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Advancing Interdisciplinary Built Environment Education Through Computation

Serdar Aşut¹

Computation is both expert knowledge and a transversal competence. This article presents how computation can enhance interdisciplinary learning in the context of built environment education. The need for interdisciplinary education is widely recognized and aligns with industrial and societal transformations. Integrating diverse know-how from various built environment professionals is challenging in an educational context. Computation can help address these challenges as a transversal competence applicable across multiple disciplines by facilitating communication between different fields. This proposition was applied over three academic years in a research and design course within the Building Technology master's program at the Faculty of Architecture and the Built Environment of Delft University of Technology, focusing on a different theme each year. The course was designed following Interdisciplinary Project-based Learning principles and integrated computation through programming as a transversal competence and expert knowledge. This article presents an overview of the objectives and methodology of this course. It specifically focuses on the second year, which explored earthquake resilience and recovery as the course theme. Based on the lessons learned, the article concludes with suggestions for creating effective interdisciplinary environments for built environment education.

Keywords: Built environment education, Computation, Programming, Transversal competences, Interdisciplinary education

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Interdisciplinary Education

Interdisciplinarity refers to the integration of methods, knowledge, and skills, as well as theories, perspectives, and different disciplinary knowledge bodies, to achieve innovative solutions and advancements in uncharted problem areas^{1,2,3,4}. It is a process that requires the synthesis of various disciplinary knowledge and methods to provide a more holistic understanding of a given problem⁵, tackle complex problems, and stimulate innovation. It is particularly valuable in addressing emerging challenges that do not usually fit within traditional disciplinary boundaries.

It is the process by which information and codes are exchanged across disciplinary boundaries in a search for new or deeper understanding because it is in the overlapping spaces that exist between disciplines where the frontiers of knowledge are located⁶. Yet, it involves challenges because it requires aligning different epistemologies, methodologies, and terminologies, demanding collaboration across fundamentally different ways of thinking and problem-solving. Professionals from different disciplinary backgrounds may struggle to navigate and overcome these challenges, partly because their education did not prepare them for interdisciplinary collaboration. Additionally, education itself presents distinct challenges in this regard.

The need for interdisciplinary education (IE) is widely recognized and aligns with industrial and societal transformations. Chen et al.⁷ originate the sense of IE from three arguments provided by Stember⁸. The first one is that ideas in any field are enriched by theories, concepts, and methods from other fields. Secondly, the problems of the world are not organized according to academic disciplines. And finally, learning is hindered by fragmentation. Designing and implementing IE remains a prominent area of research that requires further exploration. The historically discipline-oriented nature of academia often impedes such explorations⁹. Still, it also occurs within even very traditional and monodisciplinary universities, emerging in the interstices of monodisciplinary structures through strategies of ‘managing interstitiality’¹⁰.

Several scholars have emphasized this need and proposed approaches to facilitate IE within built environment education (e.g.^{2,11,12,13}). The very nature of built environments presents complex challenges related to their design, planning, production, and use, requiring input from multiple disciplines. Integrating this diverse know-how is not easy, especially in education. A common challenge discussed in the literature is the difficulty of communication between different disciplines. Yocom et al.¹⁴ argue that developing collective understanding is the most challenging theme for IE and that it should focus on sharing disciplinary vocabularies and improving students’ communicative techniques.

Creating a common ground for collaboration in an interdisciplinary environment and overcoming the communication difficulties between disciplines require strategies that bridge differences in methods, terminology, and communication styles. This can be achieved in education through structured frameworks that promote dialogue, mutual understanding, and shared problem-solving approaches. While expert knowledge and disciplinary skills are essential, interdisciplinary collaboration also depends on soft or transversal competencies, such as communication, adaptability, and teamwork. These skills are as critical as technical expertise in ensuring effective cooperation and knowledge integration. While technical competencies are applicable only in the environment for which they were developed, transversal competencies are transferable to different contexts, including leadership, communication, problem-solving, teamwork, and creativity, among others¹⁵. IE must emphasize the development of transversal competencies as strongly as the disciplinary expertise.

The Role of Computation in Interdisciplinary Education

Computation is both expert knowledge and a transversal competence. It requires students to develop both domain-specific and general problem-solving skills¹⁶. Broadly, it refers to the use of formal, mathematical systems, theories, and methods, as well as tools and technologies developed on the basis of such systems¹⁷. It refers to the thought processes involved in formulating problems so their solutions can be represented as computational steps and algorithms¹⁸. It relates to thinking at multiple levels of abstraction, and it is a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use¹⁹.

Computation is expert knowledge because it involves specialized skills, methodologies, and theoretical foundations gained through rigorous training and an in-depth understanding of the specific application domains where they are used. It requires knowledge of algorithms, data structures, programming languages, and mathematical principles. It necessitates specialized training in problem-solving techniques, software development, and computational modeling. Moreover, the effective application of these methods often requires expertise in specific fields.

Two factors make computation a transversal competence. The first is that it is applicable across multiple disciplines for diverse problem-solving, data analysis, and modeling applications. The second, which is more related to this article's arguments, is that it facilitates communication between different disciplines.

Computation provides a common language across experts with different backgrounds through data, models, and algorithms. It allows the translation of complex problems into abstract and explainable representations. It makes somewhat subjective concepts and arguments more tangible and comparable. Computational simulations and models provide frameworks for analysis and interpretation through shared and interoperable platforms. It standardizes information processing and representation, enhancing interdisciplinary collaboration and problem-solving. Hence, computation provides a shared language among multiple disciplines. It is a core transversal competence that can facilitate communication between disciplines and address some of the common challenges within an interdisciplinary built environment education, as described earlier.

CORE: Advancing Interdisciplinary Education in Built Environment through Computation

Computation is an essential competence that should be integrated into built environment education. It is both a fundamental area of knowledge necessary in the digital age and a transversal competence crucial for interdisciplinary education and practice. Therefore, effective pedagogies that address both aspects are necessary, considering the rapidly changing landscapes of computational tools and methods. Effective interventions should focus on the development of algorithmic thinking and reinforce the utility of programming as a skill, both generally and specifically within careers²⁰. Also, higher education institutions need to consider their agility to respond effectively and anticipate the challenges and opportunities created by the rapidly changing computing environments²¹.

CORE Studio was developed at the Faculty of Architecture and the Built Environment (ABE) of Delft University of Technology (TU Delft) as an intervention to enhance interdisciplinary education in the built environment through computation within the Building Technology (BT) MSc program. CORE stands for “COMputational REpertoire for Architectural Design and Engineering.” It is a research and design studio course taught at BT for three years starting in September 2022. It was taught in the fifth quarter (the first quarter of the second year) of the curriculum as a 15-ECTS (European Credit Transfer and Accumulation System) elective. It is a full-time, 10-week course with a total workload of 420 hours (including self-study), and it is the only course that students follow during the same quarter. It was coordinated by the Design Informatics chair and taught in collaboration with the Structural Design and Mechanics chair of the Department of Architectural Engineering and Technology.

CORE aimed to enable and encourage students to develop a repertoire of custom computational skills, methods, and tools to address interdisciplinary

challenges related to the built environment by addressing computation as both an expert knowledge and a transversal competence. The course design includes two main components. The first is the introduction of computational skills, tools, and methods, and the second is their application within a design assignment.

Even though computational thinking is rooted in non-digital human approaches to problem-solving, the mainstream approaches focus on programming with digital computers²², and programming assignments are still the most often used approach to interventions to teach computational thinking²³. Similarly, CORE introduced computation through programming. The students had prior knowledge of computational design through the Introduction to Computational Design course, a compulsory module in the second quarter of their studies. It introduced them to the main concepts related to algorithmic thinking, parametric modeling, simulations, and digital fabrication. In this course, students also developed skills using Grasshopper (GH), a visual programming interface, and applied these skills in the design assignments. Some students had the opportunity to further develop these skills through the electives they took in the third and fourth quarters. CORE was built on this existing experience, utilizing GH as the central design platform and advancing it with programming in Python. Therefore, it included workshops on Python programming, starting with the basics of programming, covering subjects such as data types, variables, operations, functions, libraries, data analysis, and object-oriented programming. These workshops were held as weekly sessions throughout the first year of the course. In the second and third years, they were organized as an intensive crash course in the first two weeks. Our experiences showed that the latter approach was more effective, as it allowed the students to start programming earlier and enabled better integration in their design assignments. This allowed computational thinking to shape the entire design process from the beginning, including identifying project needs, planning, resource allocation, and pre-rationalization of decisions, thereby guiding the whole process. After the second week, they were guided in their programming work through weekly supervision by tutors.

We think that the focus on computation was one of the factors that attracted students' attention, resulting in high enrollment numbers over the three years of this course. In the first year, 67% of students (38 out of 57) enrolled; in the second year, the enrolment increased to 84% (46 out of 55); and in the third year, 90% (35 out of 39) of BT students chose this elective. This situation supports McCord et al.'s²¹ argument regarding the transformation of Architecture, Engineering, and Construction (AEC) education to accommodate computational skills. They argue that students are not a barrier but a driver of change, with student usage of some technologies outpacing curricular coverage.

The course theme changed yearly, addressing an actual societal and industrial challenge. The students were asked to explore the described theme and propose

design assignments to tackle specific challenges within it. The first year's theme was "Computation for Mobility," in relation to the Mobility Program 2040 developed by the Municipality of Delft. The second year, which also led to the publication of this book, focused on "Computation for Earthquake Resilience and Recovery" in response to the devastating earthquake that occurred in Türkiye in 2023. And the last year focused on "Computation for Construction Automation," addressing the needs of AEC toward cleaner, more efficient, and safer construction practices.

The formulation of the design assignments within these diverse themes was undertaken by the students, guided by the tutors in accordance with Problem-based Learning (PBL) principles. PBL is an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem²⁴. In PBL, students work in small collaborative groups and learn what they need to know to solve a problem, which is a well-suited approach to help students become active learners because it situates learning in real-world problems and makes students responsible for their learning²⁵.

Brassler and Dettmers²⁶ present the distinctions between Interdisciplinary Problem-based Learning ((i)PBL) and Interdisciplinary Project-based Learning ((i)PjBL) and argue that (i)PBL is far more suited than (i)PjBL to support students' development of interdisciplinary competence. Based on this classification, while CORE incorporates characteristics from both approaches, it is closer to (i)PBL as explained in Table 1 (the characteristics that align more closely are identified with bold text and a coloured cell background).

Characteristics	(i)PBL	(i)PjBL
Duration	Short-term (5–6 problems per semester)	Long-term (1 project per quarter)
Problem/Task	Ill-structured cases, open and narrow	Real-world, fully authentic tasks
Definition of Problem/Task Making core choices	(mostly) student	(mostly) teacher
Process	Following specific steps	Following general, broad steps of project management
Problem solving level	Problem analyses (rather theoretical)	Problem solving (rather practical)
Role of the teacher/tutor	Process-oriented supervisor/facilitator	Product-oriented supervisor/ instructor
Outcome/focus/aim	Presentation of knowledge acquisition	"tangible" products
Assessment	(mostly) based on learning	(mostly) based on product

Table 1. Characteristics of (i)PBL and (i)PjBL (Modified from Brassler and Dettmers [26]).

It is the only course that students follow during the quarter (10 weeks, half a semester), so they focus entirely on one project. The course does not present a fully defined task; instead, it invites and encourages students to work on ill-structured cases around a defined theme, with them taking responsibility for defining the specific task within that theme. The process follows broad project management steps, tailored to the specific needs of each case. The course emphasizes both problem analysis and problem solving equally. The teachers' role is clearly process-oriented rather than product-oriented. The outcomes focus more on knowledge acquisition than on tangible products, and assessment is based primarily on learning rather than on the final deliverables.

The Interdisciplinary Dimension in CORE

An interdisciplinary learning environment can be established in different ways. Perhaps the most ideal approach is enabling collaboration among students from different faculties. However, this was not the case for CORE, as all students were part of the BT program and held bachelor's degrees in architecture (with only a few exceptions). Instead, its interdisciplinary dimension was initially facilitated by addressing real-world problems related to the design, production, and use of built environments, following PBL principles. These challenges inherently require integrating knowledge, skills, and methods from multiple disciplines. For instance, second-year projects within the earthquake resilience and recovery theme spanned a broad range of scientific disciplines (e.g., software, algorithms, control systems, artificial intelligence, expert systems, civil engineering, information systems, databases, urban studies, user interfaces, multimedia, architecture, geotechnics, computer graphics, design sciences, mechanical engineering, materials technology), increasing students' awareness of the need for interdisciplinary collaboration to tackle complex issues. The formulation of the theme further reinforced this need by incorporating all four phases of disaster management: mitigation, preparedness, response, and recovery. This approach drove students to think and act beyond their disciplinary backgrounds, seek expertise and resources from various fields, and integrate them by using computational tools and methods. A detailed analysis of the interdisciplinary content of these projects was presented in another article²⁷.

Another factor in facilitating interdisciplinarity was the diverse expertise of the teaching team. The involvement of faculty members from various chairs provided a range of perspectives, and the composition of the team could be adapted to fit the course theme each year by inviting different experts to contribute. Additionally, the course reached beyond the department and the university, engaging specialists from multiple fields. Particularly in the second year, a diverse range of experts, including researchers, engineers, architects, and designers

from industry, as well as governmental and non-governmental organizations, participated. It was particularly impressive to see the voluntary contributions from professionals dedicated to humanitarian issues, such as disaster.

The interdisciplinary dimension was further strengthened by incorporating computation as a transversal competence. This approach allowed students to comprehend workflows and methods from various disciplines, interpret them, communicate effectively with external experts, and develop innovative solutions. By utilizing computational tools and methods, they were able to bridge gaps between disciplines, integrate diverse sources of knowledge, and apply data-driven methods to tackle complex problems.

One of the outcomes of the course was that students implicitly developed T-shaped expertise in the field of earthquake resilience and recovery. The T-shape refers to a variation of the ‘renaissance figure¹’ who can integrate expertise and information technology skills and consider both the technical and social components within the larger system²⁸. The horizontal bar of the ‘T’ represents a breadth of expertise, an ability to engage with other experts across a variety of systems and intellectual and disciplinary cultures; the vertical part of the ‘T’ represents a depth of expertise in a specific knowledge domain²⁹.

In the case of CORE, students developed the horizontal bar of the ‘T’ by gaining awareness of disaster-related challenges and understanding the roles and responsibilities of built environment professionals, including the need for collaboration across various disciplines. This was primarily achieved through a diverse line-up of lectures by experts from various disciplines, some of which were (intentionally) distant from the students’ background and, therefore, challenging to grasp. They were complemented by literature research and explored further through discussions with studio tutors. At the same time, they deepened the vertical bar by acquiring specific skills and knowledge in their field of Building Technology, such as structural analysis, performance-based design, and computational modeling, particularly in the context of earthquake resilience and recovery.

They are exposed to broader perspectives and connections beyond their discipline through the horizontal bars of the ‘T.’ Even if they do not directly apply all these broader insights per se, simply becoming aware of them strengthens the T-shape expertise. As the horizontal bars of different students’ T-shapes intersect, the skills necessary for effective collaboration naturally emerge. Computation played a key role in this process by acting as a transversal competence that supported students in interpreting workflows from other disciplines on the horizontal bars of the ‘T.’ This aspect further strengthens the interdisciplinary dimension of the course and the role of computation as a transversal competence.

1. It is referred to as a ‘renaissance man’ in the original source [28].

Conclusions and Discussion

The three years of the CORE studio, especially the second year that focused on earthquake resilience and recovery, demonstrate how an interdisciplinary learning experience can be enriched through the use of computation as a transversal competence. This experience offers valuable insights for future research and provides recommendations for developing new initiatives in interdisciplinary built environment education.

One of the main suggestions is to design the assignments based on Interdisciplinary Project-based Learning ((i)PjBL) principles. This can support the development of interdisciplinary skills more fundamentally. These assignments should involve real-world, open-ended problems that require input from multiple disciplines and encourage collaboration with students or practitioners from different backgrounds.

When students with diverse backgrounds or interests work together in the same team, it is important not to expect every member to achieve the same learning goals. One common learning objective for all students must be the development of transversal skills. Besides this, an interdisciplinary learning experience should allow for the customization of learning objectives, enabling students to build on their strengths and interests. This also implies the need for flexible and adaptable assessment methods and customizable learning activities. Managing such complexity requires thoughtful course design and vigorous coordination. The teacher plays a crucial role in maintaining an overarching view of the process in a course design like this.

Computation is essential as expert knowledge and transversal competence in interdisciplinary learning. While it is commonly introduced through programming, the rise of Artificial Intelligence (AI) and Large Language Models (LLM) is reshaping how programming is practiced. Further research is needed to understand how these changes impact computational skills and how they should be reflected in educational settings.

Another suggestion is to incorporate learning activities into the course design to introduce specific transversal competencies more explicitly and raise awareness of their importance among students and the teaching team. These activities can provide students with tools to recognize, reflect on, and intentionally develop competencies needed for interdisciplinary collaboration. Thus, students can become better equipped to navigate interdisciplinary collaborations and apply these skills in academic and professional contexts.

It is also necessary to develop means to measure the impact of interdisciplinary education. Future efforts should develop new evaluation methods that assess immediate learning outcomes and long-term effects. This includes evaluating how graduates apply interdisciplinary thinking in their professional practice and how it influences their work.

Perhaps we should define disciplines more fluidly, allowing experts to grow and evolve within overlapping areas of knowledge. Instead of rigidly assigning authority to specific fields -like the shift from the master builder to specialized engineering disciplines, each operating in its own silo- we might as well acknowledge that this fragmented approach no longer suffices. The complexity of today's challenges calls for interdisciplinary, multidisciplinary, and transdisciplinary approaches. It may be time to let people move more freely across disciplinary boundaries and see what unexpected expertise emerges in those intersections. Educational environments can serve as ideal testing grounds for this approach. They can offer a safe space to explore how fluid disciplinary boundaries can function in practice and assess their outcomes. Thus, we can influence professional practices by experimenting with new ways of working during education.

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Ethical Committee Approval

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Conflict of Interest

The author declares no conflicts of interest.

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