

Article

Embedding Innovation in Engineering Education: An Iterative Approach to Curriculum Integration at Bachelor's and Master's Levels

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Highlights

Please indicate how your work links to systems science via your contributions to systems practice, theory, and/or methodology.

- The study contributes to systems practice by developing a coherent bachelor-to-master pathway that integrates innovation competencies across courses, study levels and disciplinary contexts.
- It contributes methodologically by applying iterative Educational Design Research to connect curriculum design, implementation evidence and progressive system-level refinement.

What are the main findings and/or the implications of the main findings?

- The study produced an eight-module framework, complemented by a proposed pre-thesis course, for progressively embedding innovation-related learning in engineering education curriculum.
- Four design principles emerged when developing such a framework: progressive sequencing, contextual adaptability, curricular alignment and iterative refinement.

Abstract

Engineering education is increasingly required to prepare graduates who can address complex societal challenges by connecting technical expertise with innovation, sustainability, stakeholder needs, and value creation. This article examines how an iterative curriculum design process can support the progressive integration of innovation competencies across bachelor's and master's engineering education and identifies the design principles emerging from this process. The study employed an Educational Design Research approach, combined with a case study at the Faculty of Engineering, Norwegian University of Science and Technology. Between 2022 and the 2025/2026 academic year, selected innovation modules were designed, implemented, assessed and revised in authentic engineering course contexts. The study resulted in a structured bachelor-to-master innovation pathway for students. The process supported integration by making innovation competencies explicit, testing selected modules in authentic course contexts, using implementation evidence to guide revision and organising the resulting content into a coherent curriculum pathway. The principal contribution is an eight-module framework organised into three clusters, complemented by a proposed pre-thesis course. The study also identifies four design principles: progressive sequencing, contextual adaptability, curricular alignment and iterative refinement. The findings show that a modular approach can make innovation competencies



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visible and teachable and support their progressive integration without requiring the immediate redesign of entire education programmes. These findings imply that the framework and design principles can provide a structured basis for integrating innovation-related learning within existing engineering programmes, while allowing adaptation to specific disciplinary, curricular and institutional contexts.

Keywords: innovation competencies; engineering education; curriculum design; systemic curriculum development; educational design research; modular curriculum; bachelor and master education

1. Introduction

Engineering systems are inherently sociotechnical, yet engineering education has often remained dominated by technical rationality [1], leaving limited room for students to engage with the social, organisational, sustainability and innovation dimensions of engineering practice [2,3]. Universities are increasingly exploring how to strengthen the innovation and sustainability of their research, rethinking the education system and how innovation developed by their researchers could be delivered and transferred to society [4]. The integration of engineering education, research, innovation, sustainability, technology, business understanding, and entrepreneurial thinking provides a basis for preparing graduates to contribute to competitive and sustainable societal development [5,6].

Innovation and sustainability have become increasingly important in education and research in recent years, addressing global challenges and strengthening collaboration and knowledge transfer. Current research and the literature confirm growing market demand for graduates who possess transdisciplinary skills that combine technical expertise with social scientific understanding [7–9]. This need is also clearly reflected in education policies [10]. For example, as societies face increasingly complex sociotechnical challenges, such as climate change, security, and healthcare shortages, governments and businesses will require professionals who can engage with both engineering dimensions and broader sociopolitical considerations [11]. Entrepreneurship education is increasingly relevant for engineering students, particularly those aiming to create their own ventures, as changing labour markets, digital opportunities, evolving mindsets, easier business creation processes, and public support schemes have made entrepreneurship a more viable career path [12,13].

Adding to this complex landscape, there is a common perception that engineering education remains predominantly technical [7,8,14], a view widely observed in many undergraduate engineering programmes [14–16] offered by Western universities. This challenge is further compounded by the engineering profession's persistent lack of diversity, which contributes to a broader talent shortage [11,12]. Engineers and innovators contribute significantly to the economy by tackling urgent challenges and developing novel solutions [6,14,15,17]. While this role depends on technical expertise, it also requires curiosity, the capacity to connect different forms of knowledge, and an orientation towards value creation—all of which are central to innovation competencies [4].

These conditions provide a favourable context for advancing innovation in engineering education, where innovation skills and emerging competencies are more likely to be accepted and integrated rather than opposed. Introducing innovation into engineering courses requires adjustments to traditional teaching approaches and a degree of institutional openness from higher education institutions to support, or at least accommodate, curricular change. This article focuses on approaches to embedding innovation competencies in bachelor's and master's engineering education.

In this article, curriculum decision-making, curriculum design, and systemic curriculum development are treated as related but distinct concepts. Curriculum decision-making refers to the deliberative process through which choices about curriculum content, priorities, and purposes are made, often involving multiple actors, interests, and institutional constraints [18–22]. Curriculum design refers to the pedagogical organisation of learning, including aims, intended learning outcomes, content, learning activities, assessment approaches, and learning resources [18,23]. Systemic curriculum development refers to a broader process of curriculum change that extends beyond the design of individual learning activities or courses, addressing coherence across courses and study levels, alignment with institutional strategies, stakeholder engagement, and the capacity of the curriculum to respond to societal, professional, and technological change [11,24,25].

The research question for this study is: How does an iterative curriculum design process support the progressive integration of innovation competencies across bachelor's and master's engineering education, and what design principles emerge from this process?

To address this research question, the study applied Educational Design Research (EDR) to examine the iterative design, implementation, assessment and refinement of innovation modules in existing bachelor's and master's engineering courses. In the present study, curriculum design refers to the development of the innovation modules as pedagogical units embedded within existing engineering courses. The curriculum design process includes formulating learning objectives, selecting innovation-related content, designing student activities, and aligning learning outcomes with the broader educational aims of engineering education.

In the following sections, the article presents the state of the art and the institutional context of the study, followed by the methodological approach combining EDR with a case study perspective. Section 4 reports the implementation cycles, cross-cycle findings and the resulting bachelor-to-master innovation framework. Section 5 examines these findings in relation to iterative curriculum design, systemic curriculum development, learning practices and transferability. The article concludes by outlining the study's contribution to research, implications for engineering educators and programme leaders, and directions for future research.

2. State of the Art and Case Study Background

2.1. Intersection of Curriculum Design and the Progressive Integration of Innovation Competencies

Curricular decision-making is typically a prolonged and iterative process, involving a diverse group of participants and shaped by the interests and expectations of an even broader range of stakeholders [18]. The curriculum decision-making process may be approached from different analytical angles. Goodlad [19,26] distinguishes three perspectives: sociopolitical, technical professional and substantive. The sociopolitical perspective concerns how curriculum decisions are shaped by social, institutional, political, and organisational actors. The technical professional perspective focuses on the procedures, methods, and professional practices through which curricula are designed, revised, implemented, and evaluated. The substantive perspective, in contrast, addresses the fundamental curricular question of educational content: what knowledge, skills, competencies, values, and learning experiences should be included and prioritised, thereby answering the question of 'what should be learned?' [18,21].

Curriculum design involves deliberation about the aims, content, priorities, and learning experiences that should shape education. In curriculum development, numerous perspectives have been advanced by scholars. McKenney et al. [18] distinguish three major orientations: learner, society, and knowledge. The learner orientation emphasises students' personal and educational needs, experiences, and interests. The societal orientation focuses

on the relevance of societal challenges, trends, and future needs for curriculum content. The knowledge orientation concerns the academic, disciplinary, and cultural knowledge considered essential for learning and future development. These orientations are interconnected in engineering education because curriculum content should simultaneously respond to disciplinary knowledge requirements, students' future professional needs and the changing societal contexts in which engineers operate.

Engineering education has historically placed a strong emphasis on scientific and mathematical foundations, disciplinary knowledge and the ability to solve technically defined problems [1,2,14–16]. Although these foundations remain essential, engineering education has progressively expanded to include design-based and project-based learning, problem- and challenge-based learning, interdisciplinary collaboration, entrepreneurship education and engagement with real-world problems [5,6,11,13,14,16]. These pedagogical developments reflect a gradual shift from preparing students primarily to solve predefined technical problems towards enabling them to frame problems, work under uncertainty, engage with stakeholders and consider how engineering solutions create value within broader contexts.

In this study, innovation is understood as the development and implementation of new or improved ideas, methods, processes or solutions that create value within a particular technical, organisational or societal context [27,28]. Innovation competencies refer to the knowledge, skills and dispositions that enable students to identify opportunities and needs, frame problems, generate and assess ideas, work across disciplinary boundaries, understand users and stakeholders, evaluate value and feasibility, communicate proposed solutions and consider pathways towards implementation [4,13].

Contemporary engineering problems increasingly involve not only technical systems, but also users, organisations, regulations, ethical concerns, sustainability demands, economic constraints, and societal consequences. Engineering solutions therefore cannot be understood solely as technical artefacts. They are developed, adopted and used within social, organisational, economic, political and environmental contexts. This broader understanding is associated with sociotechnical engineering education, which treats technology and society as mutually shaping rather than as separate domains [29–32]. Therefore, the substantive question of "What should be learned?" [19] becomes closely connected to the question of how future engineers can understand and act within complex interactions between technology and society. Technical expertise remains essential, but it is insufficient on its own when engineering solutions must respond to societal needs, stakeholder expectations, sustainability challenges, uncertainty, and changing contexts of use [11,30–32]. Innovation competencies are therefore central because they equip students with the capacity to identify opportunities, connect different forms of knowledge, collaborate across disciplines, understand user and societal needs, evaluate alternatives, and develop solutions that can create value in real-world contexts [4,11].

The research gap addressed in this study concerns how these competencies can be translated into learning objectives, teaching activities and learning outcomes and then progressively integrated across a study programme. Existing research has examined innovation and entrepreneurship competencies, individual pedagogical interventions and strategies for engineering curriculum change [4,13,24,25]. However, less attention has been given to the iterative curriculum design process through which innovation competencies can be embedded across existing engineering courses and progressively structured from bachelor's to master's level.

There is also a need for empirically informed design principles that explain how this integration can be adapted to different courses, study levels and disciplinary contexts without requiring the immediate redesign of an entire engineering programme. This study

addresses this gap by examining the iterative design, implementation and refinement of innovation modules embedded within existing engineering courses.

2.2. Institutional and Curricular Context for the Case Study

The study was conducted at the Faculty of Engineering at the Norwegian University of Science and Technology (NTNU). The faculty had an institutional interest in strengthening innovation, sustainability, and value creation, while the existing engineering curriculum offered limited systematic integration of innovation competencies across bachelor's and master's levels. This created a suitable context for exploring how innovation could be introduced through modular interventions embedded in existing courses.

Over the past several years, NTNU has cultivated an institutional innovation ecosystem that embraces a holistic perspective on value creation [15]. Government directives specifically prioritised sustainability, the green transition, and digitalisation, alongside post-pandemic economic recovery, public sector innovation, and enhanced workforce relevance within educational curricula. In 2022, NTNU strategically converted institutional challenges into actionable innovation goals, specifically aiming to amplify sustainable innovation emerging from its research centres and clusters. In alignment with institutional directives, the Faculty of Engineering formalised its own strategic framework. This strategy centred on cultivating a robust innovation ecosystem, underpinned by strong organisational support, a culture of creativity, and core technical competencies. By strengthening its foundational infrastructure and expanding collaborative networks, the faculty aimed to pioneer novel models to accelerate socioeconomic transformation. Ultimately, this ecosystem was designed to stimulate innovative thinking, heighten the visibility of emerging opportunities, and maximise the faculty's overall value to society [33,34].

Despite these institutional ambitions, innovation-related learning was not systematically sequenced across the faculty's bachelor's and master's programmes. Innovation concepts and activities were present in selected courses, bootcamps and extracurricular activities. However, students did not encounter a coherent progression from introductory innovation awareness towards advanced application in engineering projects and thesis work. This created a curriculum design need: to develop an approach through which innovation competencies could be introduced progressively while remaining connected to existing engineering courses, disciplinary content and programme structures.

In this environment, the innovation modules for engineering students at the Faculty of Engineering were designed, developed, tested and assessed. The intervention uses a module-based structure embedded within existing bachelor's and master's programmes, rather than positioning innovation as a stand-alone or extracurricular activity. The modules were developed as a targeted intervention to address gaps in students' preparation to engage with interdisciplinary challenges, real-world stakeholder contexts, sustainability-oriented engineering and innovation as a socially and institutionally situated practice. Selected modules were adapted to different study levels, national and international policy frameworks, engineering disciplines and learning contexts. Their iterative development and implementation subsequently informed the design of a broader bachelor-to-master pathway. Selected modules were tested over three years with more than 200 students.

3. Methodology and Research Framework

This study adopted an EDR approach, combined with a case study perspective, to examine the iterative curriculum design process through which innovation modules were developed, implemented and refined in existing bachelor's and master's engineering courses. The unit of analysis was the curriculum design process, including module development, implementation across different course contexts, the evidence used to assess

relevance and fit, and revisions made across successive iterations. EDR was selected because the study aimed not only to develop a pedagogical intervention, but also to systematically examine how evidence from authentic educational settings informed its refinement. The intervention consisted of innovation modules developed and progressively integrated into existing engineering courses at the Faculty of Engineering, NTNU.

The methodological logic of the study follows the understanding of design research as a pragmatic and iterative approach to addressing complex educational problems. In this study, the educational problem was how to introduce innovation competencies into engineering education in a way that was pedagogically meaningful, compatible with existing courses, and aligned with a broader sociotechnical understanding of engineering practice. The purpose of the methodology was therefore twofold: first, to support the design and refinement of innovation modules as curricular products; and second, to generate transferable lessons and design principles for embedding innovation competencies in engineering curricula.

3.1. Research Design: Educational Design Research and Case Study Approach

This study used EDR, drawing specifically on design research approaches in the curriculum domain, to design, test and assess the innovation modules within the engineering curriculum. The methods function as a pragmatic iterative methodology for addressing complex problems in education, particularly in settings that require the development and validation of innovative pedagogical interventions [35,36] and where systemic curriculum change is being considered [18]. EDR enables the development of educational interventions in authentic settings through repeated cycles of design, implementation, assessment, reflection, and revision. This makes it appropriate for curriculum-related studies where the intervention must respond to institutional conditions, student needs, course structures, and stakeholder expectations.

The study was also framed as a case study. EDR provided the methodological structure for the iterative design, implementation, assessment, reflection and revision of the intervention. At the same time, the case study perspective defined the institutional and curricular boundaries within which this process was examined. The study was bounded as an institutional case concerning the integration of innovation modules into existing engineering courses at the Faculty of Engineering, NTNU. The case study perspective enabled the curriculum design process to be examined within its specific institutional and curricular context. The aim was not to produce statistical generalisation, but to generate analytical insights into how innovation competencies can be embedded in existing engineering curricula, how such embedding may contribute to systemic curriculum development, and what transferable design knowledge may be generated.

The case study perspective enabled the intervention to be examined in its real educational setting, including existing course structures, institutional innovation ambitions, teaching practices, student participation, and the role of course coordinators. This was important because the embedding of innovation modules was not treated as an isolated classroom activity, but as a curriculum development process situated within a broader engineering education system.

3.2. Design Process

The curriculum design process was informed by Goodlad's substantive perspective and question "What should be learned?" [19] and by the learner, societal and knowledge orientations described in curriculum design research [18]. These orientations guided both the intended content of the modules and the types of outcomes expected from the EDR process. These orientations are summarised in Table 1. Within the EDR framework, they

also provided an analytical basis for examining how the modules responded to disciplinary knowledge requirements, learner needs and wider societal expectations.

Table 1. Curriculum design orientations for the development of the innovation modules, based on the literature [18].

Curriculum Design Orientations	Literature Definition	Application in This Study
Knowledge orientation	Which predominantly takes the form of foundational design principles or lessons learned.	Students need theories, tools, methods, and concepts of innovation.
Societal values	Tangible societal contributions, specifically the creation of curriculum products, materials, or programmes designed to benefit schools and the wider educational community.	Engineering education should respond to sustainability, digitalisation, infrastructure, and other societal needs.
Learner orientation	The professional development that participants gain through their involvement in the design research process.	Attention to learners' needs, experiences, readiness and intended competence development.

The development of the innovation modules followed an iterative EDR process structured around five interconnected phases: design, implementation, assessment, reflection and revision. Although presented sequentially in Figure 1 and Table 2, these phases were not treated as a single linear process. They were revisited as modules that were implemented in different courses, study levels and learning contexts. Evidence generated during implementation and assessment informed subsequent reflection and revision, while revised modules were introduced into later iterations.

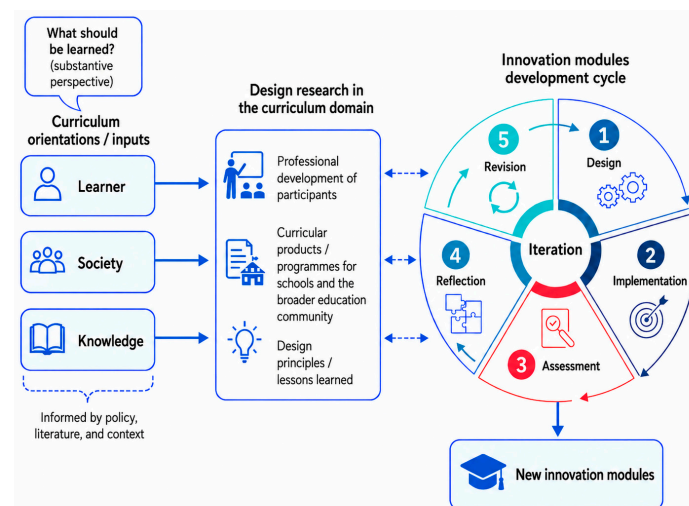


Figure 1. Design research process for the innovation modules, adapted from the analysis, design, and evaluation cycle presented in [18] (p. 76) and design-based research figure for cycles presented in [36] (p. 4).

The development of the innovation modules followed an iterative EDR process structured around five interconnected phases. These phases were used to guide both the development of the initial modules and their progressive refinement across different engineering education settings. The process functioned as a recurring cycle in which insights from implementation and assessment informed reflection, revision, and subsequent module development. Table 2 summarises the operationalisation of the EDR process.

Table 2. Operationalisation of the EDR process for the development of the innovation modules.

EDR Phase	Purpose of the Study	Activities and Empirical Material	Output of the Phase
Design	To identify the educational need and develop the initial innovation modules as curriculum interventions for engineering education.	Review of the literature on innovation competencies, curriculum development, sociotechnical engineering education, entrepreneurship education, and engineering education. Analysis of institutional and faculty-level needs. Workshops and discussions with professors, researchers, students, and course coordinators. Identification of relevant curriculum orientations: learner needs, societal needs, and knowledge needs.	Initial design principles for the innovation modules. First version of selected modules, including learning objectives, content, activities, and intended learning outcomes.
Implementation	To translate the initial module design into teaching and learning practice within existing engineering courses.	Integration of selected innovation modules into bachelor's and master's engineering courses. Delivery of module content through lectures, student activities, group work, innovation exercises, design thinking tasks, business-oriented tasks, and pitch training. Adaptation of the modules to different course contexts and study levels.	Tested innovation modules embedded in existing courses. Practical experience with module delivery across different learning settings and student groups.
Assessment	To evaluate the relevance, usability, and pedagogical fit of the modules in relation to students, course objectives, and curriculum needs.	Collection of student feedback through discussions, Mentimeter responses, classroom interaction, innovation activities, and pitching sessions. Observation of student engagement and learning difficulties. Feedback from course coordinators and academic staff. Review of how well the modules aligned with course aims and student needs.	Evidence of module relevance, strengths, limitations, and areas requiring improvement. Identification of curriculum fit, student engagement patterns, and necessary adaptations.
Reflection	To interpret the assessment material and understand what the implementation revealed about innovation skills in engineering education.	Analysis of feedback from students and staff. Reflection meetings and informal discussions with course coordinators. Comparison between intended learning outcomes and observed implementation experiences. Consideration of how the modules supported innovation competencies, sociotechnical learning, and curriculum integration.	Lessons learned from each implementation cycle. Identification and interpretation of recurring curriculum design issues concerning content, sequencing, course alignment, student readiness and progression across study levels.

Table 2. *Cont.*

EDR Phase	Purpose of the Study	Activities and Empirical Material	Output of the Phase
Revision	To improve the modules and prepare the next iteration of the innovation module framework.	Revision of module content, examples, teaching activities, sequencing, and learning outcomes based on feedback and reflection. Adjustment of the modules to better fit different engineering courses and study levels. Consideration of possible revisions to module content, structure, sequencing and progression, as well as the need for additional modules and a more coherent bachelor-to-master progression.	Revised innovation modules and an expanded module framework. Revised modules prepared for subsequent implementation cycles and a more coherent pathway for progressively embedding innovation competencies across bachelor's and master's engineering education.

The EDR process provided a systematic structure for connecting curriculum design with empirical inquiry. During each implementation, evidence was collected concerning the relevance of module content, the suitability of teaching activities, alignment with existing course objectives, student readiness and the feasibility of embedding innovation learning within the course context. This material was subsequently reviewed during the assessment and reflection phases and used to inform later curriculum design decisions. The analytical comparison of evidence across iterations supported the identification of recurring design considerations and implementation conditions. The specific changes made during the successive iterations and the design principles derived from them are presented in Section 4.

3.3. Participants and Sampling

Participants were drawn from engineering courses in which one or more innovation modules were implemented between 2023 and 2025/2026. The courses were selected because their coordinators agreed to integrate innovation teaching, and because they represented different study levels, disciplinary settings, and learning formats. Student participation in the teaching activities formed part of the respective courses. The student cohorts included bachelor's and master's students from multidisciplinary, monodisciplinary and international learning contexts. The teaching was delivered in English, although students could respond in either English or Norwegian in courses attended only by Norwegian students. Academic participants included course coordinators and teaching staff involved in planning, delivering or assessing the modules. Section 4.1 provides an overview of the course contexts, study levels, implemented modules and cohort sizes.

3.4. Data Sources and Empirical Material

The empirical material used in the study was generated through the design and implementation phases. This included literature-informed curriculum analysis, workshops and discussions with academic staff, student feedback, observations during module delivery, Mentimeter responses, innovation competition and pitching activities, and reflections from course coordinators. Together, these sources provided insight into both the pedagogical relevance of the modules and their fit within existing engineering courses. The material was collected over several iterations between 2022 and 2025.

The initial design phase included documented workshops conducted in 2022 with approximately 30 academic staff members, including professors, researchers and course

coordinators. These workshops contributed to the identification of institutional needs, relevant innovation competencies and potential opportunities for integrating innovation-related content into existing engineering courses.

During the implementation phases, empirical material included Mentimeter responses, student learning activities and assignments, post-course implementation notes, and feedback from course coordinators. Before and after module delivery, discussions were organised with the relevant course coordinator and documented in post-discussion notes. The notes included observations concerning student engagement, the suitability of the module content and activities, alignment with the course objectives, and issues requiring adaptation in subsequent iterations. The original Mentimeter exports were retained separately by year and question. These responses captured students' initial perceptions of innovation and were used as descriptive baseline material during the assessment and reflection phases. The detailed procedures used to translate, consolidate and analyse the Mentimeter responses are described in Section 3.5.

Student-generated material included pitches, Business Model Canvases, Value Proposition Canvases, written assignments and course reports produced as part of the evaluation of their semester courses. These materials provided examples of how students applied the innovation concepts and tools introduced through the modules. Participation in innovation events and competitions was not treated as a formal data source. Increased participation following the module implementations, particularly among students from the Experts in Teamwork (EIT) cohorts, was used only as contextual evidence and was not included in the formal analysis.

The course settings, study levels, implemented modules and cohort sizes are presented in Section 4.1.

3.5. Analytical Approach

The empirical material was analysed through an iterative and interpretive process aligned with the EDR cycles. The analysis focused on how evidence generated during the implementation of the modules informed subsequent curriculum design decisions. Feedback, observations, and reflections were analysed to identify recurring needs, challenges, and opportunities in module design and curriculum integration. The analysis considered how the innovation modules addressed the curriculum orientations introduced in the theoretical framing: learner needs, societal needs, and knowledge needs. The analysis was guided by four dimensions: the relevance of the module content, the suitability of the teaching and learning activities, alignment with the objectives and structure of the course where it was delivered, and the contribution of the modules to broader innovation-oriented and engineering learning. Post-course notes, documented discussions with course coordinators, student activities and assignments, and Mentimeter responses were considered in relation to these dimensions. Documentation and insights from the workshops held in 2022 primarily informed the initial identification of curriculum needs and the first module designs.

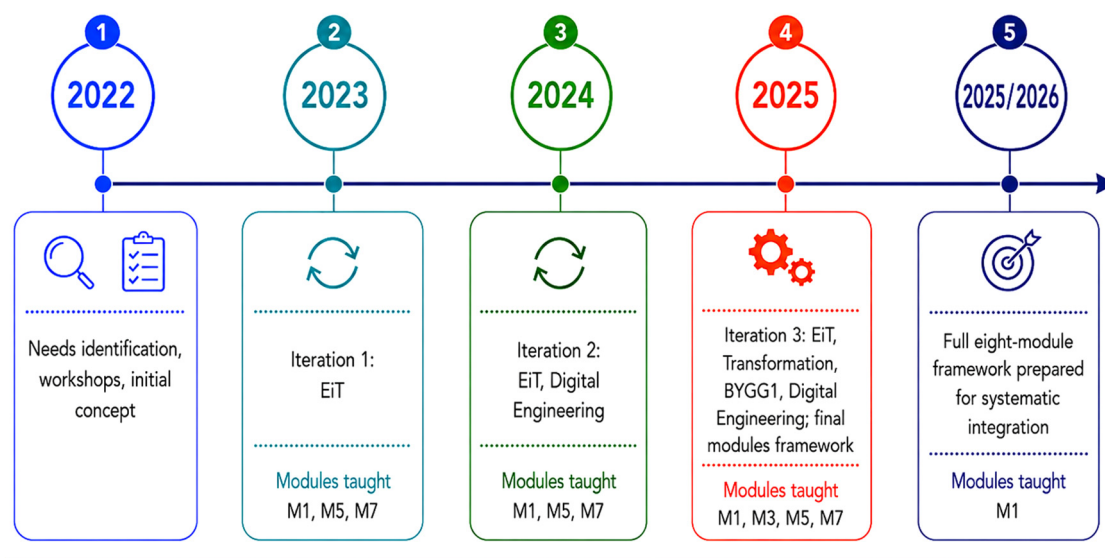
Post-course implementation notes were reviewed to identify recurring observations concerning student readiness, engagement with the innovation concepts and tools, the appropriateness of the module level and content, and the practical feasibility of embedding the modules within existing courses. The Mentimeter responses were analysed descriptively as baseline evidence of students' initial understandings of innovation. The original exports were retained separately by year and by question. Norwegian-language responses were translated into English where necessary. Responses from different years were subsequently combined for each of the three questions. The occurrence of each word or concept was counted, and the resulting frequency determined its relative weight in the word clouds.

Before aggregation, the responses were reviewed by year to assess whether substantial differences were present between the implementation cohorts. The Mentimeter analysis was used to inform the selection of examples, terminology and teaching activities and was not treated as evidence of changes in students' innovation competencies.

In the final analytical stage, recurring observations and curriculum design issues were compared across successive implementations and interpreted in relation to the learner, societal and knowledge orientations presented in the theoretical framework. Patterns that appeared across several course settings or implementation cycles were synthesised into curriculum design considerations and design principles. The specific revisions made to the modules, the cross-cycle findings and the design principles emerging from the process are presented in Section 4.

3.6. Limitations

As an EDR study situated within a single institutional case, the findings should be understood as context-sensitive rather than statistically generalisable. While the study does not include a controlled comparison group or longitudinal measurement of competence development, this is consistent with its exploratory, design-oriented purpose. The methodological value lies in documenting an authentic curriculum development process and generating analytical insights, design principles, and practical guidance that may inform similar efforts to embed innovation competencies in engineering education. The use of software tools and AI-assisted applications is disclosed in the Acknowledgements. These tools were used to prepare draft versions of Figures 1 and 2 from author-provided sketches and prompts. They were not used for data collection, analysis, interpretation or the formulation of the findings. All outputs were reviewed and edited by the authors, who take full responsibility for the manuscript.



i M1 = Introduction to Innovation and Entrepreneurship; M3 = Innovative Design and Problem Solving; M5 = Innovation Mindset and Business Models; M7 = Communication and Pitch Training.

Figure 2. Timeline of the development of the innovation modules.

4. Results

This section presents the results of the iterative curriculum design process. The findings are organised into two subsections: Section 4.1 presents the implementation cycles, the evidence generated across course contexts, and the cross-cycle findings that informed module refinement; Section 4.2 presents the resulting bachelor-to-master innovation framework.

The study resulted in a structured bachelor-to-master pathway for progressively integrating innovation competencies in engineering education through a sequence of integrated modules. The modules were introduced to demonstrate how educational institutions could operationalise innovation within technical curricula at the bachelor's and master's levels, embedding modular, innovation-focused learning across degree stages and aligning pedagogical design with the required competencies. Students enrolled in bachelor's and master's programmes will have an embedded innovation module in one of their courses each semester. Master's students can take an optional semester-long course on Innovation in Engineering in the ninth semester as preparation for the master's thesis. This was part of a systemic approach to introduce innovation competencies in engineering education. The pathway organises innovation-related learning across study levels while allowing individual modules to be adapted to different course contexts.

4.1. Implementation Cycles and Cross-Cycle Findings

Figure 2 summarises the progression from the initial needs identification, workshops, and concept development in 2022, to the first implementation of selected modules in 2023, the subsequent iterations in 2024 and 2025, and the start of full framework implementation in the first year of the academic year 2025/2026.

Across the EDR cycles, the revision process led to a clearer distinction between the different types of innovation learning required along the bachelor-to-master pathway. One of the early combined modules was divided into more specific learning components, separating design and problem-framing activities from business model activities. This led to the identification of the need to cluster the modules into a more coherent framework and to distinguish introductory, problem-framing, business/value, communication, management, and application-oriented learning. The final result of the EDR process was the development of an eight-module framework, complemented by a proposed integrative pre-thesis course for the ninth semester. Table 3 summarises how the EDR phases were reflected across the development timeline, showing the main design, implementation, assessment, reflection, and revision activities from the initial concept phase to the final module framework.

Across these implementation cycles, the innovation modules were introduced in several course contexts between 2023 and 2025/2026. The implementation covered bachelor's- and master's-level courses, multidisciplinary and monodisciplinary learning environments, and both Norwegian and international teaching settings. The first testing took place in EiT Village TBA4860—From Users to Creators, Empowering Citizens for the Development of Smart and Sustainable Cities in 2023, followed by further iterations in EiT, TBA4420 Digital Engineering, TBA4170 Transformation and Adaptive Reuse of Existing Buildings, and TBM4110 BYGG1 Introduction to Buildings and Infrastructure. The modules were adapted to each course context, with implementation formats including innovation lectures, design and business model exercises, value proposition work, pitching activities, and introductory innovation teaching. Table 4 summarises the course contexts, study levels, implemented modules, approximate number of students, and the main content of the innovation modules taught.

As shown in Table 4, the implementation expanded from one course type to several course contexts, and both bachelor's and master's students were exposed to the innovation modules. Mentimeter responses constituted one of the sources of evidence within the implementation and assessment cycles. At the beginning of the M1 module, which introduced innovation concepts and fundamentals, students were invited to respond to three open-ended questions. This step was repeated across the implementation cycles. The purpose was to capture their initial associations with innovation before the module content was introduced. The questions were: "What does innovation mean to you?", "In which

areas do you think innovation is most needed today?”, and “What qualities do you think are essential for fostering innovation?”. The responses were visualised live as word clouds and used as descriptive baseline evidence of students’ initial perceptions of innovation.

Table 3. EDR phases across the development and implementation of the innovation modules, 2022–2025/2026.

EDR	2022	2023	2024	2025	2025/2026
Design	Needs identification; workshops with faculty staff; literature review; first concept for three initial modules.	Initial modules prepared for first course implementation in EiT.	Revised design based on first implementation cycle.	Expanded design of module framework and clustering logic.	Preparation of the full eight-module framework for systematic integration.
Implementation	Three initial modules developed.	First teaching for three modules: 1. Innovation concepts. 2. SWOT, value proposition and business plan. 3. Pitching.	Three modules taught in two courses.	Four modules were implemented in four courses.	Start of the bachelor year 2025/2026: implementation with M1 in BYGG1.
Assessment	–	Student feedback collected through discussions, classroom exercises, and course activities. Students were asked three questions at the beginning of the course using Mentimeter. The responses were collected and assessed. The results are presented in Section 4.1. Discussions with course coordinators explored whether students’ approaches to subsequent course tasks had changed.	As in the previous year, student feedback, Mentimeter, and discussions with the course coordinators were used.	As in the previous year, student feedback, Mentimeter, and discussions with the course coordinators were used. We collected information from a larger and more diverse cohort.	–
Reflection	–	Analysis of feedback from students and staff. Reflection meetings and informal discussions with course coordinators.	Analysis of feedback from students and staff. Consideration of module fit across course contexts.	Identification of the need to cluster the knowledge provided by the modules and make the framework easier to communicate.	–
Revision	–	Modules revised while maintaining the aims of the three initial modules; teaching exercises updated.	Modules adapted to different course levels; one combined module was split into separate modules: the problem framing, SWOT and value proposition formed one module, while business models formed another.	Development of the final eight-module framework, complemented by a proposed full-semester pre-thesis course and presented in Section 4.2.	–

Figure 3 was generated by aggregating the words collected from student responses across all course implementations. As described in Section 3.5, the responses were reviewed by year, translated into English where necessary, grouped by question, and weighted according to the frequency with which each word or concept appeared. Because the dominant terms and overall response patterns were broadly similar across years, the results are presented as a single combined word cloud for each Mentimeter question.

For the first question, “What does innovation mean to you?” (a), the word cloud showed that students primarily associated innovation with creativity, new thinking, new ideas, value, future, development, and solutions. Other visible associations included problem-solving, imagination, improvement, disruptive thinking, sustainability, and creating something new and useful. For the second question, “In which areas do you think innovation is most needed today?” (b), the most prominent responses were related to health, technology, climate, transport, energy, sustainability, construction, mobility, and the

environment. Additional responses referred to education, systems, urban development, medicine, shipping, and engineering. For the third question, “What qualities do you think are essential for fostering innovation?” (c), the word cloud highlighted creativity, open-mindedness, ambition, courage, curiosity, collaboration, knowledge, critical thinking, and problem-solving. Other visible terms included persistence, positivity, motivation, teamwork, economic incentive, and disruptive thinking. Overall, the Mentimeter responses indicated that students entered the modules with a broad, though largely intuitive, understanding of innovation. Their responses associated innovation with creativity, novelty, problem-solving, technological development, sustainability, and societal needs, and also identified personal and collaborative qualities such as openness, courage, and curiosity as important for fostering innovation. Within the EDR process, these baseline inputs were used in the assessment and reflection phases, particularly to support the adaptation of examples, exercises, and module sequencing across course contexts.

Table 4. Implementation of the innovation modules.

Year	Course	Study Level	Module(s) Implemented	Number of Students	Main Content Taught
2023	EiT	Bachelor, year 3	M1, M3 and M5 as one module, M7	35	Innovation lectures, SWOT, Business Model Canvas, pitching
2024	EiT	Bachelor, year 3	M1, M3 and M5 as one module, M7	35	Revised modules delivered
2024	Digital Engineering	Bachelor, year 3	M5, M7	25	Value proposition, Business Model Canvas, pitching
2025	EiT	Bachelor, year 3	M1, M3, M5, M7	35	Iterated module sequence
2025	Introduction to buildings and infrastructure	Bachelor, year 1	M1	50	Introductory innovation module
2025	Transformation and Adaptive Re-Use of Existing Buildings	Master, year 1 Erasmus students	M1, M5	15	Innovation concepts and Business Model Canvas
2025	Digital Engineering	Bachelor, year 3	M3	25	Value proposition module
2025/2026	Introduction to buildings and infrastructure	Bachelor, year 1	M1	200	Introductory innovation module

EIT Village TBA4860—Experts in Teamwork—From users to creators, strengthens the inhabitants for developing smart and sustainable cities. Digital Engineering TBA4420. BYGG1 TBM4110—Introduction to buildings and infrastructure. Transformation and Adaptive Re-Use of Existing Buildings TBA4170.

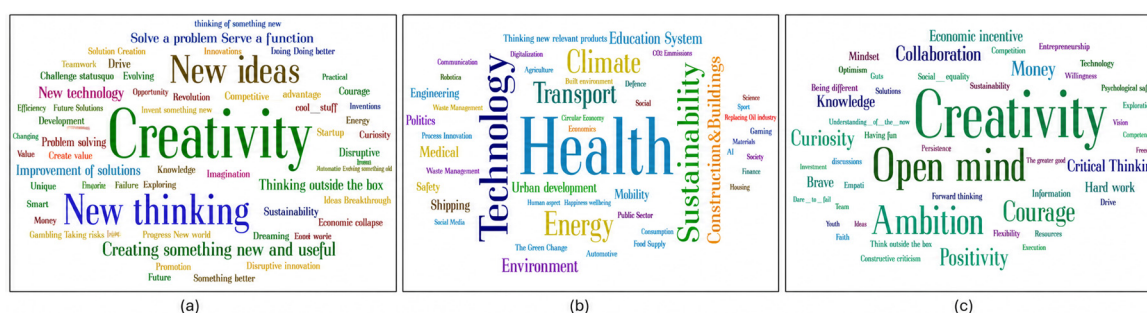


Figure 3. Students’ responses to the questions: (a) “What does innovation mean to you?”; (b) “In which areas do you think innovation is most needed today?”; and (c) “What qualities do you think are essential for fostering innovation?”.

Four recurring findings from the implementation cycles informed the curriculum design principles. First, innovation learning required progressive sequencing, with foundational concepts introduced before problem framing, value creation, communication and advanced application. Second, the modules needed a stable core while allowing adaptation to the objectives, study level, disciplinary context and student readiness of each course. Third, close involvement of course coordinators was important for aligning the module content, timing and learning activities with the host course. Fourth, repeated implementation and reflection were necessary to distinguish areas of learning and strengthen coherence across the pathway. These findings informed the structure of the final innovation module framework presented in the following section.

4.2. Final Innovation Module Framework: Tested and Proposed Elements

The iterative development process resulted in a final innovation module framework structured as a bachelor-to-master pathway. The framework consists of eight modules organised into three clusters, complemented by a proposed integrative pre-thesis semester course. The clustering was developed during the revision phases to make the module pathway more coherent, to distinguish the different types of innovation learning addressed by the modules, and to support progressive integration across study levels.

The first cluster, foundations, introduces students to core innovation concepts, entrepreneurship awareness, and the impact of technology. The second cluster, sociotechnical problem framing, focuses on design thinking, problem-solving, stakeholder needs, interdisciplinary collaboration, and the relationship between engineering solutions and their contexts of use. The third cluster, application and communication, addresses business and implementation planning, innovation management, communication, pitching, and the application of innovation principles in projects and industry-linked work.

The resulting framework was designed to support progression from introductory innovation awareness to applied innovation practice. At bachelor's level, the modules introduce students to innovation concepts, problem framing, technology development, business models, and communication. At master's level, the modules move towards advanced innovation, emerging technologies, innovation management, and the integration of innovation principles into project or thesis work. The proposed elective pre-thesis semester course consolidates prior learning by supporting students in developing an innovation-oriented thesis, project, or venture idea. Table 5 presents the final module framework, including clusters, semester progression, module objectives, core teaching content, teaching exercises or tools, and learning outcomes.

Table 5. Proposed bachelor-to-master innovation modules for engineering education.

Cluster	Semester	Module	Objective	Core Teaching Content	Teaching Exercises/Tools	Learning Outcomes
Cluster 1: Foundations	1	Introduction to Innovation and Entrepreneurship	Introduce foundational concepts of innovation and entrepreneurship in engineering.	Basic concepts of innovation, invention, improvement, and entrepreneurship; types of innovation; innovation in engineering practice; entrepreneurship as value creation; examples of engineering-based innovations.	Short concept-mapping exercise distinguishing innovation, invention, improvement, and entrepreneurship; analysis of examples of engineering innovations. Guest lectures from innovators and entrepreneurs.	Students demonstrate familiarity with basic concepts of innovation and entrepreneurship and can distinguish between innovation, invention, improvement, and entrepreneurship.

Table 5. Cont.

Cluster	Semester	Module	Objective	Core Teaching Content	Teaching Exercises/Tools	Learning Outcomes
Cluster 1: Foundations	2	Technology Innovation and Impact	Introduce the process of technology innovation in engineering and explain how technological ideas move from early concepts to development and application.	Technology innovation process; stages of technology development; opportunity identification; technology readiness; pathways from technical idea to practical implementation.	Technology readiness level mapping; collaboration with industry partners on R&D initiatives; case exercise tracing a technology from idea to prototype/application.	Students can identify opportunities for technological innovation and explain the main stages involved in developing engineering-based innovations.
Cluster 2: Sociotechnical problem framing	3	Innovative Design and Problem Solving	Develop creative thinking and problem-solving abilities by introducing design thinking as a method for framing and addressing engineering challenges.	Design thinking principles; problem definition; user and stakeholder needs; ideation methods; value proposition; prototyping; testing; Value Proposition Canvas.	Based on a real case challenge, run the design thinking sprint; SWOT analysis; Value Proposition Canvas.	Students can approach engineering challenges through innovative problem framing and develop a preliminary Value Proposition Canvas.
Cluster 2: Sociotechnical problem framing	4	Advanced Innovation and Emerging Technologies for Engineers	Develop students' understanding of how emerging technologies influence engineering practice and how these technologies can be assessed in terms of use, impact, and future applications.	Emerging technologies in engineering; digitalisation, AI, sustainability technologies, and smart systems; assessment of technology impact; technology adoption; ethical, societal, and implementation considerations.	Scenario exercise on how AI, digitalisation, or sustainability technologies have and may change engineering practice. Conduct an emerging-technology impact assessment tailored to the relevant engineering field. Guest lectures from industry leaders.	Students can analyse and evaluate emerging technologies in relation to engineering use, potential impact, and implementation challenges.
Cluster 3: Application and communication	5	Innovation Mindset and Business Models	Cultivate an entrepreneurial mindset and introduce business principles relevant to engineering innovation and value creation.	Entrepreneurial mindset; market and stakeholder analysis; customer needs; business models; Business Model Canvas.	Analyse examples of successful solutions; map stakeholder and customer needs for an engineering solution; and complete a Business Model Canvas.	Students can explain how business models, market analysis, stakeholder needs, and customer value relate to engineering innovation projects. Students can create a Business Model Canvas for a proposed solution.
Cluster 3: Application and communication	6	Innovation Management	Equip students with the knowledge and skills to manage innovation processes, teams, intellectual property, and implementation pathways.	Innovation process management; innovation teams; collaboration and leadership in innovation; intellectual property rights; implementation planning; risk, resources, and stakeholder management.	Innovation process roadmap; IPR and implementation pathway exercise for a student project or technology idea. Project management simulation and leadership development exercise.	Students can describe and apply basic principles for managing innovation processes and navigating innovation stages effectively.
Cluster 3: Application and communication	7	Communication and Pitch Training	Develop students' communication and presentation skills and provide practical experience in refining and delivering innovation pitches.	Pitch structure; storytelling for innovation; communication of technical value; audience adaptation; visual presentation; feedback and pitch refinement; pitching engineering solutions.	Three-minute pitch exercise; peer feedback using a simple pitch evaluation guideline. Run a competition between students to pitch their innovative ideas.	Students can develop and deliver a clear pitch for an innovative engineering solution.

Table 5. *Cont.*

Cluster	Semester	Module	Objective	Core Teaching Content	Teaching Exercises/Tools	Learning Outcomes
Cluster 3: Application and communication	8	Integration and Application of Innovation	Support students in synthesising and applying innovation principles in advanced engineering projects, research work, or thesis-related activities.	Application of innovation concepts in projects and thesis work; innovation potential of engineering research; collaboration with industry, start-ups, incubators, or competitions; implementation and impact planning.	Innovation reflection chapter for thesis/project work—build a plan for the chapter; innovation competition for best ideas.	Students can apply innovation concepts to engineering projects and reflect on the practical application, value, and potential impact of their work.
Integrative pathway option: Pre-thesis/transition to thesis or project work	9	Elective Course on Innovation as a Pre-thesis Course	Provide an integrative course that consolidates the previous modules and supports students in developing an innovation-oriented project, thesis, or venture pathway.	Integration of innovation theory and practice; problem framing; technology and market assessment; stakeholder validation; business and implementation planning; pitching; preparation for thesis, innovation competition, or start-up development.	Full idea-to-impact project canvas; final pitch and implementation roadmap for a thesis project, innovative solution, or venture idea.	Students can develop an integrated innovation pathway for a thesis, project, or venture idea, combining technical, societal, business, and implementation perspectives.

The final framework presents the results as a structured sequence of innovation modules that can be embedded in existing engineering courses. It provides a pathway for further curriculum integration at the bachelor's and master's levels.

5. Discussion

This section discusses how the iterative curriculum design process supported the progressive integration of innovation competencies across bachelor's and master's engineering education programmes. The section is structured into subsections that follow the design of the innovation modules, systemic curriculum development and engineering learning, and transferability.

5.1. Innovation Modules as Curriculum Design: Iterative Curriculum Design

The design of the modules was guided by the three curriculum orientations introduced in the theoretical framing: knowledge, society, and learner [35]. The study started from the premise that engineering students need more than technical knowledge alone. They also need competencies that enable them to identify needs, frame problems, collaborate across disciplines, understand stakeholders, assess value, communicate ideas, and consider the broader consequences of engineering solutions. Accordingly, the modules address the substantive curriculum question of 'what should be learned' [19] in engineering education.

From a knowledge orientation [11,22,35], the modules integrate concepts such as innovation, invention, entrepreneurship, technology development, design thinking, value proposition, business models, innovation management, intellectual property, and pitching. The resulting framework made innovation-related knowledge explicit and organised it progressively across the proposed study pathway. This addresses a curriculum design challenge identified in the literature by translating competencies expected of engineering graduates into defined learning objectives, activities and outcomes.

From a societal perspective [18,22], the module content connected engineering innovation with broader areas of societal need. This connection was also reflected in the student responses, which identified health, technology, climate, transport, energy, sustainability, construction, mobility and the environment as areas requiring innovation. These responses

suggest that students already associated innovation with societal challenges, although their initial understanding remained broad and largely intuitive. It was unexpected to note that engineering students identified health as one of the main areas needing innovation, but understandable given the growing debate about health in society.

From a learner orientation [13,29], the modules were designed to progressively build students' ability to understand and apply innovation concepts to real-world challenges beyond traditional technical education. Students' initial perceptions, learning activities and course experiences informed the adaptation of examples, exercises and module sequencing, from introductory concepts towards applications in projects or thesis work.

From a curriculum design perspective, the modules' contribution lies in translating broad innovation competencies into concrete learning objectives, teaching content, exercises, and learning outcomes. The framework operationalises innovation as teachable curriculum content. This is important because innovation competencies often remain implicit in engineering education, even when they are expected by industry, society, and higher education institutions. The module-based approach makes these competencies visible, structured, and adaptable to different course contexts. The innovation modules also connected disciplinary engineering knowledge with the wider societal contexts in which engineering solutions are developed and used. The module framework encourages students to move beyond the question of whether a solution works technically. Through problem framing, stakeholder analysis, design thinking, value propositions, business models and communication activities, students were encouraged to consider not only whether a solution was technically feasible, but also whose needs it addressed, what value it could create and how it might be implemented. Innovation therefore provided a practical entry point for considering the relationships between technology, users, organisations, sustainability concerns and contexts of use [11,29–32].

Four related design principles emerged from the cross-cycle findings and supported the development of the proposed pathway. First, progressive sequencing is needed so that foundational innovation concepts precede more complex activities involving problem framing, value creation, communication and application. Second, contextual adaptability is required because module content and activities must respond to the study level, disciplinary setting, student readiness and objectives of the host course. Third, curricular alignment depends on collaboration with course coordinators to connect the modules with existing learning outcomes, activities and assessment structures. Fourth, iterative refinement is necessary because coherence across modules emerged through repeated implementation, feedback and revision rather than through a single initial design. These principles operate together in the curriculum design of the eight-module framework: sequencing provided the progression of learning, adaptability made the modules usable in different contexts, alignment connected them to the existing curriculum, and iterative refinement enabled the pathway to evolve on the basis of implementation evidence. The eight-module framework represents the practical application of these principles across the bachelor-to-master pathway.

5.2. *Progressive Integration and Systemic Curriculum Development*

At the curriculum level, this approach supports movement towards systemic development through coherence, progression, and adaptability [11,24,25]. Clustering the modules created coherence by organising the content into key learning areas. Progression is created by sequencing the modules from basic awareness to applied innovation practice. Adaptability is enabled by modules that can be embedded in different course contexts, including multidisciplinary, monodisciplinary, bachelor-level, master-level, and international learning settings. The module-based structure provides a practical mechanism for

embedding innovation competencies across an engineering programme without requiring the immediate redesign of the entire curriculum.

The framework organises innovation learning as a progressive pathway across bachelor's and master's education. This progression is visible in the movement from introductory innovation concepts in the first year of the bachelor's programme, towards problem framing, business models, communication, emerging technologies, innovation management, and application in advanced projects or thesis work during the later stages of study. In this way, the modules create structured, repeated opportunities for students to encounter innovation throughout their studies, while remaining connected to existing engineering courses. The findings also indicate that modularity alone does not guarantee systemic integration. The modules need to be aligned with programme-level intentions, embedded in appropriate host courses and supported by course coordinators who understand their relationship to existing disciplinary content. Without this alignment, innovation teaching risks remaining additive rather than becoming part of a coherent curriculum pathway.

5.3. Learning Practices and Transferability

The module pathway also points to the importance of learning practices in engineering education. Developing innovation competencies requires repeated exposure, progressive complexity, and opportunities for application across different disciplinary and project contexts [11,12]. In this study, the modules were structured so that students could first encounter innovation as a concept, then apply it through problem framing, stakeholder analysis, value propositions, business modelling, communication, and project-based implementation. This repeated engagement supports a gradual shift from intuitive understandings of innovation to more structured thinking about innovation.

The framework's transferability to other engineering programmes depends on applying the curriculum design model and design principles while adapting the specific content, teaching formats and module placement to the relevant institutional and disciplinary contexts.

Although the study did not include a formal longitudinal assessment of student innovation outcomes, some implementation observations suggest that the modules may support students in moving from idea generation towards more applied innovation thinking. For example, one student group from the EiT implementation developed an idea that later won an NTNU Innovation Award in 2026, selected from more than 100 submitted ideas. In addition, student interest in innovation-related competitions increased compared with previous years. These examples indicate that students were willing to pursue innovation opportunities beyond the immediate teaching activities, but they were not treated as formal evidence of module effectiveness or competence development.

To answer the study research question "how does an iterative curriculum design process support the progressive integration of innovation competencies across bachelor's and master's engineering education, and what design principles emerge from this process?", the study suggests that an iterative curriculum design process can support progressive integration in two interconnected ways. At the curriculum development level, it generated an eight-module framework organised as a progressive bachelor-to-master pathway. The modules translate innovation competencies into a structured sequence that connects theoretical innovation concepts to idea development, society needs, value creation, communication, and innovation management. At the curriculum process level, the repeated design, implementation, assessment, reflection and revision cycles generated four design principles: progressive sequencing, contextual adaptability, curricular alignment and iterative refinement. Together, the framework and the principles provide both a concrete structure for teaching innovation and an adaptable approach for embedding it within

existing engineering programmes. Taken together, the framework and the design principles provide a structured basis for integrating innovation concepts and competencies within existing engineering programmes.

6. Conclusions

6.1. Contribution to Research

Innovation competencies are increasingly needed in engineering studies as interactions between technology, society, institutions, values, and environmental constraints shape engineering systems. Engineering education must prepare students to understand, frame, communicate, and develop solutions that respond to complex real-world contexts.

This study examined how an iterative curriculum design process can support the progressive integration of innovation competencies across bachelor's and master's engineering education, and what design principles emerge from this process. Using Educational Design Research within a single institutional case, selected innovation modules were designed, implemented, assessed and refined across different engineering courses and study levels.

The paper contributes to engineering education research by showing how broad innovation competencies can be translated into explicit curriculum components, including learning objectives, teaching content, activities and intended learning outcomes. The study also identifies four design principles emerging from the successive implementation cycles: progressive sequencing, contextual adaptability, curricular alignment and iterative refinement. These principles explain how innovation learning can be introduced incrementally while remaining connected to existing disciplinary courses and programme structures.

From a curriculum perspective, the modular approach supports movement towards systemic curriculum development without requiring the immediate redesign of an entire study programme. The resulting pathway is intended to provide students with progressively more advanced opportunities to engage with innovation competencies throughout their studies.

6.2. Implications for Engineering Educators and Programme Leaders

From a practical perspective, this paper provides engineering educators, programme leaders, and curriculum designers with an adaptable framework. Rather than demanding a resource-intensive, top-down overhaul of entire degree programmes, the modular approach offers a pragmatic, scalable strategy. Institutions can implement these targeted innovation modules incrementally, allowing them to test, refine, and scale learning interventions with minimal disruption to core technical courses. The findings nevertheless indicate that modularity alone does not ensure systemic curriculum integration. Modules should be aligned with the objectives, content, learning activities and assessment practices of their host courses and connected to programme-level intentions. Collaboration with course coordinators is therefore important for identifying suitable course locations, adapting the modules to student readiness and disciplinary context, and avoiding unnecessary overlap between innovation topics. The proposed pathway is intended to help students connect their technical engineering knowledge with the innovation competencies required to address complex real-world challenges.

6.3. Limitations and Future Research

The study is context-sensitive and based on one institutional case. The study focused on the curriculum design and implementation process and did not include a comparison group or longitudinal assessment of students' innovation competencies.

Further research should examine how similar module-based approaches can be adapted and implemented in other engineering education contexts. Future work should

also include more systematic assessment of student learning, longitudinal follow-up of competence development, and investigation of how innovation modules influence students' later project work, thesis development, and engagement with real-world engineering challenges. Comparative and multi-institutional studies could also examine the transferability of the module framework and the four design principles and identify the organisational conditions required for innovation modules to become part of a coherent and sustainable engineering curriculum.

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Abbreviations

The following abbreviations are used in this manuscript:

EDR	Educational Design Research
NTNU	Norwegian University of Science and Technology

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