets - infrastructure, models, data, technical expertise and customer access - into new offerings.

Volvo and Geely are sharing electrification and autonomous driving technology and car platforms with global manufacture and distribution. Since Geely owns Volvo and both firms share technology, this collaboration has sped EV development and worldwide scale. ***Ford and Google*** collaborated to use Google Cloud and bring Android Automotive & Google apps into Ford and Lincoln vehicles. TOMS Shoes has partnered with numerous NGOs to establish a model in which each purchase supports social causes, exemplifying the alignment of profit with purpose in business

BioNTech contributed mRNA vaccine platforms, while ***Pfizer*** contributed development, regulatory, manufacturing and distribution capabilities (Pfizer and BioNTech, 2020).

The increasingly fluid and complex business environment will continue to favor approaches characterized by collaboration over those based on confrontation. This will further reinforce the role of strategic partnerships as key to long-term business success. ***United We Stand***. Fostering these types of relationships and collaboration will always prove to be positive for coping and success in interdependent global economic relations. Only in this way can we create a more prosperous and united future in every aspect.

2.3 Strategic Collaborations & Alliances in Biotechnology and Pharmaceuticals

In biotechnology and pharmaceuticals, strategic collaboration and partnerships are crucial for innovation. These industries are characterized by high scientific uncertainty, prolonged periods of development, numerous regulations, and the need for a significant amount of capital.

There have been various estimates concerning the cost of R&D in pharmaceuticals, as a positive example, but the overarching conclusion remains the same: developing and launching a new therapeutic product is extremely costly and requires multiple capabilities, which are seldom found in a single organization (DiMasi et al., 2016; Wouters et al., 2020). Regulation No. 536/2014, establishing the law governing clinical research in the European Union, has harmonized the rules governing the review by the EU of applications for clinical trials via a single submission, the Law of Protection of Subjects and their Informed Consent, and the Law on the Provision of Transparency on Information after the Trials (European Parliament and Council of the European Union, 2014). Across the World, the ICH E6(R3), which is set to take effect in 2025, aims to clarify and reinforce the Good Clinical Practice (GCP) principles and introduces centralized participant and data protection, quality and centralized risk management, and trial oversight (ICH, 2025).

Often, biopharmaceutical industry alliances involve small, science-based firms, universities, contract research organizations, pharmaceutical companies, investors, and regulators. In the field of biotechnology, network research has traditionally argued that innovation and interorganizational learning are also outcomes of the networked structure of alliances as opposed to the isolated firms (Hagedoorn, 2002; Rothaermel and Deeds, 2004). Moreover, R&D alliances offer a way to effectively achieve balance between exploration and exploitation: collaborations at the early stages of scientific research serve the purpose of exploring the scientific frontier, while later-stage alliances of a different nature address the clinical, manufacturing, and commercial sides of the value chain.

The relevant body of research indicates that the most frequent motivations for partnerships are the following : accessibility to complementary scientific and technological assets, risk-sharing, enhanced R&D and reduced time-to-market, increased market reach, increased regulatory capabilities, and access to specialized infrastructure (Hagedoorn, 2002; Schuhmacher et al., 2016). In AI-based product development, these motivations are even stronger, as access to curated data, computing resources, and infrastructure/biomedical/clinical/engineering validated systems become necessary for the construction of new scientific and technological systems.

Relational governance involves trust, engagement, and communication. These factors are critical to fields of research where the outcome cannot be fully known a priori (Nevin, 2016; Poppo and Zenger, 2002).

Data may be shared among and/or consolidated into other commercial systems and be used to create value for systems that control the scientific and/or normative recommendations made in the course of scientific and/or legal entities.

In the context of this dissertation, AI is viewed as a technology+collaboration in the biotechnology and pharmaceutical alliance literature. AI-inclusive product design is dependent on the partners' capabilities to process data, experience, regulatory understanding, and marketing knowledge into trustworthy and profitable products.

2.4 Product Development Processes in Life Sciences and Functional Foods

The pathways of developing a product in life sciences are evidence-based and organized. In the case of life sciences and especially in pharmaceuticals, the pathway comprises discovery, preclinical testing, clinical development, regulatory review, approval, manufacturing scale up, commercialization, and finally, post-market surveillance (FDA, 2018; Pisano, 2006).

Every step in this pathway requires a different level of evidence and other forms of rationale, and apart from documenting each step, one must maintain the different levels of quality attained in each stage.

General product development literature emphasizes cross-functional integration among R&D, design, manufacturing, marketing, quality, and supply-chain functions. Ulrich, Eppinger and Yang (2020) define product development as an iterative process that converts needs and opportunities into tested, manufacturable, and marketable solutions. Although their model is not specifically designed for pharmaceuticals, it is valuable as it highlights the importance of concept development, prototyping, testing, iteration, and coordination across functions.

Life-science product development differs from many other sectors because scientific validity, safety, evidence quality, regulatory compliance, and traceability are central to product value.

Pharmaceutical development requires rigorous documentation and monitoring because decisions at one stage can affect future clinical, manufacturing, and regulatory outcomes. Therefore, product development is not merely a technical process; it is also a knowledge-governance process (Schuhmacher et al., 2016).[2]

Developers must consider ingredient sourcing, formulation stability, safety, sensory properties, quality assurance, consumer acceptance, manufacturing scalability, packaging, labeling, and substantiation of claims (Bagchi and Nair, 2016).

In the European Union, Regulation (EC) No 1924/2006 stipulates that nutrition and health claims made on foods, such as substantiated claims and misleading/false claims, should be addressed and avoided (European Parliament and Council of the European Union, 2006).

A relevant sector-specific dimension for this dissertation refers to bioactives and other ingredients and food supplement products which - if not standardized and batch-to-batch controlled, quality assured, and assessed in terms of safety and substantiation, claims and evidence of safety - could prove to be propolis, bee pollen, honey, and royal jelly. Thus, AI-backed formulation may be used, but it must be accompanied by laboratory evidence and formulation, substantiated claims of marketing safety, and legal compliance. (Irigoiti et al. 2021).

Knowledge integration is essential for product and service development in pharmaceuticals, biotechnology, and functional foods. R&D, formulation, quality, and evidence support, and other partners, manufacturing, and marketing may take up different roles so as to define and assess consumer needs and market integration.

AI enhances the quality of auxiliary functions in development, and therefore search, operational, and contextual variables, scale, and quality of support functions are relevant. Predictive auxiliary functions and documentation improve the quality of auxiliary functions and enhance operational variables, quality, and scale of auxiliary functions in development, scale, and quality of auxiliary functions in a product different from those of the available auxiliary functions. (Agrawal et al. 2022; Davenport and Mittal 2023).

2.5 Artificial Intelligence in Innovation, Product Development, and Inter-organizational Collaboration

2.5.1 AI in Innovation and Product Development (intra-organizational processes)

AI refers to machine-based systems that perform tasks such as prediction, classification, optimization, recommendation, planning, natural-language processing, and decision support. Narrow AI systems are designed for specific tasks, while generative and agentic AI systems can produce text, code, images, designs, or plans and may act across multiple steps under human-defined objectives (Mollick, 2024; Russell and Norvig, 2021).

In the subdomains of Biotechnology and Pharmaceuticals, AI is used to aid the targeting and breakthroughs in screening of lead compounds, prediction of adverse effects, designing and stratification of clinical trials, evaluation of evidence stemming from trials, and enhancement of the process of pharmacovigilance and production (Brown, 2020; Vamathevan et al., 2019). The AI technology utilization by the U.S. Food and Drug Administration (FDA) extends across the entirety of the drug life cycle. In particular, the FDA has provided drafts of guidance documents for the assessment of trustworthiness of AI models and the regulatory pathways available within all phases of preclinical, clinical, post-market, and production phases (FDA, 2025; FDA and EMA, 2026).

The advent of generative AI and the large language models (LLMs) have expanded the potential for AI in knowledge work. The implementation of the transformer architecture has improved large-scale modeling of language, with the added benefit of the ability to accomplish variable language objectives from simple prompts (Brown et al., 2020; Vaswani et al., 2017).

These LLMs allow for countless opportunities in the context of product development, for instance, screening literature, simple brainstorming and idea generation, protocol drafting, regulatory documentation, translation of technical knowledge across different specialties, and meeting documentation.

The introduction of these tools may allow for the design of more autonomous systems; however, the impacts of these systems in a regulated development environment require a high degree of human oversight, validation, and proof (Mollick, 2024; NIST, 2024).

This is of utmost importance when product development activities span several organizations, as the data and the results of deliberations and decisions may be diffused across several firms and institutions (academic, manufacturing, and commercial partners). AI can assist streamline governance workflows and the analysis of linked activities. However, consistently transparent governance will dictate the measures taken to verify output, record decisions, and ultimate accountability. (NIST, 2023, 2024; European Parliament and Council of the European Union, 2024).

2.5.2 AI in Strategic Collaborations (inter-organizational relationships, governance, and knowledge integration)

AI reshapes the definition and recognition of collaboration with partners. AI has the potential to assist in partner selection, due diligence, portfolio screening, tech scouting, and competitive intelligence.

AI can also aid partners in the science, regulatory, manufacturing, and commercial areas to work together more seamlessly in collaboration-enhanced areas, shared project management, and dashboards (Chesbrough, 2020; Davenport and Mittal, 2023).

At the same time, the collaboration system may develop new forms of dependency and power asymmetry where a partner controls the AI models, data, the digital environment in which the AI operates, and how the outputs from the AI are interpreted (Carlile, 2002; Orlikowski and Scott, 2008).

An important result of this research is that AI needs to be considered beyond the lens of productivity technology and interconnected organizational relationships. AI can also change the way knowledge is contributed, evidence is interpreted, and decisions are documented. AI also can change the dimensions of trust and its impacts. This encapsulates the essence of the dissertation, particularly developing collaborative product engineering models with all partners in the pharmaceutical, functional-food, and academic sectors.

2.5.3 Specific AI tools and methods relevant to the ELIXIRS case

This subsection outlines the AI tools associated with the evidence of the ELIXIRS case and the artificial intelligence technologies that have been referred to in a general sense. The ELIXIRS case-related tools are: Semantic Scholar, Elicit, SwissADME, ProTox-II, ChatGPT, Adobe Firefly, and Photoshop Generative Fill. These tools are available because they are associated with the dominant functions that were either observed or reported in the case: the review of scientific evidence, the evaluation of preliminary R&D, the preparation of documents and the coordination of activities, as well as the development of a product in the creative or packaging domain. Conversely, Microsoft Copilot Studio, OpenAI agent workflows, UiPath, and the AlphaFold Server are not presented as ELIXIRS tools. These are simply contextual examples of adjacent AI, automation, and scientific-AI technologies.

AI describes the use of various tools for different purposes within a large field of technology that is difficult to generalize. For that reason, saying simply “AI” would not describe how technology aided the ELIXIRS product development. This subsection describes a small number of tools relating to the main activities of this case, described as reviewing scientific evidence, the initial assessment of research and development (R&D), drafting and facilitation, and the inventive process. This is not an attempt to create a comprehensive description of tools and services available, nor a comparison of vendors, but rather informs about the contribution AI has made in the tertiary collaborative process.

These tools serve various purposes at different times. During the earlier development phase, AI helped facilitate targeted work concerning scientific searches, collection and organization of information, preliminary calculations, and assisted design. The next stage, occurring from late 2023 to June 2024, focused on the use of AI for design and drafting, as well as the generation of text and feedback, and cross-disciplinary communication.

While reviewing scientific evidence, tools such as Elicit and Semantic Scholar helped in identifying, screening, and organizing relevant pieces of research. These tools helped in locating publications and facilitated comparison between different sources. These tools helped in drafting structured critical assessments which can help in formulating further questionnaire constructs and discussions to be answered by the scientific and management partners. The reliability and relevance of the information reviewed still had to be addressed by the original sources and participants with appropriate scientific expertise.

SwissADME and ProTox-II provided a set of virtual tools conducting in silico assessments to help analyze the data related to characteristics of the molecules concerning drug-likeness, as well as a first approximation of the risk and potential of the toxins and some of their metabolites. ProTox-II and SwissADME helped delineate key issues in order of priority for follow-up assessments.

However, the evaluations neither provided a preliminary expert assessment for the constituents of the final formulations, their routes of administration, the safety of the products, and the health-related claims, nor for other assessments that required the expertise of a qualified professional and were supported by laboratory and other empirical data or quality evaluation and legal regulatory frameworks.

In the later stages of the project, ChatGPT facilitated the preparation of drafts and knowledge-transfer processes. It helped to consolidate and organize notes and data in order of comparison and different drafts of text and assisted in the translation of text of a highly technical and specialized nature to a language of commerce or business. The tool was especially useful in a project involving a multidisciplinary team. Generated text and documentation showed a high degree of variability and non-linearity in content and required to be reviewed before being disseminated and used as an official project document.

In creative work and in particular in design and packaging work, the use of Photoshop and Adobe Firefly supported fast generation of design alternatives and early design iterations and visual aids. They helped the design team to explore different design stimuli and design directions. The scope of the tools was to assist the design team to quickly iterate design aids. The tools did not develop the design scope, the creative design stimuli, and the design packaging. Creative authorship and final approval remained with the design team.

Table 2.1. Classification of AI tools linked to Symbeeosis ELIXIRS case evidence

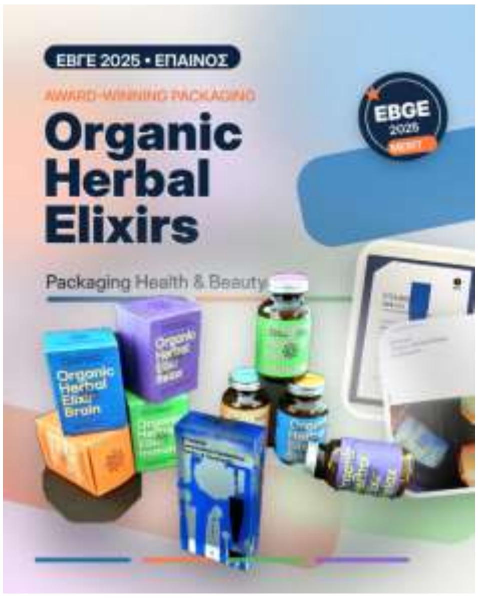
Field of use	Case-relevant tools	Practical contribution	Non-delegated human responsibility
Scientific Evidence Review	Semantic Scholar Elicit	Literature identification, screening, organisation, and preparation of structured summaries	Verification of original sources and assessment of scientific relevance
Preliminary R&D Assessment	SwissADME ProTox-II	Early in-silico indications concerning molecular properties and potential toxicity	Formulation decisions, laboratory validation, safety assessment, dosage, and claims approval
Documentation & Coordination	ChatGPT	First drafts, meeting synthesis, comparative summaries, and translation of technical information into accessible language	Review of accuracy, relevance, confidentiality, and suitability before use
Creative & Packaging Development	Adobe Firefly Photoshop Generative Fill	Visual exploration, draft variations, and adaptation of design material	Strategic narrative, brand identity, creative authorship, and final design approval

Source: Author's case study data (2026)

Table 2.1 includes only the AI tools linked to the ELIXIRS case evidence. Microsoft Copilot Studio, OpenAI agent workflows, UiPath, and AlphaFold Server have only been referenced as contextual examples and are not considered as tools that have been implemented in the case.

The EBGE 2025 awarded the recognition of the Organic Herbal Elixirs in line with this interpretation, where Beetroot is credited as the design agency, Symbeeosis is credited as the client, and Praise is listed under the Health and Beauty Products Packaging category (EBGE, 2025). The case illustrates that in the 2020 phase, AI was mainly analytic, while in the 2023-2024 phase, AI was mainly generative and multimodal. In both phases, the role of AI was to accelerate the synthesis and creative iteration, but in both phases, the responsibility for the creativity rested with people.

Figure 2.1. EBGE 2025 MERIT to Beetroot for "Organic Herbal Elixirs"



Source: EBGE (2025)

2.6 Conceptual and Theoretical Framework

The conceptual framework for this dissertation draws on four complementary perspectives to explore issues related to strategic resources and dynamic capabilities; open innovation and absorptive capacity; and ecosystems/socio-technical systems.

i. strategic resources and dynamic capabilities;
ii. knowledge integration and absorptive capacity;
iii. open innovation; and
iv. socio-technical systems and ecosystems.

These perspectives provide an understanding of how organizations combine internal resources, external knowledge, data, AI technologies, and partner governance. Rather than using these perspectives to label the empirical analysis, they will be used as interpretive frameworks.

2.6.1 Strategic Resources, Dynamic Capabilities and Knowledge Integration

Firms benefit from structuring advantageous resources in ways competitors cannot imitate, as suggested by strategic management literature. For this dissertation, these resources are scientific understanding, network of trusted partners, reputation of quality, validated quality assurance practices, data discipline, and managerial judgement (Barney and Hesterly, 2021; Grant, 2021).

Dynamic capabilities draw from the perspective of process. They are the abilities to identify and exploit market opportunities and to continually change the configuration of the firm's resources in response to changing market conditions (Teece, 2007, 2018). In the context of AI-facilitated collaboration, this entails more than the acquisition of a digital tool. It entails understanding the areas where AI can be utilized in accelerating the processes of search, comparison, and drafting; and where a final expert judgment should be retained in the validation process.

Requisite integration of knowledge is also of primary importance. The ELIXIRS case encompasses the fields of botany, formulation, substantiation of claims, assessment of feasibility of manufacturing, and creative market translatability. AI can facilitate the organization and comparison of knowledge by teams. It cannot, however, transform that knowledge into a defensible product decision. That transformation relies on the different professional judgments of the team, and the trust of the team partners (Nonaka, Toyama and Konno, 2000; Zahra and George, 2002).

2.6.2 Open Innovation, and Absorptive Capacity

Rapid change has been observed in the biotech and pharma industries due to the addition of Open Innovation (OI) and Absorptive Capacity (ACAP) as they relate to artificial intelligence (AI). Open Innovation suggests businesses should utilize both internal and external ideas, technologies, and market paths to reach the consumer since helpful ideas are developed outside of the organization (Chesbrough, 2020).

This is particularly pertinent to biotech and pharma, where university, start-up, contract research organization, supplier, regulator, and large company involvement is common in the solution of joint scientific and commercial problems. AI is effective only if a company can absorb and consequently use external knowledge.

Absorptive Capacity aids Open Innovation by stating that external knowledge alone is insufficient. Companies need to identify, absorb, convert, and commercially utilize this knowledge (Zahra and George, 2002). In collaborations relying on AI, absorptive capacity involves data agility, technical knowledge, subject proficiency, and the ability to validate. Also, the organization must be willing and ready to modify its processes.

Although AI technologies, especially those using Large Language Models (LLMs), possess the capacity to transform corporate information collection, interpretation, and integration, numerous firms persist in disregarding this element of their operations.

Large Language Models (LLMs) signify a substantial progression in natural language processing, allowing “robots/machines” to understand, develop, and interact with human language with incredible precision.

These models, trained on extensive datasets, may execute many tasks, like summarizing information, generating creative material, answering inquiries, and translating languages. LLMs can facilitate knowledge management by systematically collecting and synthesizing information from many sources, hence enhancing accessibility for employees (Devlin et al., 2019).

The efficacy of LLMs within an organization significantly depends on the company's ability to incorporate these tools into its workflows and culture, ensuring that the generated insights are acknowledged and acted upon effectively (Radford et al., 2019). For example, an organization might use LLMs to analyze market trends and customer feedback, but if it lacks the processes to effectively incorporate these insights into strategic decision-making, the potential value remains undeveloped. Similarly, a company could implement AI-driven tools for competitive intelligence; however, without a strong absorptive capacity, it may struggle to translate these insights into actionable strategies, ultimately hindering growth and innovation.

This is particularly important for functional-food and supplement innovation because health-related claims must be substantiated and communicated responsibly (Bagchi and Nair, 2016; European Parliament and Council of the European Union, 2006).

The biotechnology sector is characterized by significant uncertainty and complexity, necessitating broad collaborative networks for success. Open Innovation (OI) is essential for cultivating collaborations between academic institutions, research organizations, and industry stakeholders, thus accelerating research and development (R&D) processes (Gassmann et al., 2010). Through engaging in open innovation, companies can more effectively identify and capitalize on new trends, which is essential for sustaining a competitive advantage in this swiftly changing environment.

However, simply implementing open innovation techniques is insufficient; firms must also cultivate strong absorptive skills to effectively apply the knowledge acquired through cooperation (Zahra & George, 2002).

In drug development, novel techniques like crowdsourcing indicate open innovation by widening the search for solutions and applying dispersed expertise. Collaboration of stakeholders with areas of scientific knowledge, finance, manufacturing, and regulation bridges the OI-ACAP and sustainable value proposition resulting from partnerships (Bettanti et al., 2022). Public-private partnerships demonstrate the value of a collaborative workspace for the exchange of ideas and innovation pathways in the medical and pharmaceutical open innovation domains.

Further evidencing the OI and ACAP relationship, the data-centric approach used in AI type of development requires flexible ACAP framework designs and collaborative systems that encourage knowledge and work-related decision making between labs and technology teams. There is empirical evidence that a company that employs advanced information and communications technology (ICT) is more likely to show a positive increase in absorptive capacity (ACAP) and thus achieve better outcomes from its open innovation (Cuevas-Vargas et al., 2022).

Those organizations are likely to dominate the innovation of AI and redefine the standards in healthcare with the helping structure that facilitates collaboration and sharing of knowledge.

2.6.3 Ecosystem and socio-technical perspectives

The ecosystem theory of innovation focuses on continuous interrelated stream innovation and participation of organizations (Adner 2021; Jacobides et al., 2018). In biotechnology, pharmaceuticals and functional food industries, these organizations include R&D in conjunction with universities, suppliers, and/or technology providers, including functional food manufacturers, regulators, contract manufacturers, distributors, health care professionals as well as consumers and/or investors. Full functional integration of artificial intelligence (AI) within biotechnology and pharmaceutical industries requires both ecosystem and socio-technical perspectives.

These perspectives assist these industries' organizations to apply AI in their operations, with the aim of fostering inter-organization collaboration in innovation so as to withstand the intensifying competition in the industry.

From a socio-technical perspective, technology and organizational structures are interrelated and affect each other. When AI is implemented in organizations built within the socio-technical context, the organization's culture, socio-technical context, trust, and/or governance structure will also affect the outcome (Bijker et al., 2012; Orlikowski and Scott, 2008). This is even more critical in highly regulated environments, within which some traceability, explanation, and validation will have to be integrated into the framework of AI outputs and will have to be explainable and auditable.

In pharmaceutical manufacturers, the use of sustainable practices is located at the intersection of opportunity and challenge. Incorporation of AI-adjusted processes incentivizes reaching an equilibrium of effort. Targeting the use of AI and sustainable practices requires strategic partnerships among seemingly conflicting stakeholders and their governance frameworks, as is the case with the Finnish life science sector. Collaborative projects undertaken in the Finnish life science sector have allowed companies to collectively anticipate and adapt to technology advances (Ahlqvist et al., 2025).

The ethical and governance challenges related to AI encompass issues of bias, opacity, data privacy, cybersecurity, and data access. These issues transform the uncertainty of technology into a strategic and reputational threat.

AI frameworks require human oversight, management of risks, and documentation. The (disruptive) potential of technology can only be harnessed if balance is reached between bias and access issues (European Parliament and Council of the European Union, 2024; NIST, 2023, 2024).

2.7 Identified Gaps in the Literature Background

The literature background in this chapter reveals several gaps that justify this study.
Firstly, the intersection between biotechnology, pharmaceuticals and functional or organic supplements remains underexplored. Existing AI research in life sciences tends to focus on drug discovery, clinical development, diagnostic tools, pharmacovigilance or manufacturing optimization.
Less attention has been paid to collaborative product development in adjacent consumer-health categories, where scientific substantiation, formulation, claims management, market positioning and consumer trust intersect.
There is limited qualitative evidence on the organizational, cultural and governance conditions that enable or constrain AI use in cross-sector collaborations. Much of the literature emphasizes the technical potential of AI, but gives less attention to how partners actually coordinate AI-supported work, allocate decision rights, manage data-sharing risks, protect intellectual property and maintain trust across organizational boundaries.
The role of generative AI, large language models and more agentic AI systems in alliance governance is still insufficiently theorized. More research is needed on how these systems influence knowledge flows, evidence interpretation, partner coordination and the balance between speed, explainability and accountability. This is particularly relevant in regulated or semi-regulated health-related product development, where AI may accelerate documentation and analysis but cannot replace human responsibility, scientific judgement or compliance oversight.

Finally, the literature provides limited guidance on how to evaluate the effectiveness of AI across different stages of collaborative product development. Existing studies often refer generally to efficiency or acceleration but provide less insight into how AI contributes to partner selection, evidence synthesis, formulation screening, documentation, claims support, launch readiness or cross-partner coordination.
This creates a need for case-based research that examines AI not only as a technology, but as a collaborative capability embedded in strategic relationships.

2.8 Summary and Implications for the Research Design

This chapter aims to collect and analyze existing research on artificial intelligence (AI), functional foods and their related channels (namely nutraceuticals, organic supplements), and strategic partnerships within the frameworks of biotechnology and pharmaceutical product development. Alliances create additional value, as innovation often requires the sharing of resources, knowledge, and risk, and coordination within an ecosystem.
It also showed that AI can facilitate product and service developments by prediction, search, optimization, documentation, and knowledge integration, again, only with the proper development of human skills and governance systems.
The background provided for research design has four central implications. These are:

i. The study should aim at alliances and governing partnerships, i.e., roles, the trust, the ownership, data and governance, decisions, and the flow of distributions;
ii. The study should determine at what phase of product development AI aids collaboration and at what phase AI inhibits it;
iii. The study should focus on generative or agentic AI, as well as Narrow AI. However, it should also ensure the data is of high quality, validates, and is transparent, also providing adequate supervision; and
iv. Findings of the study must be evaluated and interpreted through the lens of strategic resources, dynamic capabilities, open innovation, absorptive capacity, and socio-technical integration.

These implications aid the justification of the qualitative research method as the collaboration, aided by artificial intelligence, is a process that is embedded into relationships and routines as well as the boundaries of governance. For this reason, the case study is a suitable approach to research this particular aspect of the collaboration and to be able to have a developed analytical (as opposed to a statistical) generalization.

The Symbeeosis ELIXIRS project makes for a good case study because, among other attributed, the area of study is highly interdisciplinary, involves multiple co-regulated and self-regulated product development, and AI-assisted collaboration. Relevant literature in this chapter provides the theoretical framework to study how AI impacts partner organization, knowledge synthesis, product development, and market readiness.

3. Research Methods

3.1 Methods and data collection

This dissertation examines the case study regarding the impact of Artificial Intelligence (AI) on the co-creation of products within the Symbeeosis ELIXIRS initiative. The analysis is focused on the collaborative development system utilized by the brand owner and their partners to progress from product idea to proof, formulation, and associated documentation, validation and preparation for market launch.

This design responds to each of the four (4) questionnaire constructs. It includes a context specific case within a collaborative ecosystem involving private industry, academia, science, manufacturing, business and creative sectors. Within this "cluster", the focus is on analytical generalization, not statistical one. When dealing with case specific evidence, the focus will be on the identification of mechanisms and conditions that may be applicable to other cases, rather than determining the case's prevalence in general (Yin, 2018; Rashid et al., 2019).

This analysis also considers AI as part of the collaboration and management support systems. This includes partnerships where AI assisted collaborators in synthesizing, interpreting, and organizing the information, and where humans retained control over the design of the information and ultimate accountability .

This analysis is based on three constructs: the phase of product development, the partner function, and the governance limit within which AI was perceived either as supportive, constraining, or inappropriate. This type of rationale connects case-specific data to QI.1-QI.4 with the general conclusions of the case study evidence.

The interview protocol was developed from QI.1-QI.4 in Chapter 1 and the literature background in Chapter 2. Nineteen (19) case-specific interview prompts were developed, organized into six (6) themed groups, and associated with QI.1-QI.4. This framework ensured consistency in the design of each interview and established direct line of sight from each case to data collection and analysis.

Table 3.1.Alignment of Questionnaire Constructs, Interview Prompts and Evidence

Methodological Note: Interview Prompts may inform multiple QIs; QI.1-QI.4 structure the analysis, discussion & conclusions.

Questionnaire Constructs Domain	Interview Prompts Addressed	Primary Evidence	Secondary Evidence	Analytical Output
***QI.1:* AI role and task boundaries**	**Q1-Q4, Q15** Use, adoption, task scope, product decisions and future use	Cross-role interviews on AI-supported and manual work, adoption drivers and human accountability.	Workflow, formulation, claims, packaging and product-development records.	Map of AI-supported and human-led tasks across the development process.
***QI.2:* Knowledge integration & coordination**	**Q1-Q3, Q8-Q14** Coordination, decisions, handoffs, data sharing, trust and access	Interviews on communication, decision rights, shared data and workflow adoption.	Meeting records, specifications, CoAs, test results, approvals and claims evidence.	Explanation of how AI supports shared understanding, coordination and decision preparation.
***QI.3:* Development outcomes**	**Q4-Q7, Q18-Q19** Speed, rework, quality, reliability and launch readiness	Stakeholder accounts of development speed, rework, documentation, quality and launch preparation.	Timelines, formulation, quality, packaging, KPI and release-related records.	Cautious assessment of perceived effects on efficiency, quality and launch readiness.
***QI.4:* Enablers, constraints & governance**	**Q2, Q9-Q18** Skills, trust, data, privacy/IP, oversight, scaling and metrics	Interviews on capabilities, trust, data readiness, access, validation and accountability.	Governance, confidentiality/IP, audit, compliance, planning and system-integration materials.	Framework of conditions that enable or constrain responsible AI use.

Source: Author's case study data (2026)

3.2 Data Analysis

This case study included three intertwining elements. The first element relied mainly on going through every single interview response and peripheral documentation to piece together the actions taken on the ELIXIRS project. This encompassed steps from conception of both brand and product, and the work relating to the ingredients and evidence, to the formulation, documentation, validation, packaging, and activities pertaining to market readiness. Consequently, the evidence was assigned to frameworks describing development stage, partner role, and governance boundary. This was useful in delineating AI-assisted preparation from the final human judgement.

In the second component, evidence was reviewed to identify the case framework through reflexive thematic analysis (Braun and Clarke, 2006; Nowell et al., 2017). During the analysis, the step involved both deductive and inductive thinking. The deductive step was guided by QI.1-QI.4 and by concepts developed in Chapter 2. These were strategic collaboration, coordination, knowledge integration, absorptive capacity, open innovation, dynamic capabilities, and socio-technical governance. The case itself guided the use of inductive reasoning. This included aspects like product structure, evidence mapping, claims, creative authorship, documentation, validation and market readiness coordination.

At this stage, the codes were grouped into themes and interpreted using triangulation. For source triangulation, case materials were compared to interview data. For role triangulation, a comparison was made between the viewpoints from the participants of the different Symbeeosis roles (science/ academia, manufacturing, commerce, and creativity). Stage triangulation focused on AI's role in different stages of the creative process: conceptualization, formulation, documentation, and validation as well as launch preparation. Theory triangulation involved checking the findings produced thus far against the conceptual frameworks in Chapter 2. The back and forth between data and theory reflects qualitative case analysis, where the aim is to derive a structured account, in contrast to generation of statistical inference (Gioia, Corley and Hamilton, 2013).

Themes closely tie the empirical case to the questionnaire constructs. In addition, themes distinguish case-specific observations from general conclusions and AI support from human accountability.

Table 3.2. Data structure for AI-enabled collaborative product development in the Symbeeosis ELIXIRS case

First-order case evidence	Theoretical / analytical category	Aggregate analytical dimension
Bee-centric brand identity, sustainability values, trust, organic positioning and health span/wellness orientation	Strategic and brand context	Case setting
IMMUNE, ENERGY, BRAIN and RELAX need-state tracks; sachet format; dry extracts; organic and free from claims	Product architecture	Product-development work
Scientific evidence on botanicals, dosage logic, functional merits and claims discipline	Evidence mapping and validation	Knowledge integration
Certified organic standards, GMP/GHP, HACCP, ISO, sourcing, specifications, supplier documentation and traceability	Quality and compliance infrastructure	Governance and control
Scientific, manufacturing, creative, commercial and market-access partners	Collaboration ecosystem	Cooperation and coordination
Market scanning, evidence review, option screening, drafting, document comparison and synthesis of cross functional information	AI-supported knowledge work	Boundary-spanning capability
Laboratory validation, regulatory interpretation, quality release, strategic approval and ethical responsibility	Human-led validation and decision rights	Accountability and AI governance

Source: Author's case study data (2026)

The structure of the data in Table 3.2 provides the narrative logic of the case. It narrates the evolution of a product-development partnership from strategic identity through product architecture and evidence into documentation, validation, and commercialization. Therefore, AI is analyzed as a part of the system of knowledge, trust, partner coordination, and governance.

3.3 Empirical setting: Symbeeosis, ELIXIRS and the AI-enabled product development field

The case study focuses on the development of the Symbeeosis ELIXIRS line. As described in Chapter 1, the project is a line of organic functional/nutraceutical supplements that integrate bee ingredients with certain plant extracts. The line stands at the confluence of the health span and daily wellness and premium organic offerings. It is not intended as a prescription pharmaceutical.

Symbeeosis is a suitable case to study as it is not a closed, internally driven development system. The company has had to integrate scientific, creative, manufacturing, supplier, and commercial knowledge in order to develop a coherent product line out of the broad wellness concept. This line of thought is consistent with the discussion in Chapter 2 on distributed innovation and digital ecosystems, where in order to innovate, firms need to rely on collaboration among multiple actors and a flow of knowledge, not merely the activities of a single company (Nambisan et al., 2017; West and Bogers, 2017).

The organizational & brand field

The first part of the case focuses on Symbeeosis, a firm operating at the intersection of nature, trust, sustainability, and bees. For the business, these values transcend branding. In the ELIXIRS project, these values determined what could be considered acceptable evidence, acceptable sourcing, acceptable communication, and acceptable use of AI. Since the brand's promise relies on credibility in science and ethics, the speed of AI-assisted work was not the sole criterion. The outputs were also assessed in terms of credibility, trust, and relevance to the firm's identity.

The product architecture field

The product framework consists of IMMUNE, ENERGY, BRAIN, and RELAX, each representing a different functional need-state track. The products are designed as personalized, daily, unit-dose powder systems. The formulation combines active dry extracts, synergistic dried botanicals, sterilized and pesticide free products. This framework posed a considerable challenge for development.

The framework of the range made the case particularly applicable to the study of AI-supported collaboration. The development team and collaborators had to conduct considerable research in order to gather and evaluate consumer and competitive insights, interpret scientific data, evaluate formulation options, draft technical and claim documentation, and transform scientific and quality information into a message relevant to commerce. In this domain, AI can support research, synthesis, and decision-preparation tasks, even knowledge work, so long as experts are responsible for interpreting and justifying the results (Davenport and Mittal, 2023; Vamathevan et al., 2019).

<u>The quality and compliance field</u>

The ELIXIRS project incorporated and adhered to quality and compliance standards. Symbeeosis and partner artifacts demonstrate the importance of certified organic structure and quality management frameworks such as GMP/GHP, HACCP, and ISO, among other safety and compliance systems. Hence, sourcing and supplier documentation, specifications and traceability, and product safety assessment were not mere administrative tasks. These were the vital building blocks of the infrastructure where collaboration was tangible and could be monitored.

This rationale of cautious optimism is evident in the literature of AI in life science and health, where data quality, expertise, and validation by a human specialist are of utmost importance (Topol, 2019; Mak and Pichika, 2019).

<u>The collaboration and market-access field</u>

Symbeeosis ELIXIRS collaborators included Symbeeosis, Sarl Lebeau Laboratoires, the Laboratory of Food Chemistry and Biochemistry (Aristotle University of Thessaloniki), Hellenic Pharmaceutical University (Athens), Beetroot, VIAN, APIVITA, BOTANIBRANDS, PHARMAGNOSE, and Q S Professional. All of them had market-access relationships. Although not a part of the main group, Synviva and BIOAGROS wished to be part of the preparatory stage and the commercialization of the product.

Each partner entered this process with their own set of interests. For the scientific partners, interests focused around evidence, dosing standards, and the scientific credibility and compatibility of the developed products.

For the manufacturing and production partners, interests centered around production feasibility, as well as the documentation and control/release processes. For the creative partners, interests involved communication, packaging, and the alignment of the cosmetics brand. Lastly, the commercial partners were interested in market readiness , launch timing, and supply sourcing. Symbeeosis integrated these interests and maintained the overall strategic control.

This differentiation is important because cooperation is not identical to coordination. Coordination refers to the alignment of activities segmented into sub-components that rely on control over timing, decisions, and handoffs. Cooperation, on the other hand, involves aligning interests and building trust and commitment (Gulati, Wohlgezogen, and Zhelyazkov, 2012). AI could help both by structuring information and documentation. That said, AI also exposed a significant and difficult challenge: how to ensure trust, responsibility, and professional credibility in a multi-partner development process.

The data-intensive background

Projects like Big Data Grapes and Bee Connected demonstrate that Symbeeosis is capable of data-centric frameworks and collaborative data practices. Hence, they designed data, quality, and coordination frameworks. Still, this experience does not imply that AI was used for every ELIXIRS decision, nor was the AI system used as a substitute for the domain expert. When it comes to ELIXIRS, AI's functions are intentionally restricted. AI is applicable where partners must organize dispersed data, set a uniform standard for data and knowledge, evaluate options, assess the quality of data, and make decisions.

3.4 Description of the case

Highly aspirational, the origins of Symbeeosis ELIXIRS can be traced back to vision inspired by nature and bees. It was immensely challenging to develop a line of wellness supplements that were functional, organic, and ethically sourced; unique and distinguishable from all wellness supplements on the market. There was intent behind each formulation, but the creator's true purpose was to integrate and apply the diverse systems of knowledge.

Phase two involved finding reliable ingredients and supporting claims. This involved combining the brand's meaning with evidence, dosage, ingredient and plant extract compatibility. In this phase of collaboration, the scope of functional collaboration was challenged. Scientists and Academics brought evidence, and the manufacturing participants offered the understanding regarding the bounds of logic and control, while the participants of the creative function began to transform product logic into communication. The resulting line was a collaboration of evidence, formulation, documentation, and branding.

Another movement outlines the cycle of commercialization. Partners in market access, along with channel-related insights, contributed to the pharmaceutical, biotech, and retail market readiness. Commercialization did not become an event that occurs after the development stage. The loops show how trade-related concerns feed back into the product architecture, claims discipline, packaging, and documentation. The case study captures this aspect of product development as a non-linear process, where market, science, and trade, as well as quality and manufacturing, and brand communication, were harmonized.

The case study's main challenge is encapsulated in the transition of dispersed knowledge to usable product development. AI assured speed but also trade structure and comparative analysis. The collaboration relied on trust, and, to some degree, validation and accountability. The range of products required a disciplined and defendable trade and creative quality. The case study is not a narrative on how AI disrupted trade partnerships. Instead, it is a narrative on how AI was integrated into a partner network that had already absorbed the limitations on evidence, formulation, compliance, communication, and market readiness.

3.5 Selection of Participants and Inclusion Criteria

The selection of interviewees was based on purpose and role. Interviewees were chosen mainly on the basis of their direct involvement in partner coordination, AI-supported work, evidence and/or testing, manufacturing, communication, and/or the commercial launch of ELIXIRS. The goal was not the proportional representation of a wider population, but evidence of maximal richness across the most relevant functions to the case.

Table 3.3. Role-based selection of interviewees

Participant role	Main case function	Analytical contribution
Founder and Owner of Symbeeosis	Strategic ownership, brand vision, partner integration and final responsibility	Strategic logic, governance, collaboration and value interpretation
R&D Director of Symbeeosis	Internal product-development and R&D coordination	Ingredient evidence, formulation, documentation and AI-supported work routines
Market Director connected with Lebeau Laboratoires	Manufacturing/market interface and implementation perspective	Feasibility, documentation, launch preparation and partner coordination
General Manager of VIAN	Commercial/channel and market-readiness perspective	Market access, distribution logic and commercialization constraints
Creative Department Manager of Beetroot	Creative communication and brand/packaging translation	Brand language, packaging alignment, communication and authorship boundaries
Food Science and Chemistry professor, Aristotle University of Thessaloniki	Scientific and evidence-based contribution	Ingredient credibility, evidence validation and quality of scientific reasoning
Pharmaceutical Sciences professor, Hellenic Pharmaceutical University of Athens	Pharmaceutical/life-science contribution	Claims defensibility, validation and health-related evidence boundaries

Source: Author's case study data (2026)

The size of the selection of participants reflects the logic of the qualitative case study design. The aim is not to achieve a statistical framework for generalization, but sufficient functional coverage to examine QI.1-QI.4 through information-rich evidence. The most recent qualitative saturation work suggests smaller selection of participants in the population of interest if the objective is depth of analysis rather than estimation (Hennink & Kaiser, 2022).

The main criteria for inclusion in the study were participation in product development decision-making and management of external partnerships, work on ingredients, formulations, quality and/or claims, AI-supported analysis or writing, creative or commercial translation, or data sharing and confidentiality. Individuals without relevant involvement in these fields were not selected, as their experience would have contributed limited evidence to questionnaire constructs.

3.6 Reliability, validity and research quality

This qualitative case study emphasizes research quality and trustworthiness as concerns of reliability and validity. The focus is not on statistical replication, but the development of a credible case account that is reliable, confirmable, and transferable (Tracy 2010; Nowell et al. 2017).

By giving a detailed account of the case's facts, they justified transferability. This chapter describes the product and partnership network, development phases, AI-assisted knowledge work, boundaries of quality and compliance, and boundaries of confidentiality and commercial interests. This helps the audience determine how closely the case represents small and medium-sized enterprises in the areas of nutraceuticals, functional foods, biotechnology, and health-oriented innovation ecosystems. This dissertation states that the findings are bound to a specific context.

3.7 Ethical Considerations

Ethical practice was incorporated into this study due to the multiple sensitivities (commercial, health-related, partner-related, legal, & AI documentation) revolving around the case study materials. Participants were told about the study, how their contributions would be used, and what the study would entail, and how the results would be constructed. Results are shown based on a person’s functions/roles and never by name. The study also took into account the ethical implications surrounding the use of AI in collaborative product development.

The use of AI to assist in the interpretation of evidence, writing assertions, or documentation and coordinating these tasks creates ethical concerns for AI in regard to traceability, accountability, bias, hallucination, and overreliance. For that reason, the lack of human judgement is an ethical risk, as AI outputs were only seen as providing substantial value within a context characterized by human judgement, endorsement and accountability (Morley, et al 2020; Topol, 2019).

3.8 Limitations of Methodology

The primary limitation involves the singular selection of the Symbeeosis ELIXIRS project as a case study. Though this case study is rich and suitable to the relevant analysis, it cannot be generalized to the entirety of biopharmaceutical, nutraceutical, or functional-food innovation. As a result, the findings should be interpreted as analytical generalizations regarding mechanisms and conditions, rather than as statistical generalizations pertaining to an entire industry.

Another limitation refers to the cross-sectional nature of the AI study . Tools, governance, regulatory frameworks, and partnerships are all fluctuating. The measurement of AI-embedded trust, data exchange, and value requires the expansion of longer research studies. The current research attempts to identify a critical moment in the collaboration rather than a long period of time within the deepening of AI-based product development.

The last restriction is mostly related to ethics and confidentiality. The specifics of some formulations, the names of certain suppliers, and the private decision-making processes and/or ethical responsibilities of some partners simply cannot be shared. Therefore, these restrictions influence the operational depth of the level of details that could be shared. Nonetheless, these restrictions had a positive impact on the study's ethics and ensured that the analysis remained focused on collaboration, governance, and cognitive work augmented by AI, rather than on confidential, sensitive data.

4. Results and Analysis

4.1 Introduction

This chapter analyzes the Symbeeosis ELIXIRS case study and describes findings on the prescribed questionnaire's four constructs. Certain specific interview and secondary source materials will be cited. The case study aims to assist comprehend AI-enabled collaboration, not to define a research problem.

This chapter will not assess the impact of any specific AI technology. Rather, it will focus on the potential impacts of AI on collaboration among diverse stakeholders within the context of collaborative product development that spans the scientific, legal, industrial, commercial and creative domains.

The main finding was that AI was viewed as an enabler. It was thought to have a role in the pre-thinking and drafting of text, but was considered to have provided no substitute for the judgment of a domain expert, be it in the field of science, law, creativity, or strategy.

This chapter is organized according to the questionnaire constructs. The context of the case and the AI-enabled collaboration is described in section 4.2. Corresponding to QI.1,section 4.3 focuses on AI's role and the limits to collaboration support, QI.2 and QI.3 are addressed in section 4.4. The perceived impacts of AI on collaboration and the resultant development are analyzed in this section. Section 4.5 presents a synthesis of the key factors and barriers, and the case's broader implications , thus addressing QI.4. Section 4.6 provides a summary of the chapter.

4.2 The Case Context and the AI-Enabled Collaboration Setting

The case study elucidates the developments made in Symbeeosis ELIXIRS which is an organic Herbal Supplement platform. It is built around the ideas of health span, longevity, wellbeing, and everyday wellness rituals. Secondary case material lists Symbeeosis as a company centered around Greek biodiversity and organic bee products.

The firm also sources bee products ethically and employs strategic, certified partnerships with producers, manufacturers, creative collaborators, and associates. The company's ethos and values also center around the idea of "symbeeosis" which enables the creation of partnerships, thereby enhancing the productivity of each network participant.

Symbeeosis Organic Herbal ELIXIRS range:

Figure 4.1. Overview of the Symbeeosis Organic Herbal ELIXIRS portfolio

Source: Author's case study data (2026)

Considering the stages in the product development process, the case encompassed the first four established components of product development: generation of ideas/research, formulation, testing/validation, and launch. It was reported that in these phases, AI was considered highly beneficial in the development of preliminary design and formulation where the need arose to sort and compare large amounts of scientific, supplier, market and consumer data.

In the design collaboration, the product owner and the firm's product development and research leadership, as well as the manufacturing, branding and communications, and commercialization partners were all included as participants.

Evidence collection, phytochemistry, formulation, and rationale for claims design was provided by scientific partners. Assessment of commercial viability for the product, product data, and guidance on dosage, safety, and release was provided by the manufacturing partner. The branding and communications partner worked on enhancing the product and brand insights.

The commercial partner advised on the balance of value distribution and demand/supply and optimizing the product launch. The product ownership partner owned the brand and the product in its extension, while also synthesizing the insights for commercial growth.

Table 4.1. Anonymized interview evidence base

Participant role used in this chapter	Main collaboration domain	Main evidentiary contribution
Founder/Owner, Symbeeosis	Strategic case ownership and overall collaboration governance	Vision for AI adoption, decision rights, collaboration priorities, perceived business value, future platform needs
R&D Director, Symbeeosis	Internal product development and technical coordination	AI-supported market and evidence review, formulation support, data standards, documentation, confidentiality controls, metrics
Market Director, Manufacturing Partner, Lebeau Laboratoires	Manufacturing and product implementation perspective	Formulation convergence, ingredient screening, finished-product documentation, technical approval, manufacturer-side limits of AI
General Manager, VIAN, Commercial Partner	Commercial partnership and launch leadership	Launch readiness, partner coordination, forecasting potential, approval flow, trust and skill issues
Creative Department Manager, Beetroot	Branding, packaging, and communications	Creative workflow support, brand authorship boundaries, asset adaptation, consistency across communication outputs
Professor, Food Science and Food Chemistry, Aristotle University of Thessaloniki	Academic R&D and formulation science	Literature screening, ingredient compatibility, dosage rationale, quality specification, regulatory evidence, data governance
Professor, Pharmaceutical Sciences, Hellenic Pharmaceutical University of Athens	Academic scientific review and evidence interpretation	Scientific validation, evidence reliability, expert accountability, confidentiality, future AI-supported systematic review

Source: Author's case study data (2026)

AI was applied to many specific tasks, and participants cited no kind of enterprise AI stack. The data indicates the use of ChatGPT-like models to generate drafts, aids for meetings, and conduct literature searches and evidence syntheses to provide ingredients; synthesis of comparison tables was completed using office and/or spreadsheet-based tools; and guided interview prompts were used to translate the technical aspects to commercial elements.

Evidence in this case suggests that, rather than employing an enterprise-level autonomous AI system, the parties utilized various forms of AI as generative, analytical, and creative support. Participants did not cite examples of a fully integrated enterprise AI system, nor of a robotic process automation (RPA) system, within the ELIXIRS project. For this reason, the technologies of Microsoft Copilot Studio, OpenAI agent workflows, UiPath, and AlphaFold Server are not analyzed as operating tools of the case. They are relevant as contextual examples in the case of AI-enabled automation and integration in workflows and a scientific context. Evidence from the ELIXIRS project points to a more limited application of AI for literature assistance, organization of evidence, preliminary evaluations, drafting, coordinating, and creatively iterating (OpenAI, 2026b; Microsoft, 2026; UiPath, 2026).

The prevailing theme was human-definition and reviewed assistance by AI. AI facilitated and expedited the organizational processes, but the ultimate accountability remained with people.

This represents a significant finding. Within a context of regulations and reputation concerns, the collaboration utilized AI to expedite and organize knowledge and information, rather than employing AI as a stand-in tool for autonomous product-development.

4.3 Findings on AI Use in Collaborative Product Development

QI.1 studies the integration of AI within the workflows and routines of the ELIXIRS product-development collaboration. The findings indicate that AI was primarily involved in upstream, knowledge-based activities, including market research, partner synthesis, evidence review, claims drafting and preliminary screening of options. AI was less involved in the stages of production, validation, final approval and in regulatory or brand authorship.

4.3.1 AI as an upstream knowledge-acceleration tool

The interviews revealed AI's value was mostly recognized for its ability to facilitate collaboration when significant volumes of information - whether scientific, technical, commercial, or creative - were required.

These views correspond to the knowledge-integration and absorptive-capacity logic outlined in Chapter 2 (Grant, 2021; Zahra and George, 2002). AI was not a source of advanced knowledge in this context. Rather, it assisted partners in the more rapid localization, organization, and comparison of external knowledge. The transformation of this knowledge into product decisions was accomplished by humans.

"AI is a strong assistant, but not a substitute for experience and responsibility. Humans remain at the last step of the decision-making process when the risk and value increase." (Founder/Owner, Symbeeosis)

This quote illustrates the boundary present in almost all the participants. AI was seen positively when it was used to enhance the quality of the preparation, but it was not seen as the ultimate authority. The academic food scientist participant noted the same in scientific terms, when the outputs of AI have to be validated against the primary sources of evidence and AI was seen as the tool of the process, not the decision-maker.

4.3.2 AI in market analysis, product architecture, and need-state definition

A major finding shows how AI drove the pivot from a broad idea of "well-being" to a more defined skeletal structure of a product offering. Several participants indicated that the initial idea was shaped into four distinct need states: IMMUNE, ENERGY, BRAIN, and RELAX. This is a more important distinction to note because it presents AI more as an options-framing tool rather than a product strategist. In terms of Chapter 2, it is more about AI-assisted search, prediction, and cross-functional concept development and less about autonomous product strategy (Agrawal et al., 2022; Ulrich et al., 2020; Davenport and Mittal, 2023).

4.3.3 AI in ingredient evidence review, formulation screening, and compatibility assessment

AI's best application was ingredient evidence review and preliminary formulation screening. The food science professor provided an example of how they use AI tools and AI-powered literature search platforms to review and synthesize evidence regarding the candidate botanical ingredients of the four SKUs.

That same participant identified an important limitation. They explained that AI could help with the development of the presentation of dosages, comparisons and preliminary evaluation of the components or nutrients. However, the final product would still require human involvement in the formulation, the steps of production, lab validation and quality assessment. This result would also support the current literature on the screening of ingredients, lab validation, and responsible management of claims (Bagchi and Nair, 2016; Irigoiti et al., 2021; Davenport and Mittal, 2023).

4.3.4 AI in documentation, claims support, and technical-commercial translation

Multiple examples documented the use of AI in various organizational functions. This included considering the four SKUs, each of which had different ingredient logic, functional territory, evidence base, labeling, and communication. Document examples included product and meeting documentation, as well as meeting notes. The function head of the R&D stated that AI function saved significant time in preparing these documents.

The main challenge was not data collection. It was necessary to create relevant scientific and technological information in clear, compliant, and commercially valuable formats. Prior to the use of this information in product descriptions, technical documents and internal communications, partners were expected to appreciate the quality of the sources and the balance of evidence and dosage, the rationale of ingredient-function relationships, and the limits of the claims. In this regard, AI was useful in drafting and providing a framework for the development of clearer documents and was instrumental in the translation of technical information into language understandable by the commercial and creative partners. The assessment of evidence, claims and responsibility for the final draft of compliant communication was, however, the privilege of humans involved.

"The hardest thing to share is usually not raw data. It is interpretation." (Creative Department Manager, Beetroot)

This supports what was said in Chapter 2 about the nutrition and health claims substantiation within Regulation (EC) No 1924/2006 and the advocacy of responsible communication related to functional foods and supplements (European Parliament and Council of the European Union, 2006; Bagchi and Nair, 2016).

4.3.5 AI in coordination routines and cross-partner alignment

A common result has been that AI improved the collaboration inputs rather than removed the collaboration altogether. Participants did not perceive AI as having taken the place of meetings, emails, and talks with partners, but rather that meetings would become more concise, as partners would come prepared with more structured information, more specific alternatives, and cleaner draft reports.

4.3.6 AI in creative, branding, and commercial work

The AI narratives are usually technical, and this interview adds a creative counterbalance to those narratives.
"AI can make the machine run faster; it does not replace the person driving it."; the Creative Department Manager (Beetroot) mentioned that AI did not influence the creative work. Humans created the strategic narrative, the visual world, the tone, and the overall architecture of the campaign. AI can help with consolidation for initial mentions, assist with aggregating visual realms, help with copy variations, structure the order of a presentation, and adapt a planned rollout. However, the unique human means to communicate were the authors. AI may have been used to synthesize an idea.
The campaign's primary creative idea was to build a new category of products that are resonantly emotional and of a premium quality, rather than the primary role of the campaign to fulfill the needs of more creative work assets to reach them.

4.3.7 Summary of AI-supported and human-led activities

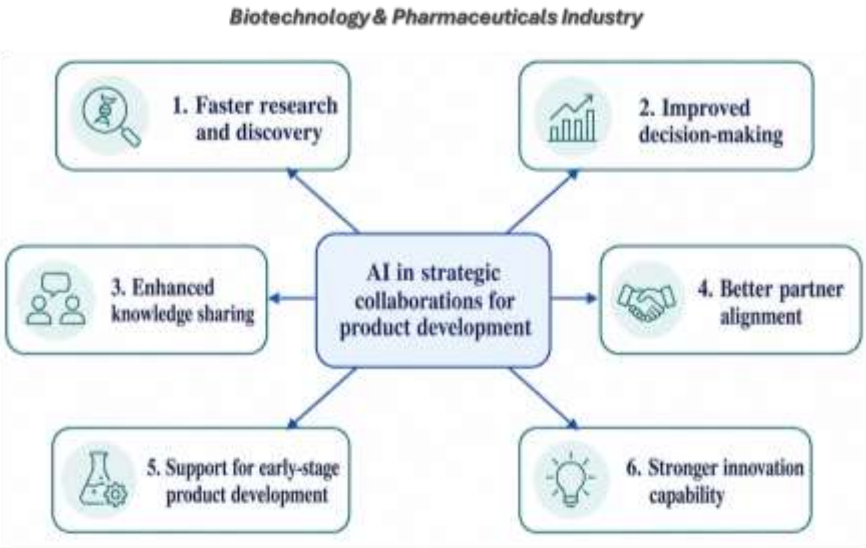
Table 4.2. AI-supported activities and non-delegated human controls

Product development area	AI-supported contribution reported in the case	Human-led control or final responsibility
Market and category exploration	Competitor comparison, customer-review analysis, trend identification, target audience exploration, market gap detection	Strategic positioning, product portfolio decision, brand fit, commercial prioritization
Ingredient evidence review	Rapid literature screening, evidence mapping, comparison of botanical ingredients, preliminary safety or interaction signals	Critical scientific interpretation, source verification, dose logic, regulatory defensibility
Formulation screening	Preliminary comparison of ingredient combinations, compatibility assessment, option narrowing, support for extract/dosage rationale	Final formulation, sensory evaluation, laboratory testing, stability validation, expert sign-off
Supplier and specification comparison	Structured comparison of certifications, pricing tiers, delivery timelines, active compound markers, missing fields	Supplier qualification, audits, relationship assessment, procurement decision, QA approval
Claims and documentation	First drafts of technical sheets, product descriptions, claims summaries, internal briefs, version comparison	Compliance review, final label wording, claims approval, legal and regulatory accountability
Partner coordination	Meeting preparation, summaries, shared reference documents, change tracking, cleaner handoffs	Trust building, conflict resolution, final decision rights, accountability for choices
Creative and communication workflow	Reference synthesis, early copy options, content adaptation, consistency checks across assets	Brand strategy, tone of voice, art direction, campaign architecture, final creative judgment
Production and release	Potential future QC analytics and deviation flagging; limited evidence of direct use in current case	Manufacturing execution, quality release, batch records, physical tests, regulatory record keeping

Source: Author's case study data (2026)

To avoid giving the impression of a false degree of accuracy, percentiles are omitted when summarizing qualitative patterns. AI assistance was observed to be greatest for early-upstream knowledge tasks. As tasks progressed to validation, compliance, production execution, and strategic accountability, the assistance diminished. This is demonstrated in Figure 4.2.

Figure 4.2. Qualitative contribution of AI in strategic collaborations for product development



Source: Author's case study data (2026)

4.4 Perceived Effects of AI on Development Outcomes and Collaboration

QI.3 focuses on how stakeholders perceived AI to affect the development of innovations that are "speed" to market, impact/resource efficient, "robust" reproducible and "regulatory-ready" innovations. The results showed a varied pattern. The perceived impact of the use of AI was the highest in relation to speed, reduced rework, efficiency in documentation, convergence in formulation, and preparation for the launch.

The completion of the innovations' quality and compliance with regulations and the initiation of the innovations' quality and regulatory impact on the production release of the innovations was considered to be "indirect" as these innovations still required manual testing and advanced judgment to compliance with formal quality systems.

4.4.1 Summary of AI-supported and human-led activities

Interviewees most commonly cited speed as a benefit. There was no mention of AI affecting the speed of all stages equally. Participants said that AI improved speed during the data processing phase and reduced the time AI spent on documentation.

The manufacturing partner preferred describing the effect as quicker convergence on robust formulation instead of faster production. This differentiation is valid. Due to the impact of AI on the collaboration, the manufacturing partner was able to reach a defensible product file faster. Nonetheless, the production, physical, and regulatory processes, as well as post-production and release timelines, remained unaltered. The creative contributor was also wary of overstating the impact. From a creative standpoint, AI was hoped to deliver incremental, yet meaningful, improvements in the areas of (a) synthesis, (b) optioning, and (c) post rollout, as opposed to a radical change in brand strategy.

4.4.2 Innovation quality and product distinctiveness

Participants indicated that AI facilitated the crystallization of ideas. Concepts such as product logic became more pronounced. The assessment of evidence became more methodical, and alternatives to the proposed solutions were evaluated prior to reaching a conclusion.

Moreover, the use of AI was not the sole factor contributing to the innovation that was ELIXIRS. The innovation of ELIXIRS was due to integrated AI assisted searching, botanical science, brand philosophy, and standards and the quality of the partners involved. This finding corroborates the argument regarding strategic capability provided in Chapter 2. The use of AI was regarded with worth only when integrated with the firm's own specific resources, the partner's knowledge, quality practices, and the discretion of management (Barney and Hesterly, 2021; Teece, 2007).

4.4.3 Shelf-life confidence, quality consistency, and resilience

AI had an impact on shelf-life confidence and quality consistency in an indirect manner. It did not substitute for stability testing, certificates of analysis, lab protocols, and quality release procedures. All respondents acknowledged that in-house shelf-life validation continued to be both manual and experimental.

This shows AI's impact on the control-related, active protection of the system. The data proves that AI reduced the chances of major quality-related issues developing late in the process, but formal proof of control-related issues still had to be completed through batch testing, CoAs, and stability studies, validation of the suppliers and third-party testing, and QA sign-off. So, AI should be seen as a component of quality control, and not a substitute.

4.4.4 Launch readiness and regulatory documentation

Participants viewed Launch Readiness as an important benefit. They associated Launch Readiness with approved formulas, validated suppliers, print-ready copy, technical support, claims support, completion of supplier documentation, and adjustments of partner documentation. AI helped by speed drafting, structuring ideas, pinpointing gaps, and enhanced clarity of the unresolved. This was increasingly valuable as each ELIXIRS SKU needed a different ingredient logic, and claims support.

Regulatory and claims related work was also mentioned by a few participants to be human led. Work participants mentioned that communication relating to health has a legal and ethical dimension in the EU nutrition and health claims which has been explained in Chapter 2 (Regulation (EC) No 1924/2006; European Parliament and Council of the European Union, 2006). AI could draft or outline evidence, but it could not determine the validity of a claim. The pharmaceutical sciences professor noted that AI provided useful outputs to the extent that they could be verified, explained, and defended.

The food sciences professor similarly insisted on a verifiable and documented AI output, traceable to peer-reviewed or authoritative sources. In regulatory affairs, the primary contribution of AI was to simplify and triage better, rather than supplanting human oversight.

4.4.5 Communication, coordination, and decision-making

AI improved the efficiency of communication by providing structures for inputs of the upcoming discussion which answered the QI.2. AI helped the participants by providing summarized drafts, comparison tables, documents, and evidence review for collaboration, to access alternatives more effectively. The partners did less debating and tried to put together the missing and unstructured drafts during the meeting, which made it more productive. The shared outputs of the shared analysis allowed partners to share the same opinion and support a more consistent understanding of technical terminology.

Some relation and governance concerns continued to exist even after the introduction of AI. AI could not assist in resolving the remaining strategic disagreements and trust deficits, nor to address the various discomfort levels of partners. The concerns of over-trust, hallucination, and the possible loss of unique, creative, and novel outputs remained.

Regarding the socio-technical nature of AI, the integration of AI in collaboration is still in an emergent phase, unless the socio-technical system incorporates a collaborative working culture and a culture of evidence review (Orlikowski and Scott, 2008; NIST, 2023, 2024). The strategic decision was still the sole discretion of the brand owner, and the internal governance was unchanged by AI. AI improved the evidence, but governance remained unchanged.

Table 4.3. Potential effects of AI by outcome area

Outcome area	Perceived positive effect	Limits or qualifications
Speed and time-to-market	Faster evidence review, formulation screening, document drafting, and partner alignment; participant estimates suggest meaningful reductions in upstream timelines	Physical testing, regulatory review, production, and launch dependencies remained largely human and process-driven
Innovation quality	Broader exploration of ingredients, clearer need-state structure, sharper product differentiation, better early option framing	AI did not replace expert creativity, botanical expertise, scientific interpretation, or brand judgment
Quality consistency	Tighter specifications, better supplier-data comparison, earlier identification of gaps and variability risks	Final consistency depended on CoAs, batch testing, QA protocols, supplier qualification, and manufacturing controls
Shelf-life confidence	Preliminary ingredient compatibility and stability-relevant signals informed formulation choices	Actual shelf-life validation remained manual and experimental
Regulatory and claims readiness	Quicker preparation of claims evidence summaries, labels, technical sheets, and product descriptions	Final claims approval and legal responsibility remained manual; AI outputs needed verification
Partner coordination	Cleaner drafts, more focused meetings, fewer clarification cycles, shared evidence references	Trust, interpretation, and accountability still required human leadership
Resource utilization and cost	Potentially fewer reformulations, fewer documentation revisions, lower hidden rework cost	No formal financial KPI dashboard was reported; cost effects are stakeholder estimates
Creative and communication output	Faster reference synthesis, option development, adaptation across channels, consistency checks	Core strategy, visual world, tone, and brand authorship remained human-led

Source: Author's case study data (2026)

4.5 Enablers, Constraints, and Analytical Synthesis

QI.4 addresses the organizational, technological, governance and relational conditions, which enable or constrain responsible AI use in ELIXIRS cross-sector collaboration. The evidence suggests that AI tools, data readiness, clear roles, human oversight, partner trust, confidentiality, and the flexibility to move between various fields of science, regulation, commerce, and creativity were valued more than the tools themselves.

4.5.1 Enablers of AI-supported collaboration

The first identified enabler was strategic leadership. The Founder/Owner described advocacy for technology for business, going beyond marketing or administration, to include strategic planning, R&D, communication, and even customer service. Support at this level legitimized the idea to experiment with AI, encouraging partner organizations to observe AI as a plausible complement to the product development process. The leadership position was also not technological determinism. It was accompanied by a strong advocacy that ultimate accountability still sits with people.

The second enabler identified, was the partnership architecture itself. Because ELIXIRS relied on a distributed network of partners, AI could capture and harness value by connecting, organizing, and translating dispersed knowledge. Inputs had to be integrated from scientific, manufacturing, commercial, and creative partners. This constructed a prerequisite for a boundary spanning system. AI was instrumental precisely because the nature of the project was knowledge intensive and inter-organizational, which is aligned to the interdependent actors' theory of innovation value (Adner, 2021; Jacobides et al., 2018) discussed in Chapter 2.

The third enabler was our quality and compliance infrastructures. From the literature background, Symbeeosis appears to have a stringent quality assurance structure and certification. Respondents provided descriptions of key collaborative artifacts, such as certificates of analysis, batch records, third-party testing, and QA/regulatory review. These systems offered the control environment to allow the drafting of the AI-assisted documents to be tested, interrogated, and refined.

4.5.2 Constraints and risks

The strongest constraint was data readiness. Participants from commercial partners, academia, and technical roles talked about data fragmentation, inconsistent formats, use of PDFs for CoAs, incomplete digital records, inconsistent data terms, variability and specificity of suppliers, and no shared templates.
"Without good inputs, AI only makes confusion move faster", the commercial partner pointed out.

"*AI is only likely to reproduce the confusion*", (Professor, Pharmaceutical Sciences, Hellenic Pharmaceutical University of Athens).

This is likely the case's most significant finding. Unlike other technologies, AI amplifies the data quality of the environment. It cannot fill the gaps of insufficient, poorly structured, and inconsistent data. This aligns with the observation in Chapter 2 about the quality of data, the importance of data validation and documentation, and the monitoring of data as central to the responsibility surrounding AI technologies (NIST, 2023, 2024).

Another constraint was concerned with confidentiality and the segmentation of intellectual property and access. The ELIXIRS project comprised several proprietary formulations, supplier partnerships, commercial strategy, claims rationale, and commercial assumptions. Participants pointed out the existence of confidentiality agreements, access segmentation, role-based access, and restrictions related to the uploading of sensitive formulations or supplier information to potentially public AI portals. Access segmentation and role-based access are practices of governance cited in the case;

The further constraint was identified as the ambiguity of rules. The use of AI to summarize is not acceptable in health and food supplements. Participants emphasized the importance of grounding AI-generated summaries and health and safety claims to scientific, evidential, justified, and regulatory controlled framing and validated sentences. AI can show some of the frameworks to be less time-consuming, but it also provides a governance risk by creating summary control and relying on the AI system as an author. A more limited claim that Chapter 2 goes beyond the trust-AI governance framework, is claim of AI regulatory control to support food supplements (AI-assisted replacement).

Table 4.4. Key enablers and constraints of AI-supported collaboration

Dimension	Enabler identified in the case	Constraint or risk identified in the case
Strategic leadership	Founder-level support for AI adoption across R&D, communication, coordination, and strategy	Risk of over-expectation if AI is framed as a substitute for responsibility
Data infrastructure	Structured templates, completeness rules, validation checks, audit trails, version control	Fragmented files, inconsistent CoAs, unstructured PDFs, supplier variability, unclear terminology
Governance and decision rights	Clear human oversight and role-based authority; AI as assistant	Ambiguity if outputs are treated as proof, if accountability is not assigned, or if AI use is not transparently documented
Confidentiality and IP	Role-based access controls (RBAC), NDAs, segmentation, anonymized or abstracted inputs, controlled environments	Limits on cross-functional AI analysis; risk of exposing sensitive data, proprietary formulations, supplier information, or strategy through external tools
Regulatory discipline	Human validation, claims review, source traceability, QA sign-off	AI-generated evidence not automatically acceptable; hallucination and overclaiming risks
Partner relationships	Established expertise, shared product goals, complementary capabilities	Different professional languages between scientific, commercial, regulatory, and creative teams
Skills and culture	Small low-risk use cases, training, explicit boundaries, critical review culture	Uneven AI literacy, skepticism, over-trust, concern about generic or low-quality outputs
Technology integration	Potential for a shared platform connecting knowledge, workflow, quality, market and R&D data	Current reliance on isolated tools and fragmented systems

Source: Author's case study data (2026)

4.5.3 Analytical synthesis in relation to the Questionnaire Constructs

These four questionnaire constructs allow findings to be analyzed generally and grounds each conclusion in specific evidence from the ELIXIRS case. The aim was to progress from case observation to conclusions that can be analytically transferred without the assertion of statistical generalizability.

QI.1: The case demonstrates that AI is optimal as a modular support tool for task automation involving search, synthesis, comparison, draft and prep decisions. With respect to ELIXIRS, formulation, quality & claims approval and strategic brand decisions were made by humans.

QI.2: Use of AI noted the preparation of meeting briefs and notes, draft comparison tables, and summaries as increased input quality and reduced the time needed for participants to prepare for meetings. The artifacts enhanced the coordination process, but did not replace trust, meeting rituals and the delegation of decision-making authority.

QI.3: Participants noted that the use of AI shortened the formulation draft and the ready-for-launch documentation. It also reduced the need for multiple iterations of the same documentation. The remaining elements of the launches were the quality of the lab, regulatory approval & the market, which were contingent on testing, and the human inputs of assessment and approval.

QI.4: AI was used in an ethical context when there was a clear and controlled use of AI-supported data, privacy was preserved and trust existed among participants. Lack of governance can lead the same technology to be misused for causing greater risk and chaos in collaborative efforts.

The combined evidence of the four questionnaire constructs leads to the same conclusion: in the context of knowledge work, AI is an innovative tool for the co-creation of products. It leads to problems when it is relied on to replace evidence, accountability, and governance of partners.

4.5.4 Interpretation through the conceptual framework

From a strategic resources and dynamic capabilities perspective, AI was not the decisive resource on its own. Its value appeared when it was combined with Symbeeosis brand assets, scientific know-how, partner networks, quality systems and managerial judgement.

AI helped the collaboration expand its dynamic capabilities by instructing AI on how the collaboration should sense the market, identify opportunities worth pursuing, and determine how to best structure workflows, and helped adjust the collaboration by providing faster documentation and clearer task handoffs and providing a better framework for systematically comparing options. (Barney and Hesterly, 2021; Teece, 2007).

Articulating from the standpoint of knowledge integration and absorptive capacity, AI enhanced the collaboration by enabling the partners to obtain, assimilate, and evaluate external information. There was a prerequisite of human transformation to incorporate this information into the decision-making process. Therefore, AI was a complement to absorptive capacity and not a substitute for the interpretation by experts.

From the open innovation and ecosystem perspective, ELIXIRS shows how value in product development was created through a network of partners. AI supported this ecosystem by acting as a boundary-spanning knowledge layer across partner boundaries, in line with Chapter 2's open innovation and ecosystem arguments. (Chesbrough, 2020; Adner, 2021; Jacobides et al., 2018; Carlile, 2002). However, the same complexity created a structural governance paradox: data needed to be shared to create value, but not so much to breach a partner's IP, trust, and confidence.

From a socio-technical perspective, case studies show that AI adoption involves much more than a technical choice. It requires several socio-organizational factors such as culture, trust, skills, accountability, and design of workflows. The most successful use cases had well-defined boundaries: AI assistance was accepted to perform organization, comparison, synthesis, and draft activities of low-risk nature, while final judgment remained with responsible and accountable humans. This boundary provided AI and over-automation skeptical users a comfortable place through a health-related product context (Orlikowski and Scott, 2008; European Parliament and Council of the European Union, 2024; NIST, 2023, 2024).

Overall, AI perfoms a boundary spanning function. It converted fragmented information into useful project data. However, that only happened when data was orderly, roles were clear and social validation was present. The case provides no evidence for the plain story of AI replacing human skills. It presents a framework of a productive collaboration of human skills, which AI greatly enhances.

4.5.5 Emerging measurement framework from the case

Measurement for AI in co-development of products has been proposed by respondents regarding a number of metrics. These metrics are based on a gap discussed in Chapter 2 on measurement frameworks regarding AI in product development stages that include evidence synthesis, formulation decisions, regulatory documentation, coordination costs, and commercialization preparedness.

Table 4.5. Suggested metrics for evaluating AI value in ELIXIRS-type collaborations

Metric	Why it matters in this case	Relevant functions
Time-to-market	Captures whether AI shortens the path from concept to first sellable batch	Strategy, R&D, regulatory, manufacturing, commercial
Formulation convergence time	Measures of how quickly teams move from candidate options to a robust formula	R&D, academic partners, manufacturer
Number of formulation iterations	Indicates whether AI reduces trial-and-error loops and dead-end experiments	R&D, manufacturer, QA
Documentation cycle time	Tracks the time needed to prepare and approve labels, technical sheets, claims files, and product briefs	R&D, regulatory, marketing, commercial
Right-first-time rate	Shows whether formulas, batches, documents, or approvals meet requirements without rework	R&D, QA, manufacturer
Deviation or error rate	Measures non-compliant claims, missing data, inconsistent specs, or quality deviations	QA, regulatory, manufacturer
Cost per iteration	Captures the financial impact of reduced rework, repeated testing, or delayed approvals	Management, R&D, finance
Approval or alignment rounds	Shows whether AI improves partner coordination by reducing repeated review cycles	All partner functions
Forecast accuracy and launch readiness	Assesses whether AI improves commercial planning and launch execution	Commercial, brand owner, distribution partners
Creative consistency and adaptation speed	Captures value in communication systems without confusing output volume with brand quality	Creative, marketing, digital teams

Source: Author's case study data (2026)

Looking forward, the participants are optimistic that Artificial Intelligence will be a part of the advanced formulation screening, regulatory documentation, predictive market analysis, quality control, and all-department collaborative platforms.

A focus and investment in this future is a positive sign, but not without conditions. Traceability and verification of the AI and output governance framework, data infrastructure, and AI proficiency will be the fundamental conditions for this to be realized.

4.6 Chapter Summary

This chapter details the use of AI during the Symbeeosis ELIXIRS collaboration and the relevant implications beyond the individual case. With respect to QI.1, AI was primarily utilized during upstream knowledge work. Regarding QI.2, AI enhanced the preparation of shared artefacts, and helped streamline focus during collaboration. In the context of QI.3, AI enhanced speed, documentation, and launch readiness, but only provided indirect support for quality and regulatory confidence. As to QI.4, AI's utility was dependent on data readiness, confidentiality, clarity of roles, trust between partners, and human oversight.

As such, the general conclusion is cautiously optimistic. Utilized in a governed support layer, AI has the potential to enhance collaborative product development. However, it should never function as an autonomous product developer, scientific validator, or substitute for managerial accountability.

5. Discussion

5.1 Introduction

In this chapter the data presented in Chapter 4 are analysed and connected to the literature and conceptual framework cited in Chapter 2. The previous chapter assigned the empirical data collected from the Symbeeosis ELIXIRS project in the observed ways, results, facilitators, and barriers to the use of AI. On the other hand, Chapter 5 aims to analyze the meaning of the results. This interpretation goes beyond the visible aspects and considers the AI use case as a collaborative product development of AI in a context that is embraced and considered a case study.

Chapter 5 argues that the ELIXIRS collaboration did not consider AI to be an autonomous system. Additionally, AI did not fulfill or take over the functions or roles of scientists, regulators, creatives, or managers. AI was a deliberate and boundary-spanning tool. It assisted collaborators in bridging inter-organizational and interdisciplinary boundaries, optimizing the processing of information, facilitating decision-making, and converting the fragmented and dispersed resources of the project into knowledge that was useful. In addition to this, the value of AI was highly dependent on human expertise, trust, and data quality. Furthermore, AI's value was dependent on sufficient governance, trust, and proper definition of the boundaries of the decision-making rights.

This chapter presents findings based on responses to the four questionnaire constructs of the case study evidence. QI.1 examines the incorporation of AI into collaborative work processes. QI.2 examines interactions that include both verbal and non-verbal communication, the sharing of information and knowledge, as well as the processes and mechanisms of decision-making. QI.3 examines the outcomes of perceived development. QI.4 examines the enabling and disabling factors regarding the use of Responsible AI. The discussion focuses on the areas of the ELIXIRS framework that are relevant to the case study evidence responses presented in Chapter 4.

5.2 Integrated Discussion of Findings in Relation to Questionnaire Constructs and Literature Background

Based on the ELIXIRS case, biotechnology, pharmaceuticals, and healthcare sectors illustrate that synergistic collaborations integrating disparate data and resources are fundamental to innovation. Touching on collaborations in various sectors and domains, initiatives combine the necessary scientific, organizational, and creative resources to stimulate the rapid development of beneficial clinical health outcomes.

The same is true for the ELIXIRS project. Symbeeosis directed the entrepreneurial and product ambitions as well as the strategic brand, while the academic partners contributed evidence, food science, and phytochemistry. Manufacturing and product execution contributions came from Lebeau Laboratoires, and Beetroot handled brand and communication of the product. VIAN filled the gap as commercial partner. AI should therefore be understood not as a technological breakthrough, but as a strategic support capability embedded within the partnership.

QI.1: Role and boundaries of AI in a collaborative product development. AI did not act as an autonomous system aimed at governing the entire product development. AI assisted in performing market and trend analyses, synthesizing competitors and consumers, providing evidence and supplier comparisons, drafting claims, preparing creative content, and summarizing meetings. While these functions were significant, they were of a preparatory nature.

This also aligns with resource and capability-based strategies (Barney and Hesterly, 2021; Grant, 2021). The AI tools' value did not originate from their scarcity, as competitor firms also have access to comparable tools. The tools' value was attributed to their use in conjunction with Symbeeosis' brand and supplier and scientific networks as well as their formulation, quality, and partnership expertise.

Another approach that would also be applicable here is dynamic capabilities theory, which argues that the ability to resource and/or routine reorganize is critical when considering opportunity identification and exploitation (Teece, 2007). With regards to the ELIXIRS, AI was present in all but one of the areas and was still constrained.

Integration of knowledge literature is also applicable. The ELIXIRS example demonstrates that product development requires knowledge of bioactive ingredients, formulation, manufacturing, branding, market access, and claims. AI rendered the relevant knowledge more accessible and more easily compared. However, AI did not make the knowledge valid.

Absorptive capacity is most applicable here. This refers to the ability to recognize, assimilate, transform and exploit external knowledge (Zahra and George, 2002). In the ELIXIRS example, the AI system was useful mostly in knowledge acquisition and assimilation than in transformation and exploitation. External peer review, R&D judgement, dose and safety assessment, as well as creative interpretation and claims review, were necessary prior to the knowledge becoming a product decision.

The case also supports the open innovation theory. ELIXIRS was created thanks to the brand owner's network , the scientific partners, a manufacturer, a creative agency, and other commercial actors. As stated in Chapter 2, the ability to access and integrate external knowledge allows for open innovation (Chesbrough, 2020). As demonstrated in the findings, AI can improve this ability to some extent, because it can act as a knowledge reference layer, offering to the partners some common points of reference to be used before the communication and decision-making processes.

As such, AI-generated or AI-assisted evidence summaries can allow the discussions on ingredients, on claims, and on functional territories to be more structured. AI also improved documentation, so the handoffs between the R&D, and the regulatory, the creative, and the commercial teams, were more seamless and efficient. The case also demonstrates the AI-enabled open innovation paradox. Knowledge is the most valuable aspect, but it is also the most fragile. Literature on alliances and on the subject emphasize the importance of order, and the establishment of some form of governance, the protection of IP, and of established trust.

This, of course, is a key finding of the dissertation. AI-assisted collaboration balances the need to share enough data to integrate knowledge, while at the same time preserving IP, ensuring trust among parties, and fulfilling regulatory obligations. AI synthesis across workstreams is unfeasible when data is too fragmented.

An excessive amount of cross-function collaboration can lead to confidentiality violations, competitive edge loss, and inadvertent release of private technologies. Therefore, the ELIXIRS case supports the idea that AI governance should be viewed as a balancing mechanism. Governance should not be perceived as an administrative component of the design, but rather as an integrated part of it, allowing partners to deploy AI in a way that preserves the legal and relationship structures of the alliance.

QI.2: Knowledge sharing, coordination and decision making. Participants did not mention AI eliminating a meeting or a partner communication. Instead, it brought about a more purposeful meeting by providing better summaries, drafts, and alternatives. The Founder/Owner of Symbeeosis mentioned meetings becoming more purposeful, since the use of AI reduced the necessary effort for processing and comparing information.

When cross-functional translation was discussed, the Creative Department Manager cited "Product Truth, Brand Truth, and Communication Truth". Product Truth refers to substantiated claims and formulation evidence. Brand Truth refers to Symbeeosis' natural, organic and science based positioning as well as premium wellness. Communication Truth would likely refer to the go-to for the end customer.

Stakeholder participation at this level was expressed through the partnering decision. With regards to conflicts, the respondents said, Symbeeosis, as the brand owner, maintained strategic integrity; the academic and technical collaborators maintained the integrity of the scientific research and the formulation, the regulatory and quality maintained the integrity of the compliance and gatekeeping, the acting and creative partners maintained the integrity of the functional brand expression, and the commercial partners maintained the integrity of market alignment. While AI might provide rationalization, it could not have positioned the providers to suggest to the parties.

These provide valuable information to the expanding literature on agentic AI in terms of governance. The presence of AI even in a multi-step function does not rule out the fact that the partnered collaborative working arrangements most likely are intentionally managing the AI's governance function to a controlled extent, in the interest of preserving responsibility and accountability.

QI.3: Perceived development outcomes. Participants expressed positive but mixed feedback. They noted the most pronounced effects for early-stage research, convergence of formulations, preparation of claims and supporting documentation, partner alignment and launch readiness. One participant involved in research and development (R&D) cited an example in which they suspected that unclear or poor quality change documentation potentially led to a 20%-30% savings in time and costs. This estimation should be viewed strictly as a range of savings from an experienced practitioner as opposed to a rigorously defined effect.

QI.4: Enablers and constraints. Preparedness of data, transparency, confidentiality controls, partner expertise and governance influenced the use of AI. Thus, the case study reinforces the literature background on the significance of data quality and the need for human supervision. AI was most useful in environments where inputs were structured and decision rights were defined. Although, it was least reliable in environments where data and responsibilities were fragmented.

The research informs and corroborates the earlier studies. The ELIXIRS case indicates that AI was not a substitute for human expertise in a general sense. As an administrative tool, it was not utilized. Instead, it was recognized as a useful socio-technical resource.

AI proved useful across different domains, and it was a socio-technical resource that combined, inter alia, knowledge, governance, trust, and expertise. So, the case fills the literature background gap that was identified in Chapter 2, as it offers an empirical case regarding AI's role in a cross-sector product development partnership in a regulated health-related domain, and its ability to balance speed vs. accountability.

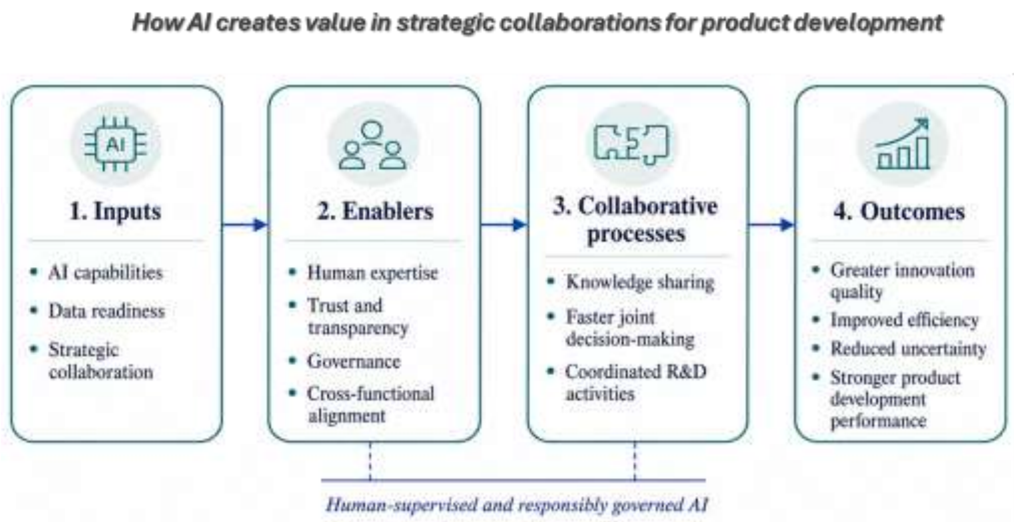
Table 5.1. Integrated interpretation of the findings in relation to the questionnaire constructs

Questionnaire Constructs	Integrated Interpretation
QI.1: Role and boundaries of AI in a collaborative product development	AI was deployed mainly in modular, upstream and information-intensive tasks such as literature screening, market scanning, formulation option comparison, documentation drafting and meeting preparation. It was not used as an autonomous end-to-end product development agent.
QI.2: Knowledge sharing, coordination and decision making	AI improved the quality of collaboration by structuring inputs, producing common reference points and translating knowledge across scientific, regulatory, commercial and creative domains. It improved discussion quality but did not change formal decision rights.
QI.3: Perceived development outcomes	The strongest perceived effects concerned speed, formulation convergence, documentation cycle time, reduced rework and launch readiness. Effects on shelf-life, quality consistency and compliance were indirect because physical testing, QA controls, regulatory review and claims approval remained human-led.
QI.4: Enablers and constraints	Effective use depended on leadership, partner expertise, data readiness, traceability, governance, confidentiality controls, trust and practical low-risk use cases. Constraints included fragmented data, IP limits, regulatory uncertainty, uneven skills, cross-functional interpretation gaps and the absence of a fully integrated shared platform.

Source: Author's case study data (2026)

In Figure 5.1, an integrated mechanism exhibits the processing of partner knowledge inputs through an AI support level. Value was added only after expert appraisal, governance, and partner trust; not independently. Therefore, AI outputs were converted into responsible decisions.

Figure 5.1. AI-enabled collaboration mechanism identified in the ELIXIRS case



Source: Author's case study data (2026)

5.3 Contributions and Managerial Implications

One theoretical contribution of this study is the characterization of AI as a controlled boundary-spanning capability. Chapter 2 has shown a gap in the literature regarding the role of AI in knowledge flow mediation in inter-organizational product development. The ELIXIRS case demonstrated the ability of AI to bridge various knowledge domains, including, but not limited to, the scientific evidence, formulation logic, regulatory constraints, supplier knowledge, commercial positioning, and brand communication. However, the boundary-spanning role has to be governed and is not autonomous. The ELIXIRS case showed that the autonomous boundary-spanning role was governed based on decision rights, data control, expert review, and confidentiality.

Another contribution is regarding open innovation and alliance governance. From the ELIXIRS case, the application of AI first acts as a foundational point for all partner organizations engaging in open collaboration. It also helps to address the growing governance dilemma of what is open to collaboration, what is to be kept, and in what technology ecosystem.

Regarding SMEs and nutraceuticals, collaborative needs go beyond patent protection since a competitive advantage can also come from a proprietary formulation, a competitive supply chain and trade, brand trust, and market claims. This case adds to the complexities of the documented and protected forms of innovation to explain AI openness. This is the "democratic" governance case to show the potential of unfettered knowledge to decline to collaboration and trust if governance mechanisms do not exist.

This case identifies both a methodological and a practical aspect concerning AI and measures the potential value of AI-enabled collaboration. Initial measures included in Chapter 4 are time-to-market, documentation cycle time, cost per iteration, convergence time under the right-first-time formulation, deviation/error, QC lead time, launch readiness, and forecast accuracy. Chapter 5 reinterprets these metrics as a people-based balanced scorecard for speed, quality, compliance, and collaboration. The key observation in AI contribution is that it should not just be measured based on the outcome, or textbook definition, as to what constitutes productivity. For AI contribution in products pertaining to the healthcare industry, this would consist of reducing claims risk, improving retraceable error handoffs, closing reformulation loops and/or documentation gaps, and improving post-validation assurance.

A further consequence is related to decision rights. Managers should have the same framework for what AI can recommend, what AI can draft, what AI can compare, and what AI cannot decide. This is especially important for products that are heavily regulated and where brand equity needs to be protected. In the case of ELIXIRS, AI could draft claims related text, but could not approve claims, and AI could support the exploration of creativity, but could not provide the brand's voice, among other things. Therefore, a decision rights matrix must be developed to categorize scientific, regulatory, quality, creative, commercial, and strategic decisions, which AI would manage.

An insulated platform with access restrictions could let partners use AI without breaching confidentiality. According to the strategies of Chapter 4, designing an integrated platform that focuses on the connection of knowledge, workflow, quality, market, and R&D data is more desirable than providing an isolated technical solution. Pioneering AI governance policies will allow firms to derive AI benefits while mitigating risks.

AI should be employed selectively in cross-functional routines where it offers real value (e.g. evidence maps, literature summaries, etc). One of the most complex collaboration challenges in ELIXIRS wasn't the absence of data but the amorphous nature of data. Scientific, regulatory, manufacturing, creative, and commercial partners generally needed the same data rendered in different specialized languages.

The case study illustrates that easier AI adoption was accomplished by using AI in low-stake, practical cases with clear added value, e.g., literature summaries, note-taking, evidence maps, first drafts, and alignment. Training should focus on confidentiality, data quality, bias, over-reliance, authorship and accountability. AI should be trusted to the degree that it doesn't stop users from exercising their editorial powers. Managers should identify and reward responsible usage of AI.

Symbeeosis illustrates a final implication concerning SMEs and entrepreneurial firms. AI will most probably be beneficial to SMEs. The use of AI may enhance Symbeeosis capacity for analysis even without the need for intensive internal structures of the company. AI may allow small teams to analyze more data, and more efficiently manage Partner engagement and documentation readiness. SMEs could be at an even greater risk and may be more vulnerable, as they may not have formal data architecture, secure AI operating environments, and Compliance Officers and AI Governance Teams. The ELIXIRS case would suggest that SMEs would be better off adopting AI in a more controlled manner from the CI-4 Governance Framework and building Governance early on.

5.4 Reflection on AI-Enabled Collaborative Innovation and Chapter Summary

This chapter examines biotechnology, pharmaceuticals, and nutraceuticals, and explains that trust will shift from informal and cooperative governance, respectively, as a result of the poor and disappointing consumer outcomes and experiences. Bioethics will augment trust. AI may support prediction, coordination and documentation, but it cannot replace trust, professional judgement or accountable governance.

The analysis confirms the need for more AI context-sensitive evaluations and how it is meant to be used. The speed AI provides is always welcome, but it could increase risks. Increased output volume is valuable only when it reduces uncertainty and improves the quality of decisions. Automated drafts save time when grounded in evidence, do not contravene legal evidence, and align with the organization's objectives. Accordingly, with the protective measures of sensitive knowledge, human accountability, value measurement, and the employees' collaborative learning, the ELIXIRS case justifies more cautious AI deployment.

Chapter 5 utilized the findings from the previous chapter in the context of strategic alliances, AI-enabled innovation, dynamic capabilities, absorptive capacity, open innovation, and the socio-technical and ecosystem perspectives. It was demonstrated that AI tools helped to accelerate, synthesize, and coordinate the preparation of decisions with no alteration to the ultimate control and decision-making framework. The value of the tools was considered to be aligned with the quality of the data, design, trust, and confidentiality, as well as the opinion of the expert.

6. Summary, Conclusions and Recommendations

6.1 Summary of the Study and Key Findings

This dissertation evaluated the supportive role of artificial intelligence in collaborative product development in a highly knowledge-intensive and regulated environment. The primary illustration of this was the case study of Symbeeosis ELIXIRS. The product development in this case was the integration of scientific evidence, the organic frame, formulation, supply, manufacturability, quality and compliance assurance, branding, and market accessibility. In this setting, AI was a supportive tool in knowledge integration and coordination, but did not substitute human judgement. The partners retained control over scientific, creative, business, regulatory, and management decisions.

The main theme of the research was the application of AI in forming responsible strategic partnerships that utilize dispersed knowledge among numerous participants. While AI can be employed in such partnerships, preserving certain boundaries is critical. These boundaries include confidentiality, quality of evidence, use of AI, and assessment of AI.

Therefore, these are the main boundaries that have been prescribed and were organized around the questionnaire constructs (QI.1-QI.4).

QI.1 – Role & Boundaries of AI use: The main applications of AI included synthesis of literature and evidentiary documentation, market and product screening, along with interdepartmental documentation and communication. AI also supported some creative and commercial activities. Most of these applications were upstream and information intensive. In contrast, formulation, validation, and approval of quality and claims, as well as strategic authorship, were human tasks. Therefore, AI was likely most effective as a support tool, rather than a replacement, for expert judgement and responsibility.

QI.2 – Knowledge sharing, coordination & decision making: AI technology assisted the generation of briefs, meeting notes, and comparison matrices. The documents helped partners prepare for and focus on the discussions. AI also helped alleviate the burden of routine coordination. That said, AI helped prepare decisions, but the decisions themselves were left to human judgement. The final decisions were dependent on expert judgement, compliance, and trust, as well as clearly assigned decision rights.

QI.3 – Perceived development outcomes: AI use was claimed to accelerate the synthesis of information, optimize the creation of drafts, and align teammates and improve the readiness of materials for the launch. The focus of this study was not to determine the effect of AI on laboratory quality, outcomes, regulation, or on brand or commercial value. These variables will continue to rely on evaluation, and a blend of creativity and strategic alignment.

QI.4 – Enablers & constraints: Impactful use of AI was associated with readiness of quality data, defined roles, limited access, review, trust, and an understanding of AI. The main barriers of AI use in the context of the study included inadequate supplier documentation, data fragmentation, consideration and respect for confidentiality and intellectual property rights, regulatory concerns, and over trust of AI. The results point to the understanding that AI has the potential to improve collaborative product development in the context of efficiency and the establishment of true accountability and good governance.

6.2 Conclusions

The conclusions presented in this dissertation address the four items identified in the case study evidence, as well as the conceptual framework described in the literature background.

With regards to QI.1, the ELIXIRS case indicates that AI was introduced in an upstream and modular, task-specific manner where it assisted the searching, synthesizing, comparing, drafting, and preparation tasks. AI did not assist or control the formulation and validation of final claims, the approval of final claims, or the strategic decisions of brand management.

Concerning QI.2, AI enhanced the quality of the generated artifacts, thus promoting better communication and knowledge sharing. AI helped generate high-quality artifacts that represented a high level of preparedness for collaboration. Examples of such artifacts are meeting notes, comparison matrices, drafts of working briefs, position notes and papers, and supportive evidence. All of these provided partners with improved meeting stimuli. Enhanced artifacts through AI still required trust, communication, and the exercise of the right to decide.

Regarding QI.3, an improvement to formulation and documentation, and the elimination of repetitive preparatory work, received mostly positive reactions. The more indirect impacts of integration, evidence, and assessment of quality of lab work were positively correlated to the extent, durability and readiness of an artifact, its regulatory compliance and robustness.
As for QI.4, effective AI use depended on trust, controlled framework, human review, real data access and established decision rights. On the other hand, negative factors were the absence of an integrated data set, lack of sufficient documentation, confidentiality & IP issues, regulatory ambiguity and an excessive dependence on the reliability of generated outputs.
Regarding open innovation and ecosystems, the ELIXIRS case study explains that AI supports collaboration by forming a "knowledge" layer that enables collaboration beyond organizational boundaries. The same open-edges configuration creates a tradeoff. There are simply uncontrolled resources that cannot be employed to be openly uploaded/shared when they concern formulations, supplier relationships, claims, quality records, and trade secrets. This case supports a selective openness model (cluster).
In a tradeoff situation, partners are prepared to share the minimum number of artifacts to manage risk, which would be structured in a well-defined and understood manner in terms of access, secrecy, and accountability.
In the drafting, searching, synthesizing and coordinating processes, AI undoubtedly adds value. Its contribution in regulatory, scientific, creative, ethical and strategic fields remains conditional on expert assessment and explicit human accountability. Consequently, the case demonstrates support for a cautious and regulated model of AI-augmented collaboration.

6.3 Strategic and Managerial Recommendations

The information gained defines guidelines for both the strategic and operational management of companies that partner to produce various health-associated, functional, nutraceutical, and biotechnology-based product lines. The guidelines are about joint ventures where the involvement in product design depends on the scientific, regulatory, manufacturability, market, and brand confidence variables.

To begin with, Artificial Intelligence should be customized to the specific development context of the exact collaboration. This means AI should be used in the design of internal assessments. All the design components for the incorporation of AI into products, where AI helps in the collaboration for the reduction of friction, consist of: marketplace assessment, evidence synthesis, formulation, supplier selection, claims, technical notes, and briefing, documentation and presentation notes, including launch documentation and presentation notes. AI is best for occupation tasks where a lot of input/output of information is needed, but little or no decision making is involved.

Moreover, management must understand the limitations and capabilities of AI before large-scale implementation. An uncomplicated governance matrix can develop, describe, cross-reference, and flag AI capabilities and limitations regarding summarization. Within the parameters of an ELIXIRS project, AI is allowed to draft the Preface for the Formulation Section. AI can also draft the content of the Formulation to justify the claims but is not allowed to assist in the final approval of the formulation and claims. AI can evaluate and compare the content of suppliers and can assist with the company's innovation but cannot act as an innovation guide due to ownership of the brand narrative.

AI can support compatible commercial scenarios but cannot launch a claim opposing ELIXIRS projects. The distinction helps keep control and guard against the risk of AI unintentionally taking over decision making in the absence of crucial tasks.

Further, partners are encouraged to use secure collaboration environments. This case study included key formulations, proprietary supplier relationships, claims rationale, commercial plans, and brand strategies. There are several tools and plans to manage these safely to avoid influencing public tools. Managers should prioritize secure shared platforms, with role-based access, control at a document level, managed AI environments, secure prompts and clear rules on the use of confidential data.

The AI-supported compliance and claims-management system must keep track of submissions, display evidence for supported claims, and give a final draft for claims review. Proprietary information is kept secure and in compliance with the law.

It should provide the means for contract stipulations. In situations involving the sale of food supplements or health products, the line between stimulating corporate growth, competitive edge, or compliance, is often thin. In such cases, it is often necessary to encourage managers to devise a controlled claims environment in compliance with claims entitlement.

AI should become a cross-functional, translation and substantiation-support tool. Many problems with collaboration stem from people putting things in the same context but from different perspectives. In case of people from the scientific community, these might be people thinking about how good the evidence is.

A manufacturer might be thinking about how feasible something is. A commercial partner might be thinking about the customer. For the creative team, this might be about the meaning, the emotional, and for a regulatory partner, about the allowed versus the prohibited. AI can do cross-disciplinary, cross-functional audience-centered summarization, and can analyze and sort evidence against contradictions and claims. It can also assist organize evidence and support a more structured argumentation. Again, we should not confuse substantiative AI with judgment AI. A senior practitioner still must decide and interpret what the product means, what the tradeoffs are, and how the brand can be aligned.

In addition, to ensure trust builds fairly, organizations should introduce the use of AI technology via training combined with incremental use cases. Training should go beyond the basics of prompt engineering to include source verification, the identification of AI hallucinations, privacy, data tiering, escalation, review duties, cases of AI abuse, etc.

Finally, attempting to quantify improvements in AI performance by using stage-related metrics is encouraged. The case for AI as a productivity enhancer is poorly argued. For managers, the differences between speed, quality, compliance, and coordination are critical. Examples of good metrics might include the time to achieve market entry, convergence time of the proposed formulation, number of formulation iterations, document cycle time, deviation and/or error rate, rounds of approval, complete supplier documentation, revision of claims, and expert time saved, among others. Metrics should not be used solely to demonstrate the positive benefit of AI. The emphasis should be on analyzing the context to reduce risk and informing where AI may reduce friction.

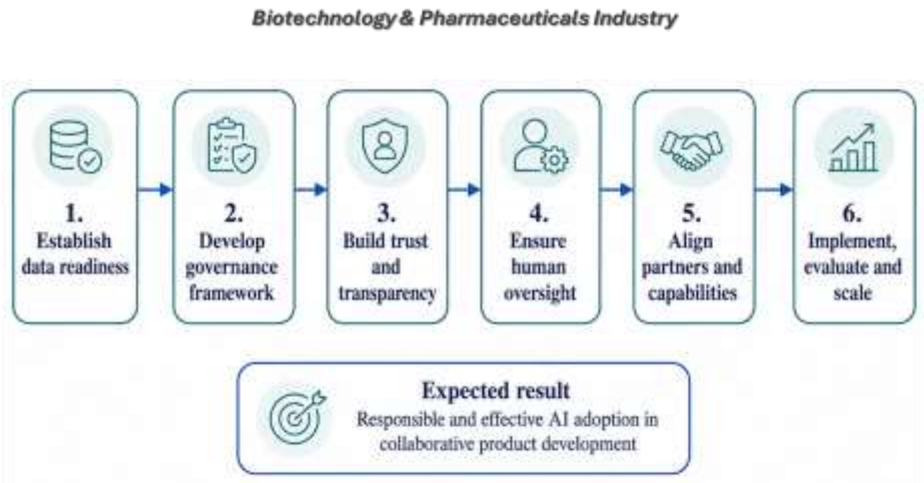
Table 6.1 Recommendations into action

Recommendation	Practical action	Analytical rationale and expected benefit
Build an AI-enabled operating model	Map AI use cases to the actual development workflow, beginning with evidence review, comparison, drafting and coordination tasks.	Turns AI from scattered experimentation into a repeatable collaboration capability.
Prepare the data before scaling AI	Standardize ingredient specifications, CoAs, claims evidence, supplier files, version control, metadata and audit trails.	Improves output reliability and reduces the risk that AI amplifies weak or incomplete inputs.
Define decision rights	Clarify what AI can draft, screen, flag or summarize and what must remain human-approved.	Protects accountability and prevents AI from becoming an informal decision-maker.
Protect confidential knowledge	Use role-based access, document permissions, NDAs, controlled AI environments and anonymized or restricted inputs.	Maintains partner trust and protects IP, formulation know-how and commercial assumptions.
Keep claims evidence-led	Require source traceability, permitted wording, expert review and versioned approval before any AI-assisted claim is used.	Strengthens regulatory defensibility and reduces the risk of overclaiming.
Use AI for translation, not judgment	Prepare audience-specific summaries and identify inconsistencies across scientific, commercial, regulatory and creative documents.	Improves cross-functional alignment while keeping final interpretation with experts.
Train for calibrated trust	Teach source verification, hallucination detection, confidentiality rules, escalation procedures and critical review of outputs.	Encourages adoption without weakening professional responsibility.
Measure stage-specific value	Track speed, quality, compliance and coordination metrics across development stages.	Supports evidence-based scaling and identifies where AI genuinely reduces friction.

Source: Author's case study data (2026)

The suggestions above could potentially be an adoption roadmap of recommendations. Figure 6.1 outlines a strategy for responsible AI collaboration that utilizes workflow mapping and data analysis prior to valuation and conditional scaling.

Figure 6.1 Roadmap for responsible AI adoption in strategic collaborations.



Source: Author's case study data (2026)

6.4 Policy and Ecosystem-level Implications

This dissertation is mostly managerial, but it does have some policy and ecosystem implications. AI-enabled product development in functionals, nutraceuticals, and biotechnological products is highly dependent on unsolved ecosystem challenges that individual firms, and particularly SMEs, lack the ability to solve. Ingredient ecosystem challenges regarding claims, quality, data standards, collaboration, and academic expertise pose challenges to the responsible use of AI.

We can consider universities and research institutions as trusted intermediaries. In this specific case, the scholar expertise contributed and validated both the scientific understanding and the interpretation of uncertainty in the AI-backed evidence summaries.

Different stakeholders at various levels of the value chain (SME, manufacturing, distribution, creative and educational) have different levels of understanding and/or experience. Some of the stakeholders have expressed resistance, e.g. misplaced confidence.

Custom-made workshops, governance frameworks, training interventions, and the support of responsible practices will mitigate most concerns.

The initiatives aim to create and understand a common language. The initiatives should also define boundaries and presumed restrictions to oversight and AI.

Additionally, shared infrastructures that allow AI collaboration may be a competitive requirement. AI enabled collaboration demands a balance of strict confidentiality and connected data. Innovation ecosystems of the future should provide infrastructures that offer safe and controlled AI supported data collaboration with select role-based access and auditability. Smaller companies could use the infrastructures to leverage AI without the risk of exposing their proprietary tools, supplier data, or claims strategies.

Public innovation schemes, industry associations, and cluster initiatives all have roles to play by providing “infrastructure” in the form of standard frameworks, training, pilot projects, and assessment of maturity. These supports would result in the large companies remaining in the “lead” position while the smaller, more agile companies, gain the trusted AI edge. Simply put, trusted AI means the ability to ensure that regulators, customers, and partners will all be protected. This will encourage innovation and improve the quality of the AI being implemented.

6.5 Limitations of the Study

A primary constraint in this study is reliance on a single case, the Symbeeosis ELIXIRS collaboration. The observations cannot be statistically generalized to the entire spectrum of biopharmaceuticals, nutraceuticals, or functional-foods. The observations should be considered analytically generalizable propositions to describe mechanisms and frameworks. The extent of their generalizable propositions should be evaluated under similar circumstances.

The second limitation is connected to the availability of the data. The analysis was mainly based on the author’s interviews and the little existing secondary data. Although the existing data are plentiful and of good quality, they are pieces of evidence of the participants’ perceptions, memories and interpretations of the profession.

This study does not provide an estimation of the impact of AI on the velocity of work, quality of documentation, and degree of collaboration. Therefore, the findings should be regarded as qualitative and perceptual, instead of causal.

The third limitation concerns the confidentiality of the ELIXIRS project. The ELIXIRS project includes commercially sensitive data, names of suppliers, decisions of formulations, and quality assurance documents, and proprietary project partner processes. For ethical and business reasons, some aspects of the operations have been left intentionally vague. Although this limits certain aspects of the analysis, it upholds the collaboration and protects the participants' interests.

AI tools and governance mechanisms are unfolding rapidly. This study documents one event in the development of AI-facilitated collaboration. The collaborations involving AI will be impacted by various tools, regulations, partner abilities, and systems of data governance. Although there are challenges, this research is significant. It provides details of instances where AI can assist with the combination of knowledge and collaborative decision-making, while maintaining the necessary aspect of human accountability.

6.6 Suggestions for Future Research

This dissertation outlines multiple avenues for subsequent research.

To begin with, integrating comparative multi-case frameworks would enhance the quality of ensuing studies. Revising AI-enabled collaborative product development across the nutraceutical, pharmaceuticals, biotechnology, cosmetics, medical nutrition, and functional foods sectors aims to investigate to what extent the mechanisms of upstream search acceleration, evidence synthesis, and documentation support, translation and governed peer oversight, as identified in the ELIXIRS case, are unique to organic supplements.

In addition, studies to consider the AI-enabled collaborative product development temporal span of activities to address formulation and validation, commercial and post-launch performance criteria would determine the extent to which improvements in the perceived commercial and post-launch performance criteria of developing a product with less effort, less rework, and more launch readiness, which are of higher quality, and meet other regulatory burdens of the task.

Further, longitudinal studies would determine the extent to which post-launch partners' trust in AI would diminish, and would show efficiencies in AI use , and in governance over time in the various collaborative product development activities in which the partners experienced trust.

Finally, the dissertation suggests a potential framework for measurement, and subsequent research should explore its application. AI research should shift towards a more quantitative stance, beyond the evidence of productivity, and work to identify the extent and degree to which AI-enabled collaborative product development would improve the development of documentation, the integration of actions, and post-launch collaborative governance frameworks.

Further research on the safe AI collaborative frameworks is definitely needed. The ELIXIRS case demonstrates this tension clearly. AI value increases when data is integrated, but the governance, open data practices, IP protection, and confidentiality are compromised. Governance, access rights, audit trails, data room design, private AI, and prompt-management algorithms are all topics for potential further research. Amongst all these areas, AI will have a positive impact when information is combined across different paradigms. This will be valuable, especially for innovation ecosystems of collaborative alliances and SMEs.

There should be further regulation for studies investigating AI-aided evidence review and claims support documentation. This research will be critical for food supplements and health product domains, where - for various legal and ethical reasons - a combination of scientific substantiation and consumer trust is required.

For online services using Autonomous AI that can do multiple steps of automated workflows, research is needed regarding agentic AI in a collaborative, controlled environment.

Further research should address these human factors. Elements such as trust, professional identity, AI literacy, scientific skepticism, creative authorship, managerial accountability, and fear of becoming redundant influence adoption.

Encouragingly, the case study of ELIXIRS found that the benefits of AI adoption increase when AI is perceived to function as embedded support rather than as a replacement for the professional. Further research may investigate the impact of different coping mechanisms on governance, training designs, and leadership messages on AI adoption across scientific, commercial, and creative roles.

Research may also look at the outcomes from the consumer side. As noted, the consumer response was beyond the scope of the collaboration and subsequent studies on product development initiatives. AI-facilitated product development may have multiple implications for consumer trust, perceptions of product development, claims to be more transparent, and increased willingness to purchase and/or use the products. It may even set a new standard for product development of consumer health products. This is especially important for companies that promote AI use in product development of health products, utilizing combinations of safe artificial intelligence and/or other natural or even traditionally integrated botanical products.

There remains the possibility of constructing a matrix of stages for a more responsible AI-driven Product Development Collaboration. Such a matrix may guide companies in ranking themselves against the company databases of governance, quality, support, deficit, trust range and collaboration. This model assists policymakers and managers distinguish between basic, guided, and collaborative AI. It also forms a more practical framework for operational scaling of AI without losing accountability. Ultimately, AI redefines the strategic core of collaborative product development.

After all, algorithms can read the map, but they can't choose the destination!

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Appendix A: Chapters' References

[1] Trustworthy AI is used here as a governance concept rather than as a guarantee of error-free outputs; it refers to documented risk management, human oversight, validation and monitoring. *(Chapter 2.2)*

[2] Functional foods and organic supplements are not treated here as medicinal products; the point is that health-related claims require substantiation and careful communication. *(Chapter 2.4)*

Appendix B: Interviews

R&D DIRECTOR SYMBEEOSIS.pdf

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