

Design of Hybrid Teaching Formats in Technical Logistics through Digital Self-Learning Phases and Structured On-Campus Sessions

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Engineering education has traditionally centered on the transmission of theoretical knowledge and abstract modelling, because implementing real systems in teaching is technically demanding and resource intensive. Digital formats now allow theoretical content to be acquired asynchronously and independently of location, which frees on-campus time for other purposes. Building on this, we present a hybrid teaching concept that moves the acquisition of theory into digital self-study and reserves on-campus sessions for application, problem-solving and discussion.

The approach promotes competence-oriented and individualized learning with a modular design that enables transfer to other teaching contexts. Theoretical content is decomposed into modular Studybites consisting of multimedia learning resources and self-assessment activities, each covering one coherent chain of reasoning. The lecturer supplies the content and records the material, while the student team manages production. Learning materials are didactically designed and complemented by learning portfolios to support reflection and continuous learning processes. The On-Campus Sessions are planned to directly build upon the preceding self-study phases and to focus on application, problem-solving, and discussion. The concept was piloted within an existing course. However, such a concept is only viable if it demonstrably supports student learning without increasing workload for lecturers. The pilot phase was therefore accompanied by continuous observation and feedback loops from students and lecturers to evaluate feasibility, acceptance and transferability from both perspectives.

The pilot showed high acceptance and a closer connection between theory and practice, which motivated transfer to four further logistics courses. The lecturers approved the student-proposed decomposition largely

unchanged. Building the first iteration was expensive; running the second was not. When the pilot course was taught again one year later, the digital material was reused unchanged and preparation effort fell well below that of the format it replaced. Initial observations also suggest that the reuse of digital materials may reduce lecturer preparation time, creating capacity for deeper student support and pedagogical innovation. The results indicate that hybrid teaching formats in logistics education benefit strongly from an iterative, student-centered development process. In particular, the early and continuous involvement of students, the professionalization of digital content production, and the clear didactic structuring of self-learning and on-campus phases proved to be decisive success factors. For practice, this suggests that hybrid formats should be designed flexibly, evaluated continuously, and supported by adequate digital infrastructure and organizational resources.

[Keywords: hybrid teaching, logistics education, student co-creation, studybites, competence-oriented learning]

1 Introduction

Higher education has undergone significant transformation in recent years, driven by ongoing digitalization, changing learner expectations, and evolving requirements of the labor market [1]. Universities are increasingly challenged to adapt their teaching approaches to ensure that students receive an education that meets contemporary labor market requirements.

Within engineering education, teaching is still frequently characterized by the delivery of theoretical content

through traditional lecture-based formats [2]. While these approaches remain important for conveying fundamental concepts, they often lack opportunities for students to apply their knowledge in authentic or practice-oriented settings. This may lead to gaps between theoretical understanding and practical application [2]. Growing demand for engineers with the ability to transfer theoretical knowledge to complex, interdisciplinary problems from the beginning of their career onwards amplifies this problem.

At the same time, the COVID-19 pandemic accelerated the digital transformation of higher education. Hybrid and blended learning formats have become increasingly common and offer new opportunities to combine the advantages of digital self-study with interactive and application-oriented face-to-face learning activities [3].

To address this challenge, the IFL developed and evaluated a Stiftung Innovation in der Hochschullehre (STIL)-funded hybrid teaching concept designed to improve student learning outcomes while keeping the recurring workload for lecturers at a level comparable to conventional teaching formats.

The remainder of this paper is structured as follows. Section 2 provides the theoretical background and introduces the key concepts relevant to this study. Section 3 describes the project context, identifies the initial challenges, and outlines the project objectives. Section 4 presents the development of the hybrid teaching concept at the IFL. Section 5 presents the evaluation approach and the resulting findings. These results are discussed in Section 6. Finally, Section 7 concludes the paper and outlines opportunities for future development and transfer of the teaching concept.

2 Theoretical Background on Hybrid Teaching

Digitalization allows for new teaching and learning formats. Hybrid and digitally supported teaching has become increasingly popular. Formats such as recorded lectures and lectures held via videocall established during the pandemic, blended learning concepts have become an integral part of many university curricula, and the application of flipped-classroom models continues to gain traction. However, these concepts lack a uniform definition throughout the literature. Therefore, the following section derives the terminology related to blended, hybrid, and competency-based learning in order to provide a theoretical foundation for the remainder of this work. Furthermore, the application of the flipped-classroom concept in engineering disciplines is discussed. Finally, learning portfolios and their influence on student participation in higher education are addressed.

2.1 Hybrid and Blended Learning

Despite the fact that the terms hybrid learning and blended learning are often used interchangeably, the literature does not provide a universally accepted distinction between them. Blended learning is commonly understood as the integration of face-to-face and online learning experiences and has become an umbrella term encompassing various pedagogical and technological approaches [4]. To date, no universally accepted definition of blended learning exists. Consequently, the concept is interpreted differently in both research and educational practice.

While Graham [5] defines blended learning as the combination of face-to-face instruction and computer-mediated instruction, emphasizing the integration of different formats, Garrison and Kanuka [6] focus on blended learning as the thoughtful integration of face-to-face and online learning experiences. Their definition places a stronger focus on the learning process itself and highlights the importance of deliberately designing the interaction between both learning environments.

Several models for implementing blended learning have been proposed in the literature. Staker and Horn [7] distinguish between six implementation models that differ mainly in the role assigned to digital learning activities. In some models, online components serve primarily as a supplement to traditional classroom teaching, whereas in others they represent an equally important part of the learning process or even constitute the dominant mode of instruction, with face-to-face sessions being used only when necessary.

Taken together, these definitions and implementation models illustrate that hybrid and blended learning are not single instructional formats but rather umbrella concepts encompassing a wide range of combinations of digital and face-to-face learning activities. Despite these differences, all approaches share the objective of combining the strengths of both learning environments in a structured manner.

2.2 Flipped Classroom in Engineering Education

The flipped classroom is a specific form of blended learning in which theoretical content is delivered through digital materials, while face-to-face sessions are reserved for interaction, discussion, and application. This structure lets students engage with material at their own pace, freeing classroom time for collaborative problem-solving and the exchange of ideas with peers and instructors. It also allows students to adapt learning activities to their individual learning needs and prior knowledge.

Research suggests that students participate more actively in flipped settings, particularly when required to engage independently with complex problems rather than re-

ceive theoretical explanations. The approach may also support the development of professional and problem-solving skills through more active participation in the learning process. However, it also increases the workload students face outside the classroom, and its effectiveness depends heavily on their willingness to complete preparatory work. If students do not prepare, they struggle to participate meaningfully during on-campus activities. Self-regulated learning skills are therefore a precondition for the model to succeed, although these skills can themselves develop through continued exposure to it [2].

The approach is particularly well suited to engineering education because it supports project-based learning [8]. As engineering education and professional practice both rely heavily on project work, shifting content delivery to the preparation phase frees classroom time for collaborative, practice-oriented tasks that build teamwork, metacognitive skills [9], communication, and applied problem-solving [10].

Beyond pedagogical benefits, flipped learning offers practical advantages for institutions. It can be implemented with relatively inexpensive technology, helping instructors manage large content volumes despite limited contact hours and reducing dependence on traditional classroom space [11, 12, 13].

2.3 Competence-Oriented Learning

Ongoing shifts in the labor market, driven by trends such as Industry 4.0, have changed the competencies expected of university graduates [1]. Higher education institutions are therefore challenged to move beyond the transmission of disciplinary knowledge and to support competencies that enable graduates to navigate complex professional environments.

Competence is commonly understood as the ability to apply knowledge, skills, and experience effectively in professional and educational contexts. It encompasses not only subject-specific expertise but also the capacity for autonomous action, critical reflection, and responsible decision-making, particularly the ability to transfer theoretical knowledge into practical application [1].

This represents a shift from learning about a subject toward learning through doing. Students need opportunities to actively apply theoretical concepts and develop competencies through practical experience, fostering deeper understanding and transferable skills [1]. Specialized disciplinary knowledge remains a baseline requirement for engineering graduates, but on its own it no longer ensures competitiveness in a dynamic labor market. Competence-oriented approaches therefore combine technical expertise with practical, social, and cognitive competencies to prepare students for professional practice [1].

2.4 Learning Portfolios and Student Participation

In higher education, learning portfolios are used to document the learning process itself, including drafts, reflections, and evidence of gradual development, rather than only presenting finished work or assessing performance [14]. Their central element is reflection: portfolios give students the opportunity to critically examine their learning experience, monitor progress, and develop self-regulation and metacognitive awareness [14]. Documenting this process can also make otherwise difficult-to-measure competencies, such as critical thinking and self-reflection, visible to instructors [14].

However, the effectiveness of learning portfolios depends heavily on their implementation. Meaningful reflection requires more than describing completed tasks; students must be encouraged to analyze experiences and connect them to prior knowledge. This only happens reliably when the purpose of the portfolio and the expectations for reflection are communicated transparently and reinforced through structured prompts [14, 15]. Studies confirm this pattern. Gerdtsen [16] found that engineering students' reflective ability improved measurably over a semester when portfolio work was guided by structured reflection prompts and continuous feedback, while Nicholson [17] found that portfolio-based assessment increased active student participation and collaborative engagement more broadly.

3 Project Context and Initial Challenges

Teaching at the IFL was, for most courses, organized around the conventional combination of lecture and exercise sessions, complemented by externally taught lectures in the same format. The course *Materialfluss in Produktion und Logistik* (MFL-B), which served as the pilot environment for HYLEING, was typical of this pattern. It covers the fundamentals of material handling, logistics systems and automation technologies, and the volume of theoretical content to be delivered within the semester left little room for discussion or application. Tutorials concentrated on standardized exercises, students were largely in a receiving role, and preparation for the examination rather than for engineering practice organized the way they worked. As a result, students had only limited opportunities to apply theoretical concepts to authentic engineering problems or experience their own effectiveness as engineers. The courses referenced throughout this paper and their relationship to the HYLEING project are summarized in Figure 1.

The portfolio was not uniformly conventional. Three courses had already been redesigned along more interactive lines, independently of one another. The discontinued predecessor course *Materialfluss in Logistiksystemen* (MFL) [18] had already been redesigned along more interactive lines. It combined constructive alignment, an

COURSE	ABBR.	LANGUAGE	LEVEL	STATUS
 Materialfluss in Logistiksystemen	MFL	 German	 B.Sc./M.Sc. elective, 9 CP	 Discontinued 2024: split by faculty regulation
 Materialfluss in Produktion und Logistik	MFL-B	 German	 B.Sc., 5 CP	 HYLEING pilot, taught SS 2025 and SS 2026
 Dimensionierung von Materialflusssystemen in Produktion und Logistik	MFL-A	 German	 M.Sc., 5 CP	 HYLEING, one iteration
 Grundlagen der technischen Logistik	GTL	 German	 B.Sc.	 HYLEING, one iteration
 Logistics and Supply Chain Management	LogSCM	 English	 M.Sc.	 HYLEING, one iteration
 Production and Operations Management	POM	 English	 M.Sc.	 In preparation: previously a conventional lecture
 Seamless Engineering	SE	 English	 M.Sc., 9 CP	 Not part of HYLEING; reference format

Figure 1: Courses included in or related to the HYLEING project, showing programme level, language, and implementation status.

inverted-classroom structure and competence-oriented assessment through open-ended case studies and oral colloquia. The concept was well founded and initially well received, but enrolment fell from around thirty students per year to only three by 2024. Interviews with lecturers and students from the final iteration indicated that the workload associated with the format was the primary reason for this decline. The high workload also made the course increasingly costly to maintain from the lecturers' perspective. Following faculty regulations, MFL [18] was subsequently replaced by the two 5-credit courses *Materialfluss in Produktion und Logistik* (MFL-B) and *Dimensionierung von Materialflusssystemen in Produktion und Logistik* (MFL-A), which together cover the content of the original 9-credit course. HYLEING was initiated during this transition and used MFL-B as its pilot environment. As a result, the pilot course was not an unrelated teaching context but the direct successor of the course whose challenges motivated the development of the project. Logistics and Supply Chain Management (LogSCM) uses a structurally comparable split between asynchronous self-study and interactive on-campus sessions, calibrated more moderately, and has maintained

high participation over several years. The flipped-classroom logic was therefore viable at the institute, provided the demands on students remained proportionate. Seamless Engineering pairs a lecture block and a mid-semester written examination with a semester-long workshop in which student groups design and implement the software for a model warehouse [19]. Feedback has been positive across four years, and instructors report stronger problem-solving among participants who later joined the institute, but preparation and supervision effort are correspondingly high.

Each of these was developed on its own. There was no shared didactic framework, no transferable production process, and no route by which what worked in one course could reach another; equally, what failed in one fed back into no common design logic. The observation is not only ours: the published account of MFL [18] closes by noting that competence-oriented teaching rarely succeeds as an isolated initiative and encourages colleagues to redesign along similar lines [18]. The institute had the individual experience and lacked the means to consolidate it.

HYLEING was initiated on that basis within the Freiraum programme of the Stiftung Innovation in der Hochschullehre, with the aim of consolidating these separate experiences into a modular teaching concept transferable across IFL courses.

4 Development of the Hybrid Teaching Concept

To address the challenges identified in Section 3, the HYLEING project followed a structured, iterative development process organized around four closely connected work areas: requirements analysis, development of digital self-learning materials, development of application-oriented on-campus modules, and student involvement and co-creation. Figure 2 illustrates their relationship; the following sections describe each in turn.

4.1 Requirements Analysis

The requirements analysis combined interviews with lecturers, staff, and students with a systematic assessment of existing infrastructure. Three findings shaped the subsequent development:

- **Limited on-campus time for interaction.** Lecturers recognized the value of application-oriented teaching, but the volume of content to be covered left little room for discussion or practice during class.
- **Underused digital infrastructure.** ILIAS was already established at the institute but served mainly as a repository for slides and documents, with no standardized process for producing structured digital learning materials.
- **Research-grade hardware unsuited for teaching.** The IFL's laboratory equipment, robotics, and automation systems offered strong technical depth but lacked the safe, accessible interfaces and appropriate complexity needed for introductory educational use.

Students additionally expressed a desire for greater flexibility and stronger connections between theoretical concepts and real-world engineering problems. Building on the experience with MFL-B (Section 3), the analysis also translated into a set of hard constraints for the new concept: it had to be at most equal in workload for lecturers and research assistants, more digestible for students than the previous format, structurally modular and reusable across courses and centrally maintainable.

Based on these findings, a course concept comprising a digital self-learning phase and structured on-campus sessions was designed.

4.2 Digital Self-Learning Modules

The development of digital self-learning materials represented one of the central pillars of the HYLEING concept. At the core of the digital learning environment is the Studybite: an atomic, self-contained learning unit representing one coherent chain of thought, roughly equivalent to a five to seven minute lecture segment. It is delivered as a multimedia container that combines, at minimum, three elements: an explanatory video, a written description in the style of a book chapter, and a self-assessment question. The self-assessment is not only intended to track learning progress but also prompts active engagement with the material and allows students to check, before the corresponding on-campus session, whether they understood the topic.

Optional materials, such as journal articles, websites, podcasts, or images, can be attached below a visual separator that distinguishes curated further reading from the core content, allowing students to explore a topic in depth without fear of missing examination-relevant material.

Studybites resulted from decomposing existing lecture content into smaller, self-contained units that students could complete independently. The Studybites thereby provide the theoretical basis for their corresponding on-campus sessions, decoupling knowledge acquisition from class time and freeing that time for application. Rather than replacing lectures with recordings, the intention was to create structured learning units that enable students to independently acquire the theoretical foundations required for later application-oriented activities.

Producing these units required identifying topics that could stand on their own pedagogically while still supporting the overall learning objectives of the course. This turned out to be a genuine instructional-design challenge, since existing ninety-minute lecture sessions were not built with this granularity in mind.

The Studybites are deployed via the learning platform ILIAS, which was identified as the most suitable platform due to its widespread use in universities, its ability to combine multimedia resources, self-assessment tools, and course administration, as well as its integration into KIT's digital identity management. While ILIAS offered the required tools in theory, their use was uncommon, and therefore training resources for lecturers and student assistants needed to be provided.

To ensure active engagement with the content, the Studybites were further supplemented with quizzes and exercises. In addition, learning portfolios were introduced to document learning progress, encourage reflection, and collect feedback regarding the digital learning experience. The portfolios later also served as part of the proof-of-concept evaluation of the overall teaching concept.



Figure 2: Conceptual framework and development process of the HYLEING hybrid teaching concept (own illustration).

Production follows a fixed workflow with two approval gates. Students propose the decomposition of a lecture into Studybites based on existing material. The lecturer reviews and approves the proposed split, usually without change and only occasionally requesting a rearrangement. The lecturer supplies the content and records the video material. The student team then prepares the approved material for recording, schedules and conducts the recordings, edits the videos, writes the accompanying texts and self-assessment questions, and presents the finished unit to the lecturer. After a revision round, the material is stored and deployed on ILIAS. The lecturer therefore controls the decomposition and the final unit, while coordination between the two approval gates is student-led. Common standards for video structure, visual design, and ILIAS integration ensure consistent output across courses and contributors.

4.3 On-Campus Modules

While the Studybites provided the theoretical foundation, the on-campus modules were built on the premise that engineering competencies cannot be developed through knowledge acquisition alone. Students needed opportunities to en-

gage with real-world problems, test ideas, make decisions, and experience the consequences of those decisions in realistic engineering contexts instead of merely repeating theoretical content in class.

As the requirements analysis had already shown, the IFL's existing experimental setups, robotics platforms, and automation equipment were built for research rather than teaching and lacked the safe, intuitive interfaces needed for independent student use.

Selected systems were therefore adapted and simplified for educational use, prioritizing modular demonstrators and experimental setups that could serve multiple courses. Technical interfaces and user-friendly controls allowed students to operate them independently without extensive prior training, while the underlying engineering problems were simplified sufficiently for teaching without sacrificing practical relevance.

One direct outcome was a modular building-block system for small-scale automation and material handling, including prototype table modules and conveyor-related

demonstrators, designed and tested together with students. Because components could be reused, exchanged, and extended, the system remained usable beyond a single course.

Beyond the demonstrators, on-campus activities included case studies, group-based design tasks, and project assignments deliberately structured around realistic engineering challenges. Rather than reproducing instructor-demonstrated procedures, students reviewed situations, evaluated competing solutions, and justified their decisions collaboratively. This shift from knowledge reproduction toward active problem-solving represented one of the core differences between the hybrid concept and traditional lecture-based teaching.

Implementation varied by course. In MFL-B, students worked with demonstrators, practical exercises, and excursions. In LogSCM, existing case-based learning approaches were expanded into the hybrid framework. In *Grundlagen der technischen Logistik* (Technical Logistics), students spent a semester collaboratively designing a complete distribution center, including the selection and dimensioning of its components.

A key lesson was that successful on-campus sessions depended less on detailed instructional scripts and more on active facilitation. Instructors took on the role of coaches by guiding discussions, asking questions, and supporting groups through problem-solving.

Through the combination of adapted demonstrators, modular experimental setups, project-based activities, and collaborative problem-solving tasks, the on-campus modules formed the practical counterpart to the digital self-learning materials. Together, both components aimed to strengthen the connection between theory and practice and to enable students to experience engineering work as an active and application-oriented process rather than a purely theoretical discipline.

4.4 Student Involvement and Co-Creation

A defining characteristic of the HYLEING project was the active involvement of students throughout the entire development process. Rather than treating students solely as recipients of the finished concept, the project adopted a co-creation approach from the outset, embedded already in the original project proposal.

Student feedback shaped the concept at every stage. During the requirements analysis, students helped identify learning challenges and use cases that grounded the concept in real learning needs. Once materials existed, continuous feedback loops allowed both the digital and on-campus components to be iteratively improved.

Turnover in the student team made onboarding a recurring challenge. A collection of how-to guides covering Studybite production, video editing, ILIAS administration, and on-campus activity design enabled new team members to take over the workflow described in Section 4.2 quickly, ensuring sustainability independent of individual team members.

Student participation was not one-directional. Through their work on the project, student assistants gained practical experience in project management, teamwork, media production, and instructional design. The assistant work itself therefore provided exposure to processes not typically part of an engineering curriculum and offered a form of competence development extending beyond the learning outcomes the courses themselves were designed to achieve.

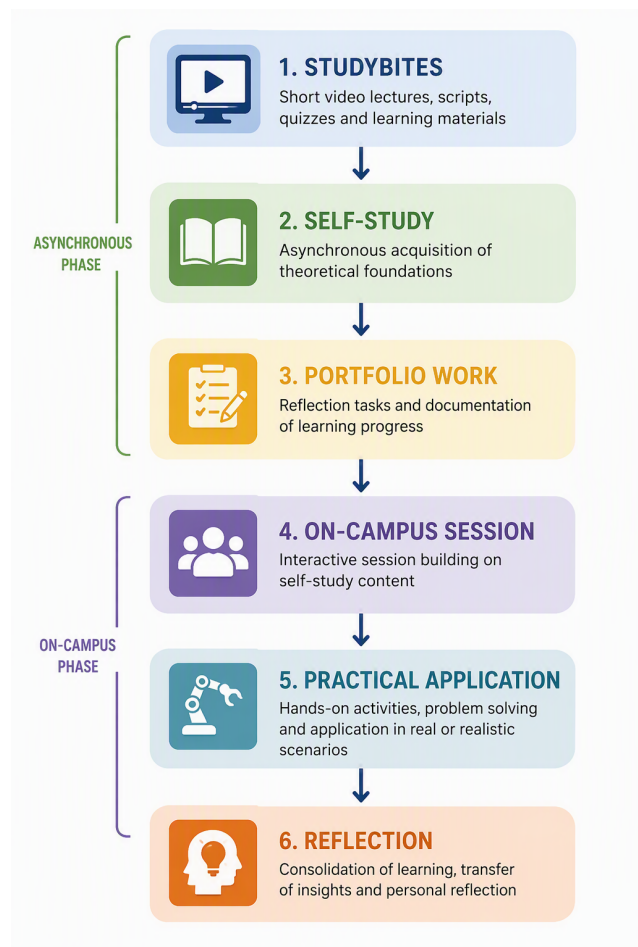


Figure 3: Learning process of the HYLEING concept, consisting of digital self-study through Studybites, portfolio-based reflection, and application-oriented on-campus learning activities (own illustration).

5 Evaluation and Results

Following its development, the HYLEING concept was implemented as a pilot and accompanied by continuous evaluation to assess both its feasibility and its perceived benefit for students and lecturers. This evaluation served two purposes: to examine whether the combination of digital self-study, application-oriented on-campus learning, and student co-creation addressed the challenges identified in Section 3, and to identify improvements during implementation itself.

This chapter proceeds in three parts. Section 5.1 describes the pilot implementation; Section 5.2 outlines the evaluation approach and data sources; Section 5.3 presents the main results and observations.

5.1 Pilot Implementation

The hybrid teaching concept was first implemented as a pilot in MFL-B. The course was selected for its combination of mathematically demanding theoretical content and practical engineering application, making it well suited to testing the concept's feasibility. The pilot served as the first large-scale application of the HYLEING approach and as the proof of concept for its later transfer to other courses at the IFL.

Students first engaged with the relevant Studybites via ILIAS (Section 4.2) before applying this knowledge in on-campus sessions structured around discussion, group work, and practical application (Section 4.3). The overall learning sequence is illustrated in Figure 3.

On-campus activities also included site visits to industrial facilities and practical work with a model warehouse.

In several course modules, case studies contributed to the final grade, with successful participation earning examination bonuses. Oral examinations further assessed students' ability to explain and justify their solutions.

5.2 Evaluation Approach

The evaluation of the HYLEING concept followed an exploratory, predominantly qualitative approach. As the project's primary objective was the development, implementation, and iterative refinement of a hybrid teaching concept, the evaluation focused on understanding how students and lecturers experienced the new learning environment and on assessing its feasibility, acceptance, and perceived educational value.

Three sources of information were used throughout the project: observations of on-campus sessions, learning portfolios, and continuous feedback from students and lecturers.

Members of the project team accompanied on-campus sessions throughout the pilot, documenting student partic-

ipation, interaction patterns, and challenges encountered during practical exercises. Particular attention was given to whether students could transfer knowledge from the digital self-study phase into practical problem-solving and to how lecturers adapted to their new role as facilitators. Observations were discussed regularly within the project team and used to inform ongoing iterations of the concept.

Learning portfolios served as a second evaluation instrument. Entries were reviewed for recurring themes, strengths, and areas for improvement in both the digital and on-campus components.

Informal and formal feedback from students and lecturers supplemented these sources. Feedback was collected during course sessions, through direct discussion, and during regular project meetings, covering experiences with the Studybites, the ILIAS environment, and the on-campus activities.

The collected data were reviewed for recurring patterns and themes rather than through statistical measures, an approach suited to a development-oriented project aimed at understanding implementation processes and deriving lessons for future iterations. The following section presents the findings.

5.3 Results

5.3.1 Acceptance and Student Workload

Students and lecturers received the concept positively. Students valued working through the theoretical content asynchronously, at their own pace, and revisiting difficult topics before the corresponding on-campus session. Portfolio entries document a range of self-study strategies, including notes, summaries, flashcards, and repeated viewing of individual Studybites. Lecturers observed higher engagement in the redesigned on-campus sessions than in the lecture format they replaced. Portfolio reflections further suggest that students perceived the combination of self-study and application-oriented learning as motivating and engaging.

Two reservations recurred. Some students initially struggled with the responsibility of preparing content independently, reflecting the shift away from a teacher-centered setting. Others perceived the course as more demanding than a conventional lecture, since continuous work on Studybites, portfolios, and session preparation distributes effort across the semester. The same students reported a correspondingly lower need for intensive revision before the examination. Given that workload was what eroded the earlier redesign of *Materialfluss in Logistiksystemen* [18] (Section 3), the redistribution rather than increase of student effort is a relevant outcome for the concept's sustainability.

5.3.2 Theory-Practice Connection and Participation

Students applied content acquired through the Studybytes in practical exercises, case studies, demonstrator-based activities, and project work. Portfolio reflections indicate that this produced a more integrated view of logistics systems over the semester. Rather than treating material handling, warehousing, queueing, and process optimization as separate topics, students described the dependencies between layout decisions, storage strategies, waiting times, and overall system performance. Several reported that they had learned to interrogate formulas, simulation outputs, and planning results instead of accepting them, with comparisons between analytical calculation and simulation making sampling effects and model limitations tangible. Demonstrators and simulations were named repeatedly as the most valuable elements. Students stated that observing queue formation and stochastic system behavior taught them more than the corresponding explanation alone.

On-campus sessions were characterized by discussion and collaborative problem-solving rather than by worked examples. Students reported that comparing alternative solutions exposed them to approaches they had not considered and that they gained confidence in using domain-specific terminology.

In Logistics and Supply Chain Management, students who worked consistently with the Studybytes tended to perform better in the subsequent examination than those who used them only selectively. No statistical analysis was carried out, so this remains an observation rather than a measured effect, but it is consistent with the portfolio and session findings above.

5.3.3 Transfer and Lecturer Workload

Following the pilot, the concept was transferred to Logistics and Supply Chain Management and *Grundlagen der technischen Logistik*, then to MFL-A, and is currently being prepared for Production and Operations Management. These courses differ in size, level, and existing format. Transfer required adapting individual Studybytes and on-campus activities rather than redesigning the underlying structure. The split between asynchronous acquisition and application-oriented contact time was retained in each case.

Producing the first iteration was expensive. Decomposing the lecture into Studybytes, recording and editing the material, and building the ILIAS structure required substantial time from lecturers, student assistants, and technical staff, exceeding the effort of running the course in its previous form. This cost, however, falls almost entirely on the digital component and occurs only once. When MFL-B was taught again in the summer term 2026, the Studybytes were reused unchanged, and lecturer involvement was largely limited to conducting the on-campus sessions.

The on-campus sessions themselves proved inexpensive to prepare. Many require little more than a dataset, a demonstrator, and a task list. The remainder of the session is shaped by the interaction between lecturer and students, which makes each run a distinct event rather than a repetition of the previous one. Preparation effort is therefore structurally low, while the sessions demand more contact-time engagement from lecturers than a conventional lecture. The overall shift is thus one of effort from preparation towards teaching, but the recurring preparation load in the second iteration fell below that of the original lecture-and-tutorial format.

This supports the workload constraint formulated in Section 4.1, though the evidence remains limited. Only MFL-B has been taught twice under the concept, while the remaining courses have completed a single iteration each. The indication that the initial investment amortizes from the second iteration onward is nonetheless a promising one.

6 Discussion

The pilot indicates that the concept worked, but not why. Two questions therefore remain: what the operative mechanism was, and under what conditions the format can be sustained. Both can be examined against earlier course redesigns at the same institute, two of which have been documented in detail.

6.1 Coupling, not Digitisation

The effects reported in Section 5.3 cannot be attributed to the availability of digital learning material as such. The Studybytes replaced the lecture as a delivery channel, but the observed changes occurred in the on-campus sessions. What made them possible was the coupling of the two phases. The Studybite establishes a defined level of preparation that the session can presuppose; the session gives the self-study phase a purpose beyond examination preparation. Neither component produces this alone. Recording the existing lectures would have digitized delivery without altering what happens when students and lecturers occupy a room together.

This is the flipped-classroom argument [2] rather than a new one, but the project qualifies it in two respects. The first concerns granularity. The institute's earlier redesign of *Materialfluss in Logistiksystemen* [18] already used self-study with lecture videos, control questions and exercise sets, organized as a one-week learning phase preceding each of five thematic blocks [19]. A learning phase of that size can be required but not precisely presupposed: a session can assume that students worked through the block, not which chain of reasoning they followed. The Studybite as an atomic unit allows a session to be built on specific prior knowledge. Decomposing existing ninety-minute lectures to this granular-

ity proved to be the substantive instructional-design work of the project and is not a by-product of recording.

The second concerns the role of the lecturer. Sessions built on prior preparation cannot be scripted in advance, because what happens in them depends on what the participants bring. Portfolio reflections further suggest that simulations and demonstrators helped students develop intuition for complex engineering concepts before engaging with formulas and calculations. Lecturers accordingly moved from delivering content to facilitating: posing questions, steering discussion, and supporting groups through problems whose solution they had not fixed beforehand. This is a demanding shift, and it is the condition under which the coupling produces anything. Where a session merely repeats the Studybite content, the format reduces to a lecture with additional preparatory work.

The portfolios qualify the project's own expectations. The literature treats them as instruments of reflection and self-regulated learning [19], and they were introduced on that basis. In practice, students documented what they had done considerably more readily than they reflected on it, and reflection appeared where explicit prompts asked for it rather than as a consequence of writing. Portfolio work is therefore better understood as a competence to be taught than as a container to be provided. The same pattern held for the concept as a whole: courses in which the rationale behind Studybites, portfolios, and session design was made explicit showed higher acceptance than those in which the format was simply introduced. A redistribution of responsibility for knowledge acquisition must therefore be negotiated rather than announced.

One tension remains unresolved. Competence-oriented teaching implies competence-oriented assessment; where examinations continue to reward reproduction, students are asked to work in one mode and assessed in another. This is not a peculiarity of the present project. A retrospective study of application-oriented courses at the same institute found that freedom in the input phase requires corresponding structure in assessment and documented students postponing engagement with self-study material until an assessment made it necessary [19]. The HYLEING courses address this partially through case studies contributing to the grade and oral examinations in which students justify their solutions, but not consistently across the portfolio. Constructive alignment is therefore a design requirement of the concept rather than an optional refinement and remains the aspect in which implementation is least complete.

6.2 Sustainability as a Design Criterion

The MFL [18] redesign combined constructive alignment, an inverted-classroom structure, and competence-oriented assessment through open-ended case studies and oral colloquia [18]. Judged against its own learning objectives, it

succeeded: across the two evaluated cohorts, a clear majority of students rated five of the six defined competencies as achieved. The same evaluation records that every respondent described the workload during the lecture period as markedly above that of comparable courses and that only about half considered the learning gain sufficient to justify that workload [19]. The concept was published in 2022 with that reservation explicitly stated. By 2024, enrolment had fallen from roughly thirty students per year to three. Enrolment in technical subjects has been declining more broadly [19], but interviews with the lecturers and students of the final iteration attribute this decline primarily to workload, confirming the signal present in the published evaluation data before the course became unviable.

The trade-off recurs across the portfolio. Seamless Engineering has sustained positive student feedback over four years, with instructors reporting stronger problem-solving among participants who later joined the institute, at a preparation and supervision effort the authors describe as high [19]. Across the institute's application-oriented courses, workload is identified as the greatest single challenge for students and instructors alike [19]. Logistics and Supply Chain Management, structurally comparable to the inverted-classroom split but more moderately calibrated, has maintained participation over several years.

Read together, these cases indicate that pedagogical quality does not predict survival. A format that cannot be repeated at acceptable cost by lecturers who also carry research obligations will not be repeated. An unrepeated format teaches no one. Workload therefore belongs among the design criteria rather than the implementation notes, which is why Section 4.1 formulates it as a hard constraint.

Three mechanisms carried that constraint. Production was divided so that lecturers supplied subject expertise and reviewed output while a trained interdisciplinary student team handled preparation, media production, and platform integration. The finding that this division does not compromise quality is what makes the volume of material feasible at all. Documented workflows for Studybite production, editing, ILIAS administration, and session design allowed recurring turnover within the student team to be absorbed, locating the process in the institute rather than in individuals. The low recurring preparation cost of the sessions follows directly from their design. A dataset or a demonstrator and a task list are frequently sufficient because the substance of the session is generated within the interaction itself.

The most consequential part of that division is who performs the decomposition. Identifying where one coherent chain of thought ends and the next begins is the substantive instructional-design step, and in this project it was drafted by students and ratified by the lecturer, who rarely revised it. This suggests that the task is performed well by people who have recently been the audience for the lecture in ques-

tion, a perspective that the subject expert, who understands the material as an integrated whole, does not possess. It is also a stronger form of student participation than consultation or feedback: students carry out a design task, and the expert approves the result rather than the reverse.

6.3 Limitations

The evidence is qualitative throughout and supports statements about implementation and experience rather than causal effects on learning outcomes. The examination-performance pattern in Logistics and Supply Chain Management is an observation rather than a measurement.

Only MFL-B has been taught twice under the concept; the transferred courses have each completed a single iteration. The claim that production effort amortizes from the second run therefore rests on one repetition and should be interpreted as an indication rather than a confirmed finding.

All courses belong to one institute, one faculty, and one institutional context, and several transfers are still ongoing. Scalability to larger cohorts, other engineering disciplines, and other institutions therefore remains untested.

7 Conclusion and Outlook

This paper described the development, pilot implementation, and evaluation of HYLEING, a hybrid teaching concept for technical logistics developed at the IFL, in which theoretical content is acquired through atomic digital self-learning units and on-campus time is reserved for application, discussion, and problem-solving.

Three results are worth carrying forward. First, the effect of the concept comes from the coupling of its two phases rather than from digital delivery. Because a Studybite is small enough to be presupposed precisely, an on-campus session can be built on defined prior knowledge instead of on attendance.

Second, the decomposition of a lecture into such units, the substantive instructional-design step, was drafted by students and approved by lecturers largely unchanged. This suggests that recent members of the audience are well placed to perform this task. More broadly, the project demonstrates that students can contribute not only as learners but also as active partners in the design and continuous improvement of teaching concepts.

Third, the concept is expensive to build and inexpensive to run. Preparation effort in the repeated iteration of the pilot course fell well below that of the format it replaced because the digital material is reused unchanged and the on-campus sessions require little more than a dataset, a demonstrator, and a task list.

The third point is the condition on which the others depend. Earlier course redesigns at the institute showed that a didactically sound format can still fail if it cannot be repeated at acceptable cost. Treating workload as a design constraint rather than an implementation concern is therefore not a concession but a requirement.

Three questions remain open. The workload evidence rests on a single repetition in a single course, and the transfers currently under way will provide the first broader test. The evaluation is qualitative throughout, and quantitative work is needed to establish whether the observed changes in how students engage with the material correspond to measurable differences in what they learn. Assessment also remains only partly aligned with the competence-oriented aims of the concept. This is the most immediate area for further development and the aspect that earlier work at the institute has already identified as decisive.

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