

ENGINEERING MINOR IN ARCHITECTURE, A MODEL FOR INTERDISCIPLINARY SPECIALIZATION AND CONTEXTUAL LEARNING

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ABSTRACT

At NTNU, the Faculty of Engineering and the Faculty of Architecture and Design have created a learning environment promoting collaboration between architecture and civil engineering students over the past ten years. Between 2019 and 2021, a Minor in Architecture program for students following the Master's Degree Program in Civil and Environmental Engineering has been piloted, evaluated, and established. The Minor in Architecture program is firmly anchored at both faculties and has become a productive arena for innovative, interdisciplinary, and contextual learning. Within the Minor in Architecture program, students and teachers work closely together, and architects and engineers from acknowledged professional practice contribute with project presentations and guidance. At NTNU, all Master of Science programs include 30 ECTS credits of elective courses in fields outside the core curriculum. The formal structure of the Minor in Architecture is a 30 credits course package consisting of four 7.5 ECTS credits courses within or closely linked to the field architecture. The NTNU Minor in architecture is an arena for collaborative and contextual learning, not only for the architecture and engineering students but also, noticeably, for the academic staff. Considering the necessity of integrating societal aspects for a sustainable world in undergraduate education, we are confident that the NTNU Minor in Architecture is a structure with huge potential to be linked to a wide range of study programs at NTNU.

KEYWORDS

Curriculum development, integrated design-build-test experience, work relevance, faculty development. Standards: 2, 3, 5, 6, 7, 8, 9, and 10.

INTRODUCTION

Both historically and in today's professional practice, architecture is a discipline that is closely connected to many engineering topics. Throughout the 115-year history of the Norwegian University of Science and Technology (NTNU), there have existed many forms of collaboration between architects and engineers. The collaborations, however, have been limited to individual courses without overarching formal frameworks. During the past ten years, there has been a new development in interdisciplinary collaboration between architecture and civil engineering education. The Faculty of Engineering (IV) and the Faculty of Architecture and Design (AD) at NTNU have established a teaching environment promoting collaboration between architecture and civil engineering students. Research reflecting these interdisciplinary collaborations between architecture and civil engineering education has been presented previously (Manum and Sandaker, 2010; Manum and Sandaker, 2011; Rönquist et al., 2019). As a further development of this interdisciplinary learning arena, the IV and AD faculties have collaborated on the Minor in Architecture program as a pilot project in NTNU's testing of Minor arrangements, aiming at formalizing interdisciplinary education. The main aim was to create a richer and more work-relevant context for students. The approach consisted of creating, or gathering, a set of courses where students from the two programs work together in design of buildings and structures, including the opportunity to carry out a Design-Build-Test (DBT) capstone project in collaboration with various practices in the community. The course package was created within the format of electable courses by the students of the Master program in Civil and Environmental Engineering. All of the courses in the package have AD as their host faculty.

By choosing a package of courses in architecture amounting to 30 ECTS and framing this in the format of a Minor, the NTNU-system of elective courses was applied to provide the option of deepened competence in a particular supplemental discipline. No new administrative measures were needed, other than identification of suitable existing elective courses and supplementing with one new. The program has been offered to students in the 5-year Master program in Structural and Civil and Environmental Engineering and is now being continued from the pilot period.

Teaching-learning activities in architectural design have two characteristics that distinguish them from civil engineering education. One is the focus on the context-specific design of particular solutions. The second is the focus on conceptual thinking – on the need for preparation, testing, and clarification of overarching guidelines or frameworks, which is crucial for the sum of many individual choices to result in a solution that appears as a meaningful whole.

In the strategy work on Future Technology Studies (FTS), "Technology Education 4.0: Recommendations for the development of NTNU's technology studies 2022 – 2030," NTNU has highlighted the importance of context-oriented planning, training in conceptual thinking, and project tasks related to real and complex issues, as important themes for strengthening the engineering education (Øien and Bodsberg, 2022; Øien et al., 2022). These are precisely the elements that are essential in architecture education. NTNU's Minor in Architecture program for Engineers aims at developing an arena for collaboration between the subject areas in teaching so that these elements from architecture education can be further developed and included in the civil engineering student's knowledge and skills.

This paper presents the design of the Minor in Architecture program and the impact it has had on the competence of both architecture and engineering students and their teachers. We

discuss the Minor in Architecture program as a model template for integrating both work-place relevance and courses from two study programs in a contextual learning environment.

METHODS

The education design within the Minor in Architecture program consists of three core elements. First, it encourages an interest in and understanding of architecture as a common interdisciplinary knowledge base. Second, it enables an insight into the practice of the architectural profession with concept-based and context-specific architectural design. Third, it fosters experience-based competence in building design as an interdisciplinary arena and how to contribute to this arena as engineers.

Experience has shown that many students from the Master's Degree Program in Civil and Environmental Engineering and the Master's Degree Program in Architecture at NTNU have an interest in both fields of study, and before being accepted to their respective programs were in doubt whether to choose to apply for one or the other study program. In professional practice, the fields engineering and architecture are closely linked to the mutual benefit of the actors within the respective disciplines. This, however, is often not the case within today's sphere of education. Thus, opportunities for development of knowledge and skills vital to operate in a beneficial way as a professional engineer are not exploited.

With this as a backdrop, as an attempt to fill this gap, one of the aims of the Minor in Architecture program at NTNU is to maximize the potential of students' abilities and interests outside the parts of their study programs defined as "crucial for learning outcome." Elaborations on the particular methods manifesting these aims are to be found in the ensuing sections.

Structure and Content of the Minor in Architecture Program

The Minor in Architecture program utilizes the potential of electable courses within the Master's Degree Program in Civil and Environmental Engineering. Such electable courses are viewed as decisive for the program's overall learning outcome with regards to the establishment of an interdisciplinary specialization. This interdisciplinary specialization is responding to demands from dedicated students, as well as to society's need for knowledge and skills concerning the application of subject-specific competence onto the complex issues of building and structural design.

NTNU has a study program structure where 30 out of the 120 ECTS credits worth of courses during the final two years of Master's degrees are electable. These 30 ECTS electable course credits must be chosen outside the students' own field of study, supporting interdisciplinary studies. NTNU has defined a Minor program – in general – as a package of courses within a field of study that must be outside the field of study of the main program, in a way such that the former supplements the latter. Following this overall structure, the Minor in Architecture program is organized as a course package consisting of four 7.5 ECTS credits courses in the field of architecture. The courses within the Minor are given during the 7th, 8th, and 9th semester of the Master's Degree Program in Civil and Environmental Engineering. Throughout the course of the pilot, the number of students admitted to the Minor in Architecture program has been limited to 12. According to the Study Program Description of the Master's Degree Program in Civil and Environmental Engineering about 170 students are admitted each year. The percentage of the students of the Program choosing the Minor in Architecture program is about 7 %. The actual numbers of admitted students for each pilot cohort has been 12, 12,

and 11, in 2019-20, 2020-2021, and 2021-22, respectively. Based on the interest from engineering students within parts of the field outside structural engineering, the 12 student limit will be omitted from the fall semester of 2023. The expected number of students admitted to the Minor in Architecture program the fall semester of 2023 is about 20. Thus, after the implemented change, the percentage of the students of the Master's Degree Program in Civil and Environmental Engineering choosing the Minor in Architecture program is expected to be about 12 %.

Students are admitted to the Minor in Architecture program by applying to one of the two mandatory courses of the program called “Introduction to Architectural Design for Engineers” (Course 1), which is a new course designed for the Minor program in particular. This course runs across all three semesters of the program, functioning as its administrative framework, e.g., allowing communication between teachers and students, and information about program-related arrangements, etc. Additionally, during the final semester of the program, i.e., the 9th semester, the course contains elaborate teaching where students from both the Master's Degree Program in Civil and Environmental Engineering and the Master's Degree Program in Architecture work together on architectural design projects in studios. As an integral part of this course joint seminars are arranged for all the Minor in Architecture students. These seminars typically feature practicing architects and engineers presenting their professional work.

Course 2 of the Minor is a 7.5 ECTS credits course called “Architecture as a Technological Practice” during the 7th semester. This is the second of the two mandatory courses of the program. This course emphasizes the relationship between architecture and scientific and technological development. With a historical lens, it aims at enlightening the students regarding their own role as professionals within the broader context of interdisciplinary collaboration towards common aims of design and construction of buildings.

Following the NTNU-structure of elective courses, course 3 of the Minor is an electable course in engineering that can be chosen from any of the other engineering programs at NTNU. For the Minor students, this course is chosen among those offered by the AD faculty. Course 4 of the Minor is “Experts in Teamwork” (EiT), a mandatory course at NTNU for all Master students, regardless of program, where the students work in interdisciplinary teams on real world projects, with detailed and explicit intended learning outcomes for personal and interpersonal skills using active and experiential learning approaches (Wallin et al., 2017). The students choose one of the EiT courses with an architectural theme. The most popular of the EiT courses are “Architecture for Non-Architects,” “Improve Your City” and “Future Wood.”

See Fig. 1 for a visualization of the structure of the Minor in Architecture program. For a more detailed description of the structure and three courses of the Minor in Architecture program, see the paper presented at the Fifth International Conference on Structures and Architecture, ICSA 2022 (Taraldsen, et al., 2022).

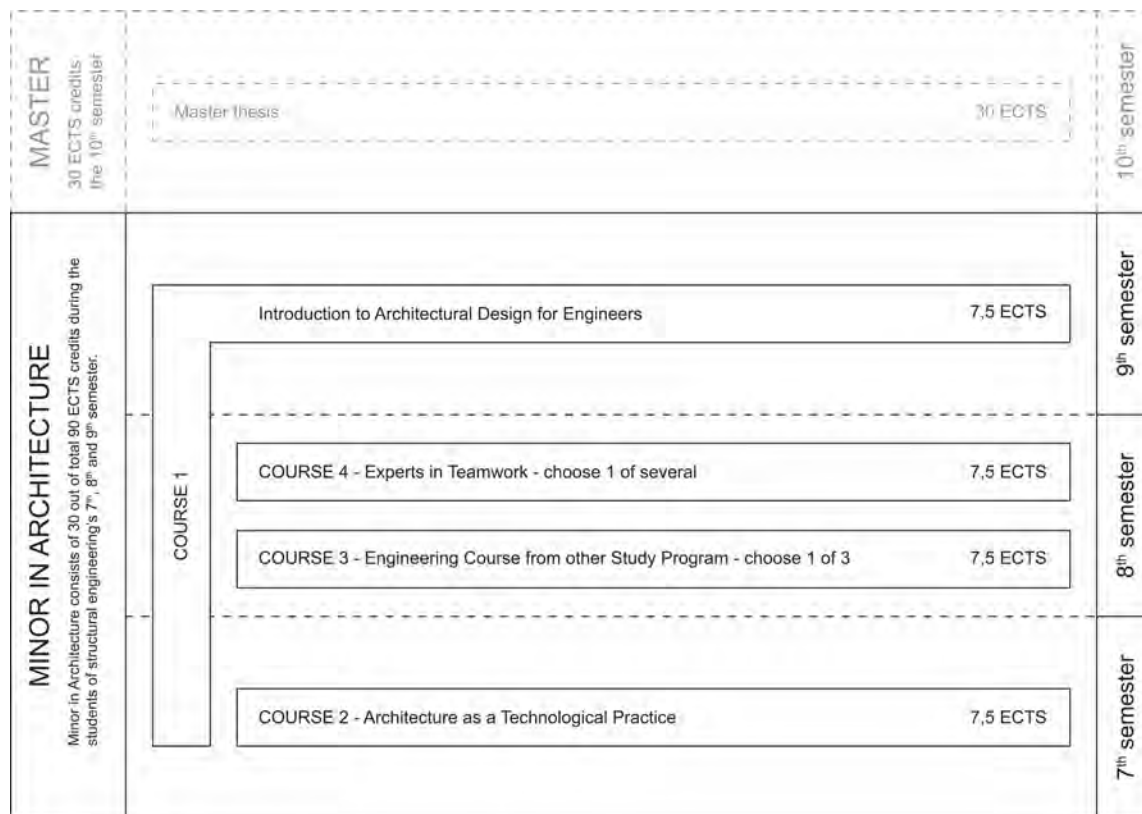


Figure 1. The structure of the Minor in Architecture program.

An essential element of the Minor in Architecture program's learning environment is that the students are learning from each other. This happens through direct collaboration between students of architecture and civil engineering in the design studios supplemented by group work on digital platforms. Another essential element is that the students across cohorts (as the program runs for three semesters, two cohorts overlap in the autumn semesters) continuously inform each other about the contents and learning outcome of the various courses within the Minor in Architecture program, which also serves as a consultancy practice for electing courses.

Academic staff at both faculties (IV and AD) contribute to the teaching in the courses constituting the Minor in Architecture program, especially concerning supervision of the students' architectural and structural design projects. Particularly important in this respect is the course "Introduction to Architectural Design for Engineers." Interdisciplinary teaching-learning activities are present throughout the program, exemplified in a clear fashion in the course "Structural concepts in architectural design, models and methods," where engineers and architects from prominent international offices participate in both project supervision and presentations from their own architectural practice, with special emphasis on conscientious collaboration between architects and engineers that has led to innovative structures and highly acknowledged architecture.

In order to ensure quality and develop the scheme of the Minor in Architecture program, reference groups, consisting of students in the course, and joint meetings are actively used to evaluate the individual students' disciplinary development, as well as how the courses of the Minor in Architecture program contribute to the overall learning outcome within the scope of their respective Master's Degrees in Civil and Environmental Engineering.

RESULTS

The scheme is rooted in both faculties (IV and AD) and has become an arena for innovative, interdisciplinary, and contextual teaching-learning activities. Students and lecturers from Faculty of Architecture and Faculty of Engineering work closely together, and architects and engineers from acknowledged professional practice contribute with project presentations and with supervision. By way of this, the students of engineering develop experience-based competence in the tacit knowledge of design practice, while the students of architecture get experience in discussing and developing architectural design project in collaboration with competence outside their own field. For both the architecture and the engineering students, this is highly relevant for their future professional practices.

Concerning the competence developed by the engineering students in the Minor program, there are three noteworthy aspects. First and foremost, the Minor in Architecture program shapes the students' thinking not only about architecture, but also, and more importantly, how they think within their own discipline of engineering. When we compare engineering students that have undergone the Minor in Architecture program with their fellow students who did not, we observe that the former have become skillful in developing context specific design proposals and in discussing, evaluating, and developing these in insightful ways, including both structural and architectural concerns. What we observe, is that the Minor in Architecture program not only strengthens the students' abilities to oversee and solve structural design tasks but also their ability to see the engineering tasks in broader contexts and devise solutions that respond to complex issues. The students have via the reference group reports confirmed this, for instance, the 2021-22 cohort noted that "it was also very instructive to work with architects who could teach us about concept development."

A second aspect is what the students have learnt from participating in the design processes in the architectural design studio classes – a frame of thinking and working very different from what they know from their Master program in engineering. Key elements are the focus on conceptual thinking, essential in the architect's education but more or less absent in the education of engineers, and the context specific approach of architectural design. This has been confirmed by the students in the written reference group reports. For instance, the cohort of 2020-21 stated that "[the] best learning outcome, [was from] guidance in the classroom with the group."

Finally, learning about architecture in terms of key buildings through history, has provided insight into the close links between architecture and engineering, and new perspectives on the background of their own discipline of engineering. This, too, is supported by formalized feedback from the students, e.g., the cohort of 2020-22 wrote that course 2 "was good for learning about buildings and architects that you can refer to in the later subjects, especially in the context of the Minor, but also otherwise."

As mentioned in the introduction, the Minor in Architecture program is not a project developed from scratch, but a development and a formalization of existing collaborations between educational scholars and professional practice bridging the disciplines of architecture and engineering. An inspiring outcome of the Minor in Architecture program is that the collaboration between the two faculties has provided new contacts and interest across the disciplines for many scholars at the concerned departments at respective faculties. Most importantly, these are scholars at the Faculty of Architecture and Design hosting the engineering students in the design studios, and scholars at the Department of Structural Engineering teaching structural engineering courses collaborating with courses at Faculty of Architecture and Design.

The collaboration between the faculties in organizing and teaching the Minor in Architecture program has also initiated further collaboration and development of curriculum. The Minor in Architecture program situates competence by way of applying knowledge and skills in realistic and complex contexts at the center of the student's learning. This is what makes the Minor scheme particularly innovative. One example is that the Department of Structural Engineering this year, for the second year in a row, is taking part in teaching in first class at the Master in Architecture program. A second example is how the engineering students at the final course of the Minor in Architecture program present architecture-relevant knowledge about structures and construction materials to the entire second year class at the Master of Architecture program. A third example is the projects course of the 9th semester at the Master in Civil Engineering, where the design task for the past two years has been to design footbridges in collaboration with the municipality of Trondheim. This is an interdisciplinary capstone project which provides the students with ample opportunity to apply the expertise acquired through the Minor in Architecture program to a structural engineering design that offers solutions to several issues of urban complexity. In parallel to and in collaboration with the bridge design course at IV faculty, two students of architecture chose one of the footbridges as task for their architectural design course. By collaborating with engineering students at a Minor in Architecture course the previous semester, the architecture students had built a strong background concerning the unification of architecture and structural design, and their bridge proposal was astonishing, uniting context specific architectural concerns with advanced structural analyses in a way that neither of the two approaches would have managed alone, see Fig 2.



Figure 2. Bridge design project by students of architecture Andre Berlin and Krzysztof Jan Pietura at 9th semester, fall 2022. (Photo: Bendik Manum)

DISCUSSION

The Minor in Architecture program integrates deep subject knowledge and contextual learning with problem solving in an environment characterized by interdisciplinary collaboration and provides both civil engineering and architecture students with insight into building design as a collaborative arena for the architecture and engineering professions. The engineering students gain new perspectives on the relevance and potential of their engineering field and an understanding of their own field's contribution to architecture, both historically and in the present.

New perspectives emerge as the students develop experience-based competence in conceptual thinking and building design in an interdisciplinary arena. By working together with students of architecture in design studios, and through the course on the history of interaction between engineering and architecture, the engineering students develop interest in and understanding of historical and contemporary architecture as references and a knowledge base not only for architecture but also for their own particular discipline of engineering.

An additional and unexpected benefit of the Minor in Architecture program is that the teachers from both study programs are able to put their students' education in a broader professional context. It is a common problem in higher education that teachers to a large extent focus solely on their own field, and thus risk neglecting the students' need to apply field-specific skills and knowledge to wider contexts. Architecture and civil engineering are professions that are in close collaboration in practice, making it desirable that the teachers have a firm understanding, not only of the profession the student's education is aimed at but also of adjacent professions.

The connection to practice, the collaboration between the students and the scholars from both study programs, in addition to important contributions from highly acknowledged professional practitioners, makes the Minor in Architecture program highly relevant and desirable.

The goal for any five-year Engineering program is that the matriculated students will be highly competent to assume demanding professional roles. The sought-after competence is far more than the mere sum of the knowledge and skills acquired in the separate courses throughout their education. It also requires the ability to determine which knowledge or skills that are relevant, and when it is necessary to bring in competence from actors outside their own discipline, in order to meet real-world challenges. Real-world challenges are often characterized by numerous conflicting boundary conditions, such as, e.g., sustainability issues, budget constraints, and legal frameworks, as well as potential ethical challenges, sometimes challenging to the extent that they are characterized as “wicked problems” (Lönngren & Van Poeck, 2021)

A key value of this Minor in Architecture program, and the reason why its framework is applicable to other disciplines, is the course design that links a set of elective courses together into a Minor, providing knowledge and skill in a complementary field of high relevance for the master program. This includes the feature of building the Minor around a central course unit, which in the case of Minor in Architecture is the course “Introduction to Architectural Design for Engineers”, a course that provides the opportunity for an interdisciplinary capstone project, anchored in both society and professional practice.

Reflecting on the Minor in Architecture program in the context of the CDIO Standards, we believe that the established Minor illustrate many of the CDIO Standards. The Minor increases depth and context for both course and program learning outcomes (Standard 2). The Minor

aims to integrate knowledge and skills in several relevant contexts (3), and make use of examples of design-implement experiences (5), and of engineering learning workspaces (6). The course design is characterized by integrated learning experiences and by active contextual learning (7 and 8). Of additional interest is that the Minor construction also addresses Standard 9 and 10 – Faculty Competence and Faculty Teaching Competence, by creating a joint interest in the Minor for teachers from both programs, thus providing a fertile arena for setting subject knowledge and skills in a wider work relevant context. While the CDIO Standards are formulated from an engineering perspective, it should be pointed out that the corresponding aspects also conversely apply to architecture study program and the teachers on that program.

CONCLUSION

While the Minor in Architecture program at NTNU responds to students' demands and develops competencies in demand in working life, the scheme inspires the development of interdisciplinary competence among teachers in both disciplines. The Minor in Architecture program has extensive potential for development for architecture aimed at disciplines other than civil engineering, and as a model for interdisciplinary teaching between other disciplines. The latter applies at NTNU and at all universities with strong professional environments in various disciplines.

The Minor in Architecture program has become a basis for collaboration between architecture and engineering and can serve as a model for course structures supporting integration of joint work relevant for several other programs and across other disciplines.

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