Developing a New Course in Design, Construction, and Society

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Recent studies have indicated a ‘culture of disengagement’ in engineering students, with an over-focus on technical aspects, to the detriment of social implications. Furthermore, the Architecture, Engineering, and Construction (AEC) industry is experiencing a burst of technological transformations. Given the significant impact of the built environment on the population, it is important to address how changes in society and technology affect the AEC industry. By understanding the interactions between social and technological developments, professionals may be better prepared to avoid ineffective operations and unnecessary corrective interventions. In the fall of 2022, a new course in architectural design, construction technology, and society was introduced into a construction-related program in a large midwestern university. The course was required for students enrolled in the Design and Construction Integration major and minor and open to all other students with no prerequisites. Over 29 biweekly classes and book discussions, the lecturers utilized: (i) architectural history as a background to discuss the relationship between the changes in society and the architectural developments from the first industrial revolution to post-modernism and (ii) recent technological and societal changes to reflect on the foreseeable future challenges. The present paper describes our experience developing and deploying this course for the first time. We start by presenting the motivation behind this new course, the learning objectives, the schedule of topics, and assessments. Following, the instructors provide lessons learned from the course's first iteration. Finally, we conclude by making suggestions for improving future iterations of the course. These suggestions can also be relevant to others considering the inclusion of this type of content into their construction courses or programs.

Introduction

Previous research argued that engineering students have a 'culture of disengagement' about societal issues [1]. Furthermore, recent work on engineering and technology students' perceptions of using new technology suggests an over-focus on technical aspects within those programs, to the detriment of social implications [2].

Considering the societal impact of the built environment on the population, this lag seems unjustified and concerning. Furthermore, history has several examples that indicate the effect of poorly functioning construction and infrastructure on the deployment of unsatisfactory service levels, high operation and maintenance costs, and unjustified environmental impacts. Examples can be seen in the cases of the failure of the Pruitt-Igoe housing complex [3] and the constant vehicle congestion in large American cities, such as Los Angeles [4].

Moreover, radical technological transformations may affect the functioning of Architecture, Engineering, and Construction (AEC) in the near future [5]. Examples of disruptive technologies include the potential market outbreak of autonomous vehicles and the expansion of e-commerce and remote working options, both of which may radically transform the future needs for transport infrastructure, retail, and offices. Additionally, the uncertainty in the availability of resources, such as water and fossil fuel, can directly affect how we construct and use the built environment. Therefore, future professionals must critically understand how changes in society, the environment, and technology affect the AEC industry. This understanding would provide

them with the skills required to anticipate evolving needs and avoid building assets destined to provide ineffective operations or require unnecessary corrective interventions in the long term.

In this work, the hypothesis is made that this prominent topic can be addressed from two perspectives:

- By observing how changes and transformation in these exogenous factors have influenced the AEC industry in the past, i.e., the reductions in the availability of resources (i.e., true or perceived), the societal developments (e.g., the growth of needs and instances that did not exist before) and the technological advancements (e.g., the invention of the elevator or the air conditioning). Indeed, although the current magnitude and speed of these changes are unprecedented, these exogenous factors have – to a certain extent – always played a prominent role in driving innovation in the AEC industry.
- By reflecting on how the current socio-economical transformations could drive possible changes in the future needs for construction and infrastructure.

In line with this hypothesis, a new course in architectural design, construction technology, and society was developed for the first time to investigate the evolving relationship between societal needs, resource availability, and design solutions for the built environment. The present paper includes information related to the development of this new course, its schedule, and its major components. Both co-authors participated in the development and deployment of the first iteration of this course in the Fall of 2022. This paper will conclude with lessons learned for future course iterations and for other programs that would like to include similar courses or modules in their curriculum.

Course Context

In the fall of 2022, this new course in "architectural design, construction techniques, and society," or CM 33200, was introduced into a construction-related program at Purdue university. The course was open to all other university students with no prerequisites; it was required for junior-level students enrolled in the Design and Construction Integration (DCI) major and the DCI minor. Table 1 includes the formal course description and learning outcomes. This course aligns with the DCI major by fulfilling the following program-level student learning outcome: "Understand the sociological, environmental, and cultural implications of the construction industry."

Table 1. CM 33200 course description and learning outcomes

Course Description	Learning Outcomes
A course in which students will be exposed to the evolution of architecture and building techniques that influenced the Western-built environment. Emphasis will be given to the use of appropriate vocabulary and also how social and cultural factors have influenced the design of the built	1. Recognize architectural and technical traditions of the Western cultures; 2. Identify relationships between cultural patterns and social responsibilities of designers; 3. Recognize ways that history or related arts, humanities, and technologies influence the built environment;

environment throughout the centuries. The course will survey topics from the XVII century to recent times.	4. Use appropriate architectural and technical vocabulary.

The instructors consider aligning the course with the universities' core curriculum in the future, fulfilling its humanities course requirement. This core curriculum covers a set of eight pre-specified outcomes and provides consistency for the general education of undergraduate programs at Purdue university. Furthermore, the course aligns with the requirements of common construction-related accreditation bodies, such as the American Council for Construction Education (ACCE) [6] and the Accreditation Board for Engineering and Technology (ABET) [7], by providing discussions related to ethics and risk management.

The course is a lecture-based, 3-credit hour course. Two one-hour and fifteen-minute lectures per week were scheduled for the course for the Fall 2022 semester. Through over 29 biweekly classes and book discussions, the instructors utilized: (i) architectural history as a background to discuss the relationship between the changes in society and the architectural developments from the first industrial revolution to post-modernism and (ii) recent technological and societal changes to reflect on the foreseeable future challenges. The authors of the present paper, both of who also have architectural backgrounds and current research on technology in construction, taught the first iteration of the course. The following section will provide more details on course development.

Course Development and Schedule

In addition to discussing historical aspects of society, the course guides students to reflect upon how these aspects influence the future of the built environment. Therefore, the course was structured as six modules in a sequential approach: (1) introduction, (2) first and second industrial revolutions, (3) arts and crafts movement, (4) modern architecture, (5) post-modernism, and (6) present and future implications. The goal of each module is described below:

- Introduction: three lectures are included in this module. The first lecture, taught by both course instructors, covers the basic of the course and introduces students to the relationships between society, technological advances, and built environment design. Following, a lecture about the design brief is given. This lecture focuses on helping students to understand how design solutions closely relate to clients' needs and available resources. Then, this correlation between needs, resources, and design solutions is further analyzed in the third lecture through a lesson on the socio-economic causes of the rise of the gothic style in Northern Europe. In this last lecture, the work of Roland Bechmann [8] is used to investigate the relationship between population dynamics, the availability of resources (wood and stones in particular), and the advancement in construction techniques (e.g., glass production) in France in the XXIII century, and the rise and rapid spread of the Gothic style in place of the Romanesque.
- First and second industrial revolutions: four lectures occupy this module. The first lecture covers societal changes in the 1800s, focusing mainly on the mechanization of labor, the unregulated growth of cities, the poor living conditions of workers, mass uprisings, and changes to the urban fabric (such as urban interventions and the emergence of suburbs). A second lecture then discusses explicitly the technical

innovations of the time and how they have affected the construction of the built environment. Particular focus is given to iron, steel, glass, and concrete. A third lecture discusses how the neo-classical architectural movement has emerged as a response to societal changes. The final class of the module presents a case study about how events leading up to the creation of the Victorian sewer system in London, including ethical discussions about the unsanitary conditions of large cities and the establishment of a public sanitation company. This module then culminates in presenting the efforts to update the current sewer systems in London through the Thames Tideway Tunnel [9].

- Arts and crafts movement: Like the second module, four lectures occupy this module. The first discusses societal events, including how prominent figures of the time evaluated the division of labor and the mechanization of work. In the same class, John Morris's utopian views on the emergence of the garden city English movement are presented along with discussions around the creation of work guilds by English artisans. Following, a lecture on construction technologies is included, with a particular emphasis on the high-rise. In this class, we discuss the influence of the Arts and Crafts movement in the work of Adler and Sullivan in Chicago and how Adler and Sullivan's work influenced the development of the aesthetic of the international style. In the following lecture, we present the work of Frank Lloyd Wright. We highlight the differences between early and late Frank Lloyd Wright's work and the influence of non-western architecture, including his utopian views and the role of technical developments in the future of society. Finally, the module concludes with a presentation on Art Nouveau and the rising architectural movements of four European countries, including Spain, France, Belgium, and the Netherlands. Again, the discussion includes current societal contexts, such as how Madrid's influence over Barcelona may have influenced the development of Antoine Gaudi's unique architectural style. Additionally, the last lecture discusses the completion of La Sagrada Familia and how technological advances are used in its construction.
- Modern architecture: six lectures were dedicated to the modern movement. The first lecture discussed the German work guild (Deutsche Werkbund) and its influence on the creation of the Bauhaus. The instructors also highlight how the pedagogy used in Bauhaus has influenced how we teach built-environment disciplines. Following, a lecture on prefabrication techniques is included. Ethical concerns about elevated housing costs and the ability for user customization are also considered when presenting prefabrication for housing in the United States and Europe from the early 1900s to recent years. Following, two lectures cover the architectural career and work of two modernist architects, namely Mies van der Rohe and Le Corbusier. We discuss how major societal events have contributed to their work, such as World Wars, and technical advances, such as concrete and steel. The fifth lecture on modernism discusses how it influenced urban planning and the organization of contemporary cities. During the class, we discuss the motivations and issues behind the segregation of land uses and their effect on land prices. In this lecture, the instructor also outlines how the popularization of private automobiles allowed for the widespread use of this type of design, especially in American cities.
- Additionally, three case studies on the application of modern movement urban planning are presented: the Biljmermeer complex in the Netherlands, Pruitt Igoe in the United

States, and Brasilia in Brazil. Finally, the last lecture discusses how countries have used the built environment to display their power. The class ends with a reflection on how the rise of radio and television has affected the relationship between the built environment and the state.

- Post-modernism: this module only contains three lectures. The first lecture provides an overview of post-modern tendencies after the 1960s. These tendencies included: rationalism, structuralism, productivism, and neo-avant-garde, as classified by the work of Frampton [10]. American, European, and Japanese architects' work is presented, expanding the class topics beyond the Western world. During the presentation about each post-modern tendency, we discuss the evolving role of architecture and architects and users in the design and production of the built environment. The second lecture examines the work of Robert Venturi and Denise Scott Brown and revisits the role of architecture and its ability to dialogue with end users. This lecture culminates in a hands-on exercise during which students are asked to recreate an American landmark (choosing from the White House, an airport terminal, the high-rise office building, or an apartment complex) through the lenses of one of the post-modernist tendencies. The instructors provided printed materials (such as printed visuals of architectural elements), tape, markers, and foil for students to utilize to represent their creations visually. Finally, the last lecture of the post-modernism movement included a presentation on post-modern urban design and the work of Jane Jacobs in questioning the premises of land use segregation. Again, the students are prompted to rethink the role of the end-users in the decisions about the built environment.
- Present and future implications: this portion of the class includes five lectures. The first is a panel organized with three faculty or staff members at Purdue university with professional or academic experience in land regulation, real estate development, and homebuilding. For this panel, students were asked to provide questions and read two texts discussing the lack of starter homes and the current building aesthetics in the United States. The panel was named "American Housing Crisis" and debated the causes, consequences, and potential solutions to this issue. The following classes included a lecture on the relation between agreed required services (i.e., the needs expressed in the design brief) and future uncertainty, a lecture on flexibility in design to cope with future uncertainty on needs (as from [11]), a lecture on the real options method to identify and evaluate the required investments on flexibility (as from [12] and [13]), and the last one in which some example of future-roof design are presented (such as these provided in [14]).

The lectures are mainly presented through power points, and students are often asked to stop and reflect on the relationships between culture, technology, and architectural or engineering design. The lectures draw information mainly from the course's textbook, Modern Architecture: A Critical History [10], combined with additional electronic resources, including a few podcasts from 99percentinvisible within the modernist and post-modernist movements [15, 16, 17, 18]. In addition, pre-class readings were assigned to students so that the content could be discussed during the scheduled meeting times.

Course Assessments

The instructors debated including the attendance or participation points as part of the course assessment but ultimately decided to leave them out. There were four major assessment components in the course:

- Quizzes – a total of 200 points (50 points each)
- Book Discussions – a total of 200 points (50 points each)
- Exam – a total of 200 points (120 points for closed-ended questions; 80 points for open-ended questions)
- Semester Paper – a total of 400 points divided in:
    - Topic selection: 20 points
    - Paper outline: 60 points
    - Paper draft (past): 120 points
    - Final paper: 200 points

Quizzes were given at the end of each historical module (modules 2, 3, 4, and 5). These were 'open-book,' individual online quizzes timed to one hour with a closed-end (true or false, multiple choice or matching) and open-ended questions. After the first module assessment, the instructor added a quiz so that students could utilize their best four of five quiz scores. The additional examination was added within the modern architecture module because this was the module with the highest number of lectures. As the semester progressed, the open-ended quiz questions were changed to either (a) short-open-ended questions or (b) more structured open-ended questions, in which students were provided discussion points required to be covered in their answers.

Book discussions. Four book discussions were included in the course calendar: 1 in week 4, one in week 8, one in week 10, and one in week 13, to discuss the socio-economic drivers of the development of the city of Chicago. To that end, the text of Marco d'Eramo [19] was used as a base. For the book discussions, the students were grouped into four teams. During the 75 minutes of the classes, these groups had to prepare and present the answer to a question. Therefore, during the lecture time, approximately 20 minutes were reserved to prepare the response, i.e., to discuss within the team the question and prepare a response based on the readings of the week. Following, each of the four grous had 12 minutes to deliver their response, i.e., to present the response previously elaborated by the team, including 4 minutes for Q&A. The first book discussion covered chapters 1 and 2 of the book, focusing on the influence of geography and the railway expansion on the growth of Chicago. Chapter 3 of the book provided topics for the second book discussion, which examined the meat processing industry's role in the city's development. The third discussion focused on chapters 4 and 5 and addressed the socio-economic factors influencing the invention of the skyscraper and the stock market "futures" in Chicago. The fourth and last elaborated on chapters 6 and 7, which analyzed the invention of balloon-frame houses and their role in ensuring a wide residential coverage to Chicago during its expansion.

A cumulative online exam was given during the week of Thanksgiving, but students could take the exam starting as early as the Thursday before Thanksgiving. The content of the exam included all lectures, readings, and book discussions up to the date of the exam. In addition, the

exam was divided into two online quizzes – one with all the closed-ended questions that could be automatically graded at the end of students' attempts and one with open-ended questions that instructors manually graded. Students were provided a second attempt at the automatically graded quiz during the exam period if they wished.

Finally, a semester paper was given to students. This project was individual, and four deliverables composed their final grade for the paper. This breakdown was done to not overwhelm students, given that the class had no prerequisites and should accommodate all undergraduate levels. Figure 1 visually presents the progression through the four deliverables of the paper. Both instructors provided students with feedback on each deliverable. Furthermore, the final paper deliverable included points for addressing input provided for the third deliverable (paper draft). The goal of the final paper was for students to individually explore a topic of their interest and analyze how society, technological changes, and architectural (or engineering) design have contributed to it.

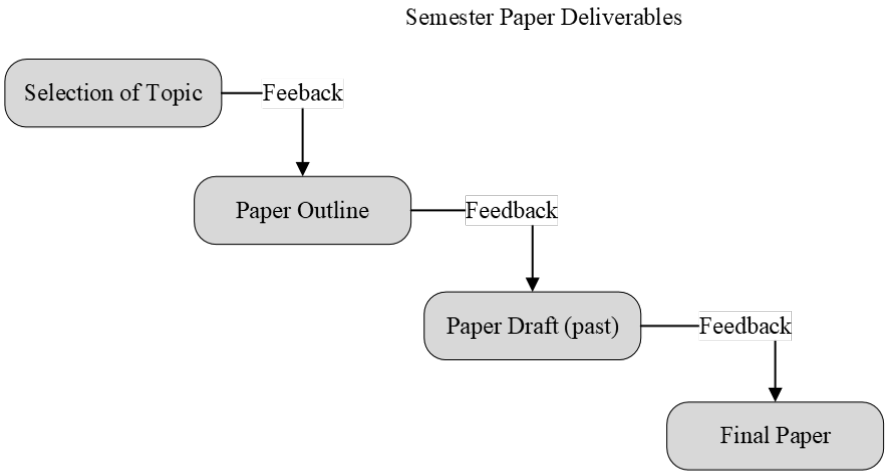

Figure 1. Organization of semester paper deliverables

The assessments provided allowed instructors to evaluate students' performance in learning the course objectives outlined in Table 1. And, except for the exam, course assessments were spread out throughout the semester. Figure 1 provides a visual framework of how the learning outcomes, teaching modules, and assessments were related.

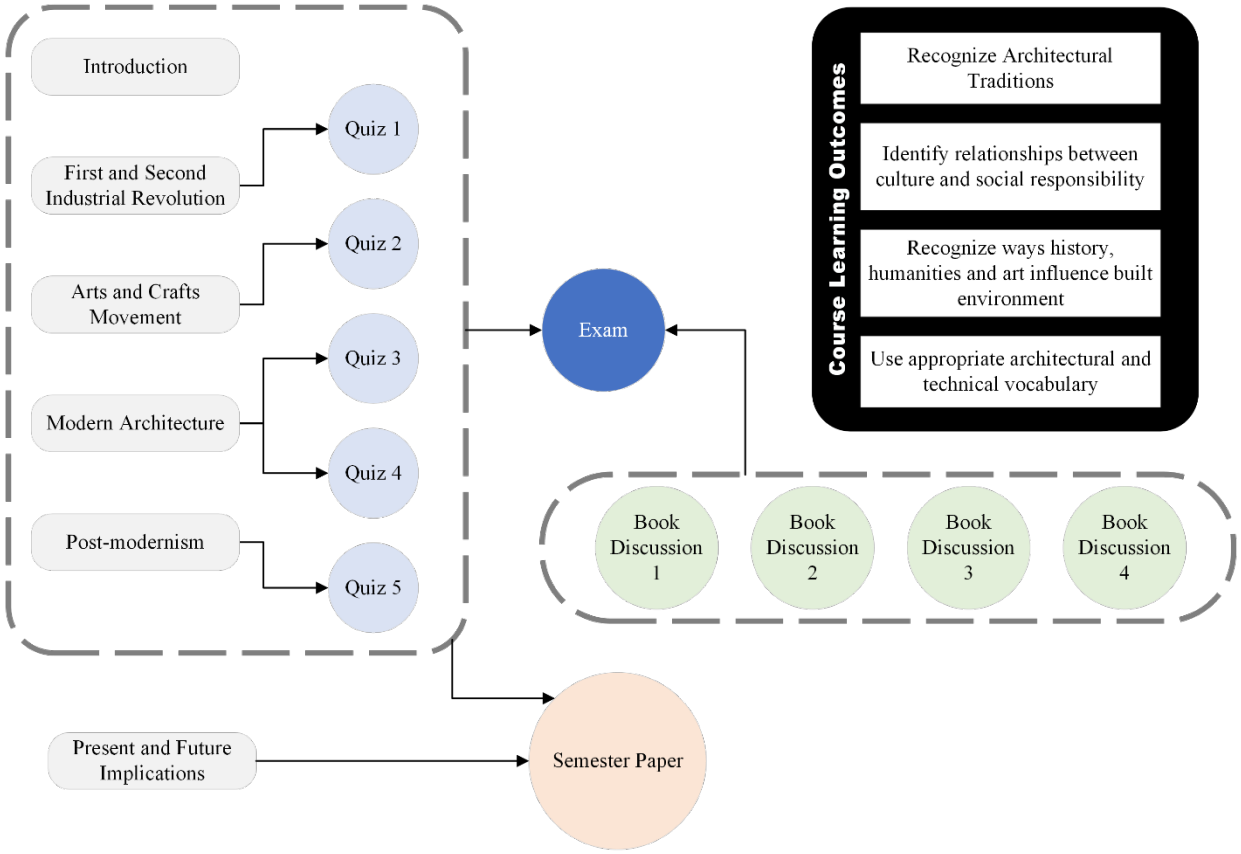

Figure 2. Organization of semester paper deliverables

Lessons Learned

A debrief session with both instructors was conducted approximately one month after the course ended. Based on that meeting, the co-authors agreed on three major lessons learned:

- Scaffolding students to effectively respond to more complex questions and discussions;
- Maintain class engagement by strengthening the connections of past, present, and future;
- Improve the focus of the semester-long project;

Scaffolding students toward more complex questions and discussions.

As the semester progressed, the instructors noted that students needed more scaffolding in providing more complex answers in the quizzes, exams, and book discussions. For example, the original intent for the quizzes was to have them with primarily open-ended questions to allow students to elaborate on more complex relationships in their answers. However, we have recognized that students in a more technical field, such as construction, needed help with the idea of open-ended exams. Therefore, the instructors decided to have a balance of closed-ended questions (such as matching, multiple-choice, or fill-in-the-blank) and open-ended questions in the quizzes and later on in the exam. Furthermore, after the first quiz, the instructors decided to add a quiz in the longest course module (modern architecture) to provide students with the

possibility of dropping their lowest quiz grade. Therefore, the final quiz score only considered students' best four quiz scores out of five. In addition to this, the instructor responsible mainly for the past-based lectures added a lecture review at the end of every class, during which she discussed two potential open-ended quizzes or exam questions. This review helped students model expectations of articulating more complex answers.

The elaboration of open-ended questions is complex but, in general, is well-suited for showing complex thinking. However, they also have setbacks, such as confusing students when they are not well-stated, demotivating or stressing students who think they may be unable to answer the question, and increasing instructors' workloads [20, 21]. Yet, given the primary goal of the class of connecting design, technology, and society, open-ended questions still seem to be adequate for the intent. However, it is clear that students need more scaffolding and modeling of examples to provide the depth of knowledge expected, which is also a challenge when the course has students from first-year students to seniors.

Maintain class engagement by strengthening the connections of past, present, and future.

Another issue we noted as the semester progressed was that students sometimes struggled to understand the connection between their learning and their future careers. This difficulty might be because most of the present- and future-related content was only addressed at the end of the semester. And, even though in most classes the instructor related some of the historical content to present design, technology, or societal challenges, it was less direct than the last module of the course. Furthermore, despite present and future only being the focus of the last two weeks of the semester, half of the semester project focused on contemporary issues. The present and future topics were also excluded from the exam.

Even though the logical progression from past to present and future seemed logical, more emphasis on applying the content to practical concerns could be added, given that the course is taught within the Purdue Polytechnic Institute, an applied college within Purdue University. Furthermore, after the course debrief, both authors concur that having the content about the future earlier in the semester would be a better fit. This change would highlight the importance of the topic to students and connect a topic that might seem distant to them with their future careers in the technical construction field.

Improve the focus of the semester-long project.

Finally, the instructors realized at the end of the semester that having the students discuss the evolution of the relationships between technology, society, and design might have been ambitious at the undergraduate level. There were some good elements in the project, especially the breaking down of the project into partial and progressive deliverables and the ability of students to choose an area of focus. However, the requirement for students to evaluate a topic over time, meaning exploring the connections between society, technology, and design in the past and the future, was too complex. Therefore, we suggest improving the project's focus by selecting one period of time to discuss the relationship between society, technology, and design. Furthermore, as the semester progressed, we realized that students could benefit from more scaffolding about paper formatting and referencing styles. Reducing the focus of the semester paper to one period in time will allow instructors to improve scaffolding paper writing skills and help students identify the necessary connections between society, technology, and design.

Future Recommendations

Finally, the instructors are already considering some changes to address the lessons learned mentioned above for the course's second iteration. Therefore, these are our main recommendations for moving forward:

- Improve students' scaffolding into complex thinking by modeling our expectations in book discussions and open-ended questions. For example, for the book discussion, this could mean providing an example to students on articulating answers and requiring team members to coordinate amongst themselves to avoid overlaps during the presentations. In the quizzes and exams, the instructor could embed example questions during the lecture and ask students to provide input to the answers and then conclude by showing verbally to students what a 'complete' answer to that question could look like. Moreover, we could add low-stakes assessments in every class, such as a one-question in-class assignment. This type of assessment could inform the instructors on how students are performing and make students more comfortable with the kinds of questions they would find in quizzes and exams in this class.
- Revise the course schedule to move the block on future changes in society, technology, and architecture to earlier in the course. This change would allow students to better related the content to their future careers.
- Revise the scope of the semester-long project. This suggestion relates to having semester-long papers focus on discussing the relationships between the three elements of the
- class (society, technology, and design) in one given time in history. The change could yield having more than one project in the semester or including some of the present and future content in quizzes and exams. Furthermore, additional scaffolding to address course expectations related to the project, such as utilizing proper formatting and referencing systems, could be added as online modules, therefore not consuming in-class time.

The first iteration was helpful to also align instructors' expectations in terms of content and complexity. Although we have not gathered student feedback in this first iteration, our contributions are important because of the uniqueness of the course proposed. Furthermore, our challenges and lessons learned can be helpful to hers that are considering similar courses within their programs or departments.

For future studies, we plan on capturing more empirical data, including students' reflections and feedback, to assess growth from the beginning to the end of the semester. Finally, as more students join the class, we look forward to being able to interview students after their course experience to understand how this class changed (or not) the way they view the relationship between the AEC industry and society.

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