Building AI Hardware Expertise: Edge AI Curriculum Design and Implementation in German Universities

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Abstract

Edge artificial intelligence (AI) redistributes AI computation from distant cloud to local processors for real-time processing and enhanced privacy. This fundamental shift underscores a critical gap in current university curricula, which predominantly focus on AI fundamentals and algorithms while often neglecting essential AI hardware topics. To address this deficiency, this paper presents *Edge AI*, a postgraduate curriculum co-designed by two universities in Germany. Guided by the Dagstuhl triangle, the curriculum is designed to comprehensively cover technical, sociocultural, and application perspectives. Courses are developed using the Four-Component Instructional Design model to encourage action-oriented skill development, with a Learning Management System template available to assist in the design of individual courses. Selected practical courses are formulated as self-managed projects and inverted classrooms, enabling students to learn at their own pace with just-in-time guidance. All curriculum materials are accessible online and maintained by the Open Science Framework to enhance collaboration across institutions and promote applicability in diverse domains. Evaluation results from 176 students over two years (2023-2025) demonstrate universal satisfaction across various curriculum components.

Introduction

The increasing demand for low-latency responsiveness, minimal network dependency, and user data privacy in artificial intelligence (AI) applications is propelling Edge AI as a transformative deployment paradigm that delegates computational workloads to local hardware at the network edge, thereby circumventing reliance on remote cloud infrastructure (Li et al. 2020; Ding et al. 2022; Meuser et al. 2024). This trend has motivated extensive research and products from industry focusing on AI hardware design and corresponding synergistic software development to optimize onboard AI efficiency regarding computational load, memory usage, and power consumption (Kathail 2020; Karumbunathan 2022; Akin et al. 2022; Li 2024).

In contrast, the deficiency of AI hardware topics in current computer science education is prevalent. For instance, the latest computer science curricular guidelines jointly produced by ACM, IEEE Computer Society, and AAAI classify hardware for machine learning as *non-core*, i.e., elective topics (Kumar et al. 2024). Such neglect of AI hardware education consistently recurs in curriculum recommendations for programs with related orientations, such as computer engineering, data science, and information systems (Joint Task Force on Computer Engineering Curricula 2016; ACM Data Science Task Force 2021; Leidig and Salmela 2021). Similar situations also exist in Germany (Zukunft 2016; Maehle et al. 2018). Despite several specialized courses incorporating AI hardware content, they remain insufficient to enhance entire programs at the curriculum design level (Xiong et al. 2023; Kuo and Wu 2023). Consequently, existing AI curricula with limited AI hardware content may discourage prospective students with interests in this domain and provide suboptimal AI expertise for the emerging trend of edge AI, potentially constraining students' career opportunities.

This significant gap motivates the design of a dedicated curriculum focusing on AI hardware. In this paper, we present *Edge AI*, a postgraduate curriculum offering AI hardware expertise, collaboratively developed by two German universities. Beyond common technical perspectives, the *Edge AI* curriculum design seeks to evaluate anticipated practical capabilities acquired by students and incorporate essential ethical education to cultivate comprehensive professional competencies. To this end, the Dagstuhl triangle is employed as an analytical framework to assess the entire curriculum (Brinda et al. 2016). All curriculum courses are mapped onto the triangle according to their content across three dimensions: technical, application, and sociocultural, thereby providing an intuitive overview of the curriculum's topic coverage and focus. Through participatory design processes (von Unger 2014), we iteratively refine our curricular design and finally obtain the proposed *Edge AI* curriculum, wherein Table 1 lists all contained courses, with the corresponding Dagstuhl triangle illustrated in Figure 1.

Proficiency in AI hardware topics requires students to possess the ability to apply theoretical knowledge to real-

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*These authors contributed equally.

#	Course	Type
🟥	*Fundamentals*	
1	Artificial Intelligence Fundamentals	*LE*
2	Computer Science Fundamentals	*LE*
3	Digital Hardware Fundamentals	*LE*
4	Embedded System Design Fundamentals	*LE*
5	Research Data Management	*LE*
6	Ethics Fundamentals	*SE*
🟧	*Architecture and methodology*	
7	Hardware-Software Co-Design	*LE*
8	Introduction to HDL and Tools	*LE*
9	Development and Integration of HW Accelerators	*SE*
10	Reliable Hardware: From Logic Gates to Processors	*LE*
11	Hardware Architectures for AI	*LE*
🟨	*Implementation*	
12	Accelerating CNNs using PL	*PR*
13	Electronic Design Automation	*PR*
14	Chip Design	*PR*
15	Engineering Project	*PR*†
16	Lab Course Mobile Computer Vision	*PR*‡
⬜	*Deep dives*	
17	Lab Course Photogrammetric Data Acquisition	*PR*‡
18	Ethics Advanced	*SE*
19	HDL Projects	*PR*
20	Neuromorphic Chip Design	*SE*
21	Applied Machine Learning for Natural Hazards and Environmental Changes	*PR*
🟦	*Free electives*	
🟦	*Master thesis*	

Table 1: The full course list of the *Edge AI* curriculum. Lectures with exercises, seminars, and practical courses are denoted as *LE*, *SE*, and *PR*, respectively. *PR*† and *PR*‡ represent exemplary practical course variants structured as *self-managed projects* and *inverted classrooms*, respectively.

world tasks that typically involve collaborative hardware and software development. Furthermore, the diverse backgrounds and prior experiences of students necessitate personalized learning paths. Therefore, we leverage the Four-Component Instructional Design (4C/ID) model and develop a Moodle template for individual course design, emphasizing real-world applications and supporting tailored learning plans (van Merriënboer, Kirschner, and Frèrejean 2024). Meanwhile, to provide student-centric, active learning experiences, we formulate selected practical courses as self-managed projects and inverted classrooms. These approaches afford students the flexibility to progress through material on their own schedule while receiving timely support from instructors. Materials of all courses are open access and maintained by Open Science Framework (OSF) (Foster and Deardorff 2017), encouraging inter-institution collaboration and promoting applicability across fields.

We collected 176 evaluations from students using regular questionnaires and teaching analysis poll (TAP) (Johannsen and Meyer 2023) over the past two years (2023-2025). Students expressed general satisfaction with the course content and organization. Constructive suggestions and feedback were considered and contributed to the continuous improvement of the curriculum. We believe that the proposed curriculum serves as a promising framework to address the significant gap in AI hardware education, equipping students with essential skills for the emerging field of Edge AI.

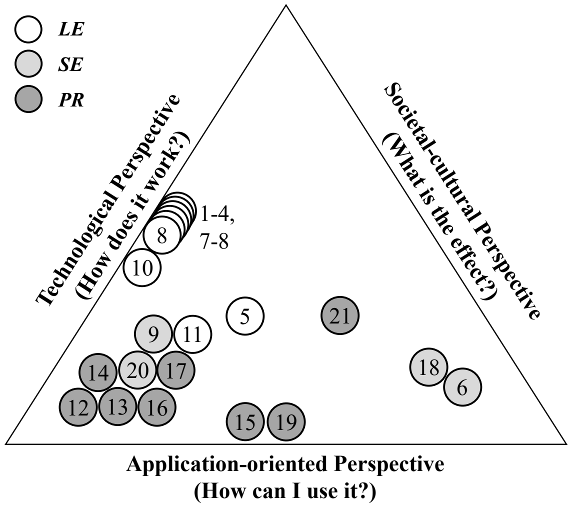

Figure 1: The Dagstuhl triangle of the *Edge AI* curriculum. The indices correspond to Table 1.

Curriculum Design

This section elucidates the design procedure of the *Edge AI* curriculum as shown in Table 1, guided by the Dagstuhl triangle through participatory design. Then, we present the resulting curriculum structure with an exemplary study plan.

Dagstuhl triangle

While edge AI fundamentally constitutes an engineering discipline, a sound edge AI curriculum necessitates practical competencies for real-world implementation with critical ethical considerations essential for responsible development and deployment. To address this multifaceted challenge, we employ the Dagstuhl triangle (Brinda et al. 2016), established for designing and evaluating computer science curricula, as the foundational theoretical framework for developing the *Edge AI* curriculum. The Dagstuhl triangle provides a clear overview of the curriculum's topic coverage and focus by positioning each course within the curriculum onto the triangle based on course content across technological, application-oriented, and societal-cultural perspectives.

The curriculum design based on the Dagstuhl triangle is implemented through participatory design (von Unger 2014) involving all educators in this curriculum. We first conducted a comprehensive comparison between the learning objectives of existing related courses from universities and the *Edge AI* curriculum scope to obtain an initial curriculum and its corresponding Dagstuhl triangle encompassing existing courses that directly align or require modification, and missing new courses to be developed. Subsequently, we held periodic meetings where each lecturer briefly updated their teaching activities, potentially with feedback from students, to all other curriculum design colleagues. The discussion among lecturers explored whether each course should (to some extent) cover all three perspectives, or whether the curriculum as a whole should maintain balance or establish specific focuses within the triangle. This procedure iteratively improves course contents, promotes collaboration, serves as quality assurance, and leads to updated Dagstuhl triangles in a transparent manner, which in turn guides future directions for curriculum enhancement.

For example, during an early discussion of curriculum design (mid-2023), bifurcated opinions emerged regarding the sociocultural perspective. Some attendees acknowledged that it is reasonable for the social perspective not to be explicitly covered for exclusively hardware-oriented courses, particularly in graduate programs within highly technical disciplines. However, a suggestion was also proposed to incorporate a module on the social implications and ethical considerations of AI, as this would enrich the course content and potentially increase student engagement. Consequently, we decided to offer dedicated courses regarding AI ethics (`#6`, `#18`). Meanwhile, we emphasize social values in certain courses. For instance, we added good scientific practice (e.g., data anonymization for privacy) in Research Data Management (`#5`). We also designed a practical course with a focus on natural hazards and environmental changes (`#21`). These modifications collectively enhance the curriculum to provide professionalism in multiple aspects.

In this way, we obtain the proposed *Edge AI* curriculum as listed in Table 1 with its corresponding Dagstuhl triangle depicted in Figure 1, which reveals a clear focus on the technological and application perspectives of AI hardware while relatively marginalizing the sociocultural dimension. The imbalances evident in Figure 1 highlight the necessity of future adjustments to the curriculum.

Curriculum structure

The *Edge AI* curriculum comprises 120 ECTS (European Credit Transfer and Accumulation System), which is consistent with most master's programs in Germany. The curriculum contains the following five complementary modules alongside the final master's thesis.

- **Fundamentals** This module provides essential knowledge for AI hardware. Students can acquire the fundamental machine learning concepts and algorithms that underpin modern AI systems. These courses establish the foundation for addressing challenges at the intersection of hardware design and AI.
- **Architecture and methodology** This module provides comprehensive expertise in the design and implementation of specialized systems for AI workloads. Through these courses, students acquire knowledge of hardware-software co-design, simulation tools, hardware description languages, and design methodologies. They also develop an understanding of performance optimization and system-level integration for AI hardware platforms.

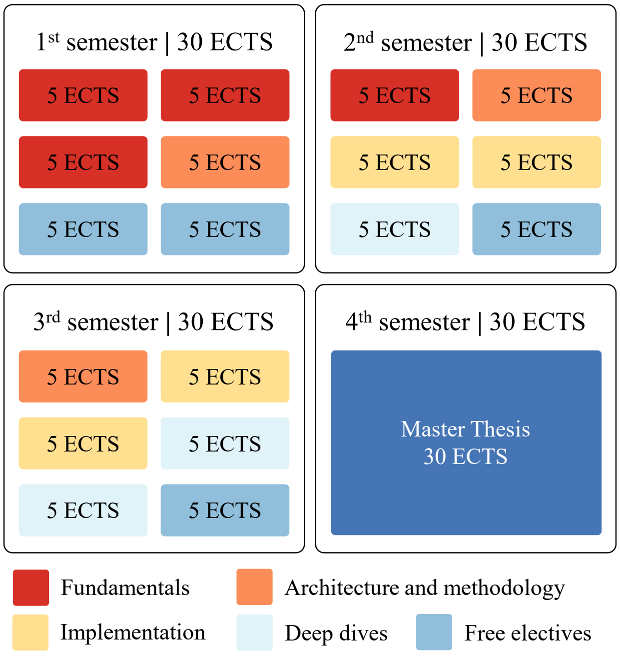

Figure 2: An example schedule for the *Edge AI* curriculum.

- **Implementation** The module provides practical experience in hardware design and development for AI applications. Students are expected to acquire practical skills essential for AI hardware engineering. These courses collectively ensure that graduates possess practical competencies for both industry and research endeavors.
- **Deep dives** This module offers students the opportunity to delve into specialized and advanced topics in Edge AI, allowing them to explore specific, cutting-edge applications and technologies. The deep dives are designed to build upon the foundational knowledge and practical skills acquired in earlier modules, preparing students for research-oriented roles and specialized career paths.
- **Free electives** Free electives enable students to customize their educational choices according to their interests and career objectives. Students may select courses from any department for interdisciplinary ex ploration. This flexibility encourages students to develop a unique profile that complements their Edge AI expertise.

The final master's project of 30 ECTS should be research-oriented. The practical execution may be conducted in industry or a research institute. Additionally, the curriculum design consortium also includes an institution with chip manufacturing capabilities, providing students with opportunities for tapeout. The curriculum trains students for various roles in AI hardware design, spanning low-level electronic engineering to high-level software development. This program qualifies graduates for diverse careers, including positions in VLSI, embedded systems, electronic design automation, ethics and governance, and academic research.

Figure 2 illustrates an example study schedule for the *Edge AI* curriculum over two years, with the same color scheme as Table 1, where each course comprises 5 ECTS. It should be noted that this paper focuses on the methodology and experiences of curriculum design rather than the curriculum itself. All details regarding the curriculum schedule, admission, assessment, course descriptions, etc., can be found in our project webpage here[1].

Didactical Design of Courses

In this section, we zoom into individual course design, where the core methodology is the Four-Component Instructional Design (4C/ID) model (van Merriënboer, Kirschner, and Frèrejean 2024). We explain its fundamental principles, highlight successful implementations across various domains, and reference exemplary cases. Subsequently, we describe the concrete implementation of course development. Finally, we explore the concepts of inverted classrooms and self-managed projects, which play a significant role in the curriculum by enhancing student engagement and fostering independent learning experiences.

4C/ID model

The instructional approach for course design employs the 4C/ID model, an instructional design framework for action-oriented learning that emphasizes the development of complex skills and key competencies while facilitating knowledge transfer to novel contexts (e.g., from classroom settings to real-world applications). The subject of a course is first decomposed into task classes that represent authentic whole-task experiences. Each task class incorporates four fundamental components:

- *Practical learning tasks* address the subject matter with progressively increasing difficulty and decreasing support, focusing on action-orientation and the higher levels of Bloom's taxonomy (Bloom et al. 1956).
- *Part-task practice* offers targeted repetition of specific routine aspects of learning tasks, emphasizing those that demand a high level of automaticity.
- *Supportive information* for the task class offers guidance on non-routine aspects by providing cognitive strategies and mental models, and is continuously available.
- *Procedural information* supports learners in performing routine aspects of learning tasks and is presented during task execution, tailored to their level of expertise.

Task classes have evolved from addressing application field demands to concentrating on hardware design requirements within this curriculum. The 4C/ID model is selected due to its capabilities to accommodate diverse backgrounds and prior knowledge of students from multiple disciplines. This model facilitates personalized learning trajectories and emphasizes real-world procedures as the foundation of academic activities, thereby promoting action-oriented learning. Therefore, instructional design is more targeted than alternative approaches in the context of professional program development (von Unger 2014; Arnold 2000). For example, Frerejean et al. utilized the 4C/ID model to coach primary school teachers in differentiation skills to meet the diverse needs of students. Gursch et al. also leveraged the 4C/ID model to develop two distinct courses, each presenting specific challenges: one focused on practical programmable logic, the other on ethical reflection.

Activity or resource	*Learning Tasks*	*Part-task Practice*	*Supportive Information*	*Procedural Information*
Assignment	✓	✓		
Book			✓	
Database			✓	
Pad	✓			
File			✓	✓
Folder			✓	
Forum				✓
Glossary		✓	✓	
Interactive Content		✓		
Journal	✓			
Lesson	✓			
Mindmap			✓	
Quiz		✓		
Wiki	✓		✓	
Peer Feedback	✓	✓		

Table 2: Mapping of LMS modules to the 4C/ID model.

Implementation

The multi-institutional nature of the curriculum necessitates a unified approach to course delivery that can accommodate diverse student needs while maintaining pedagogical consistency. An open Moodle platform was selected as the delivery mechanism for its extensive collaborative features and flexibility to support the constructive alignment principles inherent in the 4C/ID model. This choice enables tailored learning paths while ensuring open accessibility across institutions.

To systematically implement the 4C/ID model within this digital environment, we developed a dedicated Moodle template that serves as both a structural framework and a didactic support tool for educators (Gursch, Hasse, and Lucke 2025). This template provides a comprehensive course architecture with modular blocks that directly correspond to the four components of the 4C/ID model. Table 2 illustrates a systematic mapping between standard Learning Management System (LMS) modules and the 4C/ID model's four components, demonstrating how LMS modules can be purposefully deployed to support action-oriented learning.

This mapping reveals that individual LMS activities can fulfill multiple functions within the 4C/ID framework. For instance, the *assignment* activity includes elements that align with two components of the learning process: learning tasks, which provide real-world challenges for students to solve, and part-task practice, which focuses on sub-tasks essential for completing the broader assignment. Conversely, the *database* activity primarily supports the delivery of supportive information. Consequently, only selected components have been chosen to illustrate the underlying principle.

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[1] BB-KI Chips: https://www.bb-ki.de/.

Progressive strategy The course template represents a milestone in operationalizing the 4C/ID model within an LMS, such as Moodle. Our strategic plan involves progressively adapting all project-related courses to the 4C/ID model using this template, with an emphasis on continuous assessment and refinement. The iterative nature of this implementation serves multiple purposes. First, it enables evidence-based optimization of the template structure through real-world usage data. Second, it provides educators with gradual professional development opportunities, allowing them to build familiarity with the 4C/ID model while maintaining instructional continuity. Third, it ensures that technical and organizational challenges inherent in cross-institutional collaboration can be addressed systematically rather than overwhelming the implementation process.

Transferability for broader applications While initially developed for this curriculum, the template is intended for wider application and provides didactic support for lecturers. The mapping between LMS modules and 4C/ID components can be readily adapted to other learning management systems, as most modern platforms offer analogous tools and features. This transferability extends beyond technical implementation to encompass various disciplinary domains.

Long-term accessibility All course materials are maintained as freely accessible resources online (Arango et al. 2025) through the Open Science Framework (OSF), a research data repository operated by the Center for Open Science (Foster and Deardorff 2017). Its backup functionalities ensure courses are archived with all essential components while excluding participant-specific data. This approach supports long-term accessibility and enhances interoperability across platforms. Availability through OSF provides a robust foundation for academic dissemination and collaboration. This commitment to open access ensures that the educational innovations developed through this curriculum can benefit the broader academic community.

Practical course variants

Practical courses serve as critical components of this curriculum, given the engineering nature of Edge AI. Meanwhile, the simultaneous development of software and hardware presents considerable challenges for students new to this field, resulting in frequent requests for assistance, which impedes the scalability of teaching. Therefore, we implement two variants of practical courses, self-managed projects and inverted classrooms, to investigate better solutions. These two formats can effectively offload teaching workloads to students by promoting self-directed learning, thereby potentially enabling scalable instruction.

Self-managed projects (*PR*†) The curriculum formulates several practical courses as self-managed projects using an adapted Scrum framework (Fowler, Highsmith et al. 2001; Marnewick 2023) tailored for academic contexts. Students assume three conceptual roles through self-reflection or rotation: *project manager* (vision and priorities), *scrum manager* (workflow coordination and methodology adherence), and *developer* (technical execution). Work is structured through three artifacts: *Sprints* (2-4 week iterations with deliverables), *Backlogs* (transparent task documentation from all role perspectives), and *Kanban boards* (visual sprint-based project management). This methodology transforms complex AI hardware projects into manageable iterations with periodic sprint reviews for knowledge integration and adaptive planning. Tutors provide assistance only during requested sprint reviews. The approach particularly benefits individual projects by encouraging multi-perspective self-reflection, preventing tunnel vision in solo technical work.

Sprint 1	**Sprint 2**	
☑ Task 1: docker ☑ Task 2: reproduction	☑ Task 1: KV260 usage Task 2: LiDAR library Task 3: LiDAR web GUI	
dd.mm **Backlog**	dd.mm **Backlog**	
[06.11] **PrM** Topic discussed. Sprints and kanban are formulated. Periodic meetings with the supervisor are scheduled. **ScM** Practice docker usage by the end of this week. Reproduction is scheduled for the next week. **Dev** A docker usage document would be helpful as suggested. The reproduction shall be easy as the previous work is well documented. [13.11] **Dev** A docker usage document for myself is ready. [19.11] **PrM** Sprint 1 is ready for review in the next meeting. **ScM** Sprint 1 is ready for review as planned. **Dev** The results from the previous project are reproduced and very close to what the report states. I tried the docker image (vitis-ai-gpu) provided and tried to build one from scratch. Both are working for reproduction.	[21.11] **PrM** Sprint 1 is accepted. I can start to work on Sprint 2. **ScM** Task 1 is done during the meeting thanks to a prepared bootable SD card. Task 2 & 3 should be easy, as they are covered in the previous work. **Dev** A USB-to-Ethernet adapter is needed as two Ethernet slots are required (network & LiDAR). The Blickfeld library is online access-able. WebGUI should be ready if the LiDAR camera settings are correct. [25.11] **Dev** Got the adapter. [27.11] **Dev** The network setting of the LiDAR camera is finished. But the live point clouds are not shown in the web GUI. **ScM** Use the LiDAR library to get real-time point clouds. [04.12] **Dev** Managed to get LiDAR frames using the library (Task 2). Web GUI not working. **PrM** Will discuss the issue during the meeting. Task 2 is ready for review.	…
Under review:	**Under review:** Task 2	
Done: Task 1, 2	**Done:** Task 1	

Figure 3: The segmental Kanban board of the self-managed project *Real-time LiDAR Point Cloud Classification on FPGAs*. A total of five Sprints were defined in detail. Due to space limitations, only the Kanban board of two Sprints are presented with minimal task descriptions.

The *Engineering Project* (`#15`) is developed following the above settings. The effectiveness of *PR*† is demonstrated through field implementations, such as the project *Real-time LiDAR Point Cloud Classification on FPGAs* (finished in Feb. 2025), where part of its Kanban is illustrated in Figure 3. The Kanban board reveals how role-based reflection enabled proactive problem-solving. The project achieved all acceptance criteria with comprehensive outputs delivered through reports, a demonstration video, and a code repository. This approach enables students to navigate complex technical challenges independently and maintain professional project management standards, with supervisor involvement minimized to strategic checkpoints and technical consultations. Although Sprint formulation requires considerable time from tutors, it eliminates the need for fragmented supervision and eventually proves worthwhile overall.

Inverted classroom (*PR*‡) The inverted classroom format contains multiple rounds with progressive topics, where each round includes a preparatory phase and a synchronous session. During the preparatory phase, traditional lecture content is delivered asynchronously via curated resources, including video lectures, guided programming demonstrations, technical documentation, and research papers that students can access independently at their own pace without lecturers' involvement. While synchronous sessions with lecturers and tutors are reserved for higher-order activities such as collaborative problem-solving, critical discussions of complex topics, and clarification of challenging concepts. This approach aligns naturally with the 4C/ID model's emphasis on supportive information (delivered through self-study materials) and procedural information (addressed during interactive sessions).

We implemented *Lab Course Mobile Computer Vision* (`#16`) and *Lab Course Photogrammetric Data Acquisition* (`#17`) as pilot courses for trials of the inverted classroom methodology. Both courses adhere to settings above. Students need to form teams and complete an AI hardware project on a designated topic. The final assessment is conducted through public presentations in a poster session, where more than five reviewers evaluate presentations, pose questions, and determine final grades. Taking `#15` as an example, in 2024, 22 students participated in the final poster session, where 13 (59.1%) students achieved *very good* grades (1.0-1.5 in the German grading system, where lower grades are better, the same applies hereafter) and all students obtained grades no lower than *good* (1.6-2.5). In 2025, 16 out of 28 (57.14%) students attained *very good* grades, and only 3 students performed below the *good* threshold. These results significantly outperform comparable courses addressing similar topics within our universities. Meanwhile, 41 evaluation sheets from this course indicate that students generally responded favorably to the course settings. These results demonstrate that the inverted classroom is a viable format for practical courses with scalability.

Evaluation

We collected a total of 176 student evaluations between 2023 and 2025, comprising 139 *regular teaching evaluation* and 37 *teaching analysis poll* (TAP) evaluations.

Regular teaching evaluation

We conducted regular teaching evaluations using questionnaires that inquired about difficulty ratings, preferred aspects, potential areas for improvement, and provided free space for additional comments and suggestions.

There are 38 evaluations of *PR* collected, demonstrating a consistent pattern of moderate-to-high perceived difficulty (3.67 ± 0.47 on a 5-point scale, where higher values indicate greater difficulty) with notable time management issues. Despite these challenges, 17 students (44.7%) explicitly valued the hands-on nature of AI hardware projects, while 15 students (39.5%) highlighted the course content as intellectually engaging and relevant to modern computing challenges.

For *self-managed projects* (*PR*†), we have 6 evaluation results. The number is small as most *Engineering Projects* (`#15`) are individual projects. All students appreciated the flexibility of this course format. Meanwhile, the teaching quality and learning outcomes remained consistent despite this new pedagogical model. One representative example is the bird detection demonstrator for bird strike prevention by a second-year bachelor student (finished in 2024), as shown in Figure 4. The student expressed appreciation for the timely support from the tutor, and stated that "*such courses make you learn way more than a classic class*".

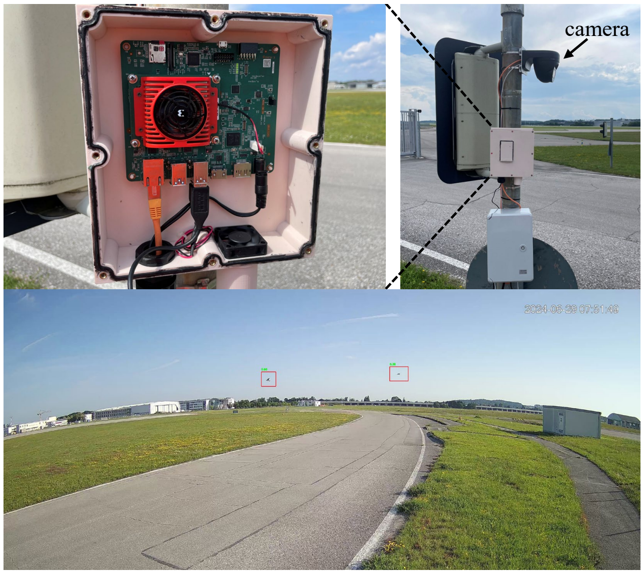

Figure 4: The bird detection demonstrator deployed at an airport in Germany, with detection examples below. A 3D-printed case is designed to accommodate the AI hardware with waterproof sealing, cable management, and air cooling.

Regarding *inverted classroom* (*PR*‡), 59 evaluations were received, where 20 (33.9%) students indicated that the provided teaching materials may be insufficient, particularly lacking examples, necessitating supplementary online research. The dichotomy between positive instructor feedback (23.7%) and workload concerns (15.3%) indicates that while pedagogical support is adequate, the temporal organization of synchronous sessions requires restructuring. Albeit these challenges exist, the final grades (mentioned above) remained competitive compared to conventional lectures, revealing the potential of the inverted classroom format.

From the remaining 36 evaluations, we find that, despite varying difficulty levels and content areas, instructor accessibility and responsiveness constitute a decisive predictor of course satisfaction, with ratings consistently exceeding 80% satisfaction when instructors are readily available for questions. Courses with identical difficulty ratings show divergent satisfaction based primarily on organizational clarity rather than content complexity. Meanwhile, students sometimes expressed dissatisfaction with the misalignment between lecture content and exercises, i.e., often requiring knowledge not yet covered in lectures. Future improvements will address these identified deficiencies.

Teaching analysis poll

To complement standard surveys using questionnaires, we conducted teaching analysis poll (TAP) (Johannsen and Meyer 2023) within two cross-institutional block seminars on AI ethics (`#6` in Table 1), with 20 participants in one course and 17 in the other. The seminars integrate the ethical dimensions of AI into scientific writing processes. Anchored in the 4C/ID model, this approach combines asynchronous online learning with synchronous in-person seminars.

Within the TAP framework, students actively engaged in discussions on critical course components in small, self-managed groups. Feedback was analyzed during a plenary session, in which students identified and ranked suggestions for modification. The TAP process was supported by the Center for Quality Development in Teaching and Studies of the host university. The TAP evaluation revealed key areas for improvement alongside successful practices. In terms of what supports learning most, students from both courses consistently emphasized the value of personalized feedback and self-directed research, which align well with the 4C/ID model's principles. Students valued the structured debates, cultural exchanges, and preparation of ethical topics, recognizing mixed-program settings and organized environments as particularly beneficial and enriching experiences.

However, challenges in transparency and organization, specifically in grading criteria and assessment timing during exams, were noted as impacting engagement. To address these issues, students suggested refining grading guidelines for greater clarity. They also recommended improving interactions with supervisors and separating peer reviews from assignment deadlines to optimize course structure. We will continue to apply the evaluation methods described above in all future iterations to further improve and evolve the curriculum and the individual courses.

Discussion

The development of the *Edge AI* curriculum addresses existing gaps in AI hardware education. Utilizing the Dagstuhl Triangle as an analytical framework facilitated the integration of technical and application dimensions while maintaining consideration of sociocultural aspects, thereby providing comprehensive coverage aligned with industry requirements. The observed imbalances of the curriculum presented in Figure 1 imply the necessity for future adjustments.

The application of the Four-Component Instructional Design (4C/ID) model played a central role in facilitating action-oriented learning. By utilizing a flexible LMS template, e.g., Moodle, we are able to structure personalized learning paths that support students in transferring theoretical knowledge to authentic, practice-oriented tasks.

Evaluation results are positive overall. Students generally valued the opportunities to gain AI hardware experience. For practical courses formulated as self-supervised projects and inverted classrooms, students endorsed the time flexibility offered by these two formats. The course output (Figure 4) and final grades demonstrate that two formats are feasible ways to design practical courses. The TAP evaluation revealed strengths, such as personalized feedback and structured debates, facilitating learning and content engagement. They also identified challenges related to transparency and scheduling, requiring attention to enhance the curriculum's effectiveness. However, as no graduates have yet completed the entire curriculum, a comprehensive assessment of the effectiveness of the whole curriculum remains forthcoming.

Acknowledging the constraints inherent to the employed methods is crucial for a thorough understanding of the results, underscoring the importance of a balanced and adaptive approach. Regular teaching evaluations offer valuable perspectives, but they do not yet comprehensively reflect the full scope of the curriculum. Although the overall results are positive, relatively high course difficulties, insufficient materials for inverted classrooms, and the problematic course organization colliding with the dependency between lectures and exercises warrant further reflection and enhancement.

The TAP evaluation was conducted in only two courses, so its results may not be entirely generalized to the whole curriculum. Moreover, since the feedback relies on students' subjective perceptions, the objectivity of the findings may be compromised. In addition, the TAP addresses only specific aspects of teaching and feedback quality and does not comprehensively assess all learning processes or outcomes. In the future, TAPs should be conducted across a larger and more diverse selection of courses to provide a more comprehensive perspective, complementing regular teaching evaluations based on questionnaires.

Furthermore, emphasizing student evaluations as the primary metric for curriculum success might lead to neglecting essential factors, such as long-term career trajectories and the growth of interdisciplinary competencies. In future assessments, these elements should be tracked to comprehensively evaluate the curriculum's impact.

Conclusion

This paper presents the *Edge AI* curriculum jointly developed by two German universities that aims to address the critical gap in AI hardware education. The curriculum employs the Dagstuhl Triangle to ensure comprehensive coverage across technical, sociocultural, and application dimensions. The 4C/ID model integration facilitates action-oriented learning, supported by an LMS template, exemplified by Moodle, which can be adapted for use across various platforms. By providing open access to all materials through the Open Science Framework and developing replicable frameworks for course design, this work contributes both a practical solution to immediate industry needs and a methodological foundation for curriculum development in rapidly evolving technical fields. Practical course variants, including self-managed projects and inverted classroom, demonstrate effective alternatives to traditional instruction while maintaining educational quality. Evidenced by generally positive evaluation results from 176 students over two years, the curriculum serves as a promising model for general adoption, equipping graduates with comprehensive AI hardware expertise while demonstrating how theoretical frameworks can guide effective educational innovation for the emerging edge AI landscape.

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