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Future World Vision Integrated into a First-Year Civil Engineering Course

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Abstract

Civil engineering (CE) has faced stagnant or declining enrollments in recent years, in contrast to majors such as mechanical engineering that have been increasing. This may be partially due to students not perceiving civil engineering as exciting. ASCE's Future World Vision project (FWV) may provide a way to spark student interest in civil engineering. This paper explores the reception of first-year students enrolled in an introductory CE course to FWV. In 2022 FWV was integrated at multiple points during the semester by making small modifications in the topics and assignments that were already part of the course. The FWV video was shown on the first day of class. On the first significant homework assignment of the semester, students were given a choice of learning about civil engineering by selecting two of four readings or websites; among the four options, FWV was the most popular, selected by 59% of the students. Additional integration of FWV occurred in homework 3 about the design process (the Floating City was the most popular scenario), homework 8 on data science, and homework 9 on creativity and innovation (again, as an option among multiple choices). The final culminating essay assignment included a prompt that mentioned FWV, although students were not required to discuss FWV. There were 32% of the students that discussed FWV as something that inspired them about civil engineering, and another 23% discussed FWV more generally. The results indicate that FWV may be effective in stimulating student interest in civil engineering, and can be integrated in simple ways that do not require major changes within a course.

Introduction

Civil engineers play an indispensable role in providing the infrastructure that enables society and communities to be healthy, efficient, and thriving. To fulfill this responsibility, civil engineers must be trained to be leaders with an array of socio-technical skills, knowledge, and attitudes. Further, there must be a sufficient number of trained engineers to meet societal needs. The president of the American Society of Civil Engineers (ASCE), Dennis D. Truax, recently called attention to "a workforce shortage that's going to be exacerbated in the near future" and noted that the ASCE's Future World Vision (FWV) project could contribute to workforce development [1]. This paper begins by framing enrollment and student interest challenges in civil engineering. This is followed by a brief overview of FWV and describing small changes that were made in a first-year introduction to civil engineering course to integrate FWV. In two assignments the expectation was that students would consider FWV elements, and in two other assignments FWV was provided as an option to other resources. The goal was to use FWV to spark student interest in civil engineering. Evidence as to whether or not this was successful, and if there were demographic differences in student interest in FWV are provided.

Background

Enrollment

The enrollment trends in civil engineering in the U.S. give cause for concern. For example, the American Society for Engineering Education (ASEE) "by the numbers" data show that Bachelor's degrees awarded in civil plus civil/environmental engineering have declined from 15.5% of all engineering degrees in 2010-2011 to ~10% in 2017-2021 [2]-[12]. This represented a declining number of degrees from 2013 to 2016 (13,417 to 12,404), then increasing numbers to 2020 (15,052). Further, ASEE [3] reported the year-to-year median percent change in freshman enrollment for civil or environmental engineering of -3.0 and -3.6 in 2019 and 2020, respectively (among 167 institutions). In contrast, the number of mechanical engineering degrees has increased steadily from 19,241 to 35,120 in 2011 to 2020, comprising around 23 to 24% of all engineering Bachelor's degrees. These trends are shown in Figure 1.

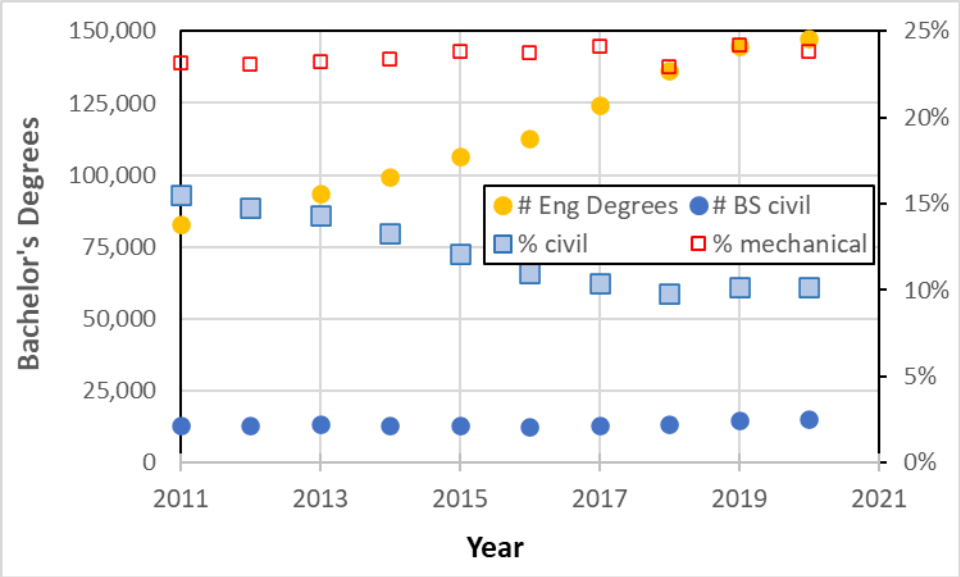

Figure 1. Number of engineering and civil engineering Bachelor's degrees in the U.S. over time; percentage of Bachelor's degrees awarded to civil and mechanical engineering (ASEE *By the Numbers* [2]-[12])

There has been some discussion as to whether the stagnant enrollment in civil engineering compared to other disciplines (e.g., mechanical) is due to civil engineering not seeming exciting to students. For example, in 2022 there was a discussion thread on the ASCE Collaborate site [13] asking "does civil engineering need to be made more zoomy and how". The discussion on Collaborate primarily revolved around issues of intrinsic (i.e., personal interest) and extrinsic motivations (e.g., salary). It is unclear whether or not those perceptions are accurate.

Why Students Select Majors

Few studies have looked specifically at why students did or did not elect to major in civil engineering. A survey in 2013 asked engineering students currently majoring in civil, environmental, or mechanical engineering what factors led them to choose their current major [14]. Among 601 open responses, the most commonly cited factors for civil engineering students (n=172) were impact on society (28%), math and science enjoyment and/or proficiency (26%),

and interest in building things (14%). This was significantly different among environmental engineers (41% help the environment, 30% impact on society, 20% math and science) and mechanical engineers (26% math and science, 23% build things, 16% broad field). Among the small sample of first-year students in the study, having a family member who was an engineer was among the top three reasons (18% civil engineering, 17% mechanical engineering). Meyers and Mertz [15] found that first-year engineering students discussed similar reasons for pursing engineering, with the most prevalent being math/science (61.3%), problem solving (36.8%), and a better world (32.5%). Differences were found by major. For example, the highest percentage of mechanical students cited innovative/creative (44.4%) compared to the lowest percentage in civil engineering (5.6%). These perception differences might be influential in the differences in enrollment trends between civil and mechanical engineering, despite similar fundamental courses and topics in both disciplines (e.g., math, physics, statics, fluid mechanics, strength of materials).

Other studies have found differences among engineering majors, but did not include civil engineering. For example, Benson et al. [16] identified differences in the motivational factors for Biomedical versus Mechanical engineering majors, such as more agreement that 'I like to design and build things' among mechanical engineering majors and more 'opportunities to benefit society' among biomedical engineering majors.

Some studies have been conducted among engineering students in general that do not distinguish between majors. Sundley and Galway [17] looked at decisions to pursue an engineering degree among 151 undergraduate engineering students. "Respondent decisions were mainly influenced by personal factors (e.g., aptitude, personal desire to work in the field), earnings potential, social value/status of engineering as an occupation, academic focus/success in STEM subjects, parental pressure to be academically competitive, and parental advice/encouragement." Cruz and Kellam [18] discussed a "call to adventure for engineering students" that rests on "whatever might have sparked students' initial interest in the engineering profession." For example, 10 of the 21 students interviewed expressed a desire for a job that allowed for creativity and production of tangible, useful work. In students' pathways to persistence or leaving, feeling belonging / isolation were important (n=11) and some students thought of engineering as fun (n=8). These results provide ideas about activities in a first-year course that might be impactful, such as teamwork to build belonging providing benefits, while focusing on weighty topics such as ethics might be viewed as detracting from fun and/or creativity.

More broadly, the American Freshman study [19] found that among 95,505 first-time, full-time freshmen in fall 2019 attending U.S. universities (all majors) the most commonly cited "very important" reasons in deciding to go to college were being able to get a better job (83.5%) and to learn about things that interest me (83.4%). In addition, the objectives most commonly considered essential or very important were being very well off financially (84.3%) and helping others who are in difficulty (80.0%). Akosah Twumasi et al. [20] explored factors impactful in youth career decision making, which included extrinsic factors (financial remuneration, professional prestige, job accessibility, and job security), intrinsic factors (personal interests, self-efficacy, outcome expectations, professional development opportunities), and interpersonal factors (influence of family members, teacher and educators, peers; social responsibility). The relative importance of many of these factors was found to vary between individualistic and collectivist cultures.

Factors relevant for selecting majors and interest in different engineering majors has been found to differ among demographic groups. For example, while an affinity or belief in one's ability in math and science was cited most frequently among their reasons for selecting their engineering major among both male and female students (26%), a higher percentage of female versus male students described a desire to positively impact society (26% vs. 16%) [21]. Across U.S. first-year college students in general in 2019 [19], 6.4% more female than male students indicated that learning more about things that interest me was a very important reason in deciding to go to college, while 2.6% fewer female versus male students cited "to be able to make more money".

As the demographics of high school graduates change [22], it is also of growing importance to consider the interests of racial/ethnic groups historically underrepresented in engineering, in particular Hispanic / Latinx students. Among open-ended responses to the question 'what factors led you to choose your current major', helping society, people, the world was among the reasons described by 17.9% of Hispanic/Latinx engineering students (n=319) compared to 15.7% of non-Hispanic white engineering students (n=1442), not a statistically significant difference [23]. Significantly, fewer Hispanic/Latinx engineering students described enjoyment or aptitude for math in their response (19.1%) compared to non-Hispanic White engineering students (29.1%) [23]. Thus there may be different factors that are motivating and are worth highlighting about civil engineering to attract and retain different groups of students.

(Mis)Information

While the literature points to a variety of aspects of civil engineering that can be emphasized to help attract and retain students, it is important to consider that students can choose among an array of engineering majors with similar attributes. Further, misinformation might contribute to student selection or non-selection of civil engineering. In the study by Cruz and Kellam [18] misinformation about engineering was cited by 5 of 21 students interviewed. Specific types of (mis)information available online might spur a student to choose mechanical over civil engineering. For example, one website exploring differences between mechanical and civil engineering [24] stated that key skills for mechanical included teamwork, creativity, and reasoning versus for civil engineering they listed decision-making, leadership, and communication. Other traits noted were [24]:

> Mechanical engineers use creative skills to construct complex designs, whereas civil engineers usually follow a clear and accepted path for working on projects. Mechanical engineers have less regulation over their designs. Mechanical engineers have the ability to expand their knowledge and expertise throughout their careers. They can more easily transfer their skills into other engineering branches than civil engineers.

The statement about creativity being higher in mechanical versus civil engineering mirrors the first-year student findings from Meyers and Mertz [15].

Another website [25] summarized differences in mechanical versus civil engineering as:

> Mechanical engineering offers better scope than civil engineering… In case you are looking to learn hard and want to have better future benefits, you can opt for Mechanical Engineering. …are after more prestigious jobs by choosing mechanical engineering. …mechanical engineering is an older engineering stream. Mech Eng: higher pay….

Many civil engineers would dispute these statements. Some of these attributes will be more important to some students than others; results from *The American Freshman* survey [19]

indicate that the salary information will likely be more salient to male than female students, for example.

A YouTube video comparing the majors [26] indicated that civil engineers focus on knowledge in physics and math versus physics, math, design, and programming for mechanical engineers. They stated that the courses in civil engineering have a heavy structural focus, which neglects water resources, environmental, and other areas of civil engineering. In addition, prestige was stated as being associated with mechanical engineering, where graduates could get a job at 'big name' companies.

Thus two sources [25], [26] indicate higher prestige associated with mechanical than civil engineering. Prestige was previously found as a motivator for career selection in the study by Akosah Twumasi et al. [20] The idea of prestige is also relevant to how students learned to draw boundaries between "high-status" and "ordinary" jobs [27]. Practices within engineering such as limited enrollment programs [28], higher GPA for admission [29], or higher pre-requisite grade requirements [30] may contribute to students' judgements of the relative prestige of civil engineering compared to other engineering majors.

In summary, depending on where prospective students get their information about civil and mechanical engineering, misperceptions might be an impediment to recruiting students to civil engineering. Differences in perceived creativity and prestige might be significant.

Future World Vision

At its core, Future World Vision (FWV) is centered around creating immersive, interactive digital environments that predict what cities might be like in 2070 [31], [32], [33]. ASCE began its FWV initiative in 2018. FWV was grounded in science and technology, and thinking ahead to what might be possible for engineered infrastructure. Research identified six key trends that will be important drivers of civil infrastructure: alternative energy, autonomous vehicles, climate change, smart cities, high-tech construction, and policy and funding. These trends will be encompassed within five different future worlds: Mega City, Floating City, Rural City, Frozen City, and Off-Planet City. FWV was unveiled at the 2019 ASCE Convention, with a specific focus on the Floating City. Some high quality videos highlighting the initiative were released. The FWV desktop app of the Mega City 2070 was released in February 2022.

In discussing the audience for FWV, David Odeh [34] stated, "We're especially interested in reaching young people who might be thinking about a career in civil engineering and getting them excited about how our profession can lead the way to face all these emerging challenges." Similarly, John W. van de Lindt, a professor of Civil and Environmental Engineering at Colorado State University, stated, "As a recruiting tool, it will definitely have an impact on the overall profession by getting some of the best and brightest into civil engineering" [35]. However, there is a dearth of publications discussing the application of FWV in civil engineering education. Hall [36] briefly mentioned FWV twice in his paper about the future of civil engineering. ASCE hosted an online webinar to discuss integrating FWV into courses [37]. This paper gives an example of the integration of FWV into a first-year course.

Research Questions

This paper explores the following research questions. Among students enrolled in a course with a goal to introduce incoming first-year engineering students to civil engineering:

1) Is there evidence that FWV sparks the interest of first-year engineering students in civil engineering?
2) Are there differences among students from different demographic groups (female versus male; underrepresented minority, URM) in their interest in FWV?

First-Year Introductory Course

At the University of Colorado Boulder (CU), a 1-credit *Introduction to Civil Engineering* course is offered in the fall semester for entering first-year (FY) students. The course is required for student majoring in civil engineering, but also open to students in other majors. In particular, at CU students can enter the College of Engineering directly into specific majors or into an 'open option' for those who have not yet decided on a major.

The stated learning goals for the course, as articulated to students on the syllabus, have been consistent from 2019 to 2022:

1. describe what civil engineering is, what you may do as a civil engineer, the skills required to be a civil engineer, and similarities and differences compared to other engineering majors
2. describe the process to gain the skills required to be a civil engineer and successfully graduate with a degree in civil engineering from CU
3. describe the ethical behavior expected of civil engineers
4. define sustainability and describe its importance to civil engineering
5. explain the importance of professional licensure (PE) for civil engineers

The course also has additional aims:

- Help students transition to college. The course includes announcements about tutoring, extracurricular activities, encourages students to attend career fairs, etc. Starting in 2020 (during COVID as required of a 'CU101 course') the course added explicit information on student mental health and resiliency.
- Help students make an informed choice of major.
- Help students become more interested and motivated toward CE, which may help them weather the decontextualized and sometimes difficult and frustrating courses in the early curriculum (e.g., calculus, chemistry).
- Help retain students in civil engineering by providing a supportive environment where they meet other civil engineering students.

The course meets once per week for 50-minutes. Typical weekly homework assignments are intended to take students 1 to 2 hours outside of class to complete. They generally require students to complete a reading on a selected topic and then answer a series of questions.

The course is designed to engage student motivation, grounded in Expectancy Value Theory (EVT) and Self Determination Theory. Within EVT the elements that pertain to motivation are expectancy of success (usually interpreted as self-efficacy or self-confidence) and values (including intrinsic and utility) [38], [39], [40]. For engineering students, their choice of major

might be viewed through an EVT lens as confidence that they can successfully earn an engineering degree, their intrinsic interest, and utility elements such as the ability to acquire a stable and lucrative job.

Self determination theory posits that individuals will be more motivated to learn when their psychological needs of autonomy, competence, and relatedness are fostered [41]. Of particular focus in the design of the first-year course were elements of autonomy. The ways in which students can exercise choice in the course and feel that their choices matter is one embodiment of autonomy. Within courses, giving students control and choice have been found to be motivating [42], [43], [44]. At a curriculum level, engineering students often have less choice and freedom in the courses they can take to earn a Bachelor's degree as compared to students in other majors [45]. Thus, choice may be novel in engineering and therefore particularly meaningful.

Given the breadth of civil engineering and the different motivations and background that entering first year students bring to the course, the instructor chose to integrate opportunities for students to exercise choice within the course. This came in two forms: choice of topics within assignments and choice of submission format on three assignments. Some topic choices allow a student to focus on a sub-discipline of interest within civil engineering, such as the final three assignments related to professional society opportunities, internships, and undergraduate research. The submission options also align with tenets of Universal Design for Learning [46], allowing students to demonstrate their knowledge in preferred ways. The three options were a short self-recorded video, such as from a phone; meet in-person or over zoom to discuss with instructor; or a standard write-up. Giving options to the traditional assignment that requires submitting a written response may be helpful for students who struggle with grammar, which sometimes includes international students, for example.

In this educational intervention, FWV was added as an option on two assignments. It was of interest if students would elect to explore FWV or select the other alternatives. The choices that students make can reveal their interests. For example, rational choice theory indicates that choices are based on a cost : benefit analysis of alternatives [47], [48]. So choices may reflect perceived costs like requiring more time or difficulty, rather than intrinsic interest in the topic. However, students' choices can also reflect other factors such as primacy bias, which results in preferential selection of options listed first [49], [50].

For local context, over the past ten years the overall number of undergraduate students majoring in civil engineering at CU has declined from a high of 294 in 2012, making up 8.8% of undergraduates in the College of Engineering, to a low of 219 in 2022, making up only 3.8% of the undergraduates in the College of Engineering [51]. Historically, civil engineering was a strongly gaining major (in 2012, 4.3% of the first-year students declared a major in civil engineering compared to overall enrollment in the college of 8.8%). The number of first-year engineering students starting undeclared at CU ranged from a high of 21.9% in 2012 (n=164) to 10.8% in 2022 (n=96). This open option represents a local pool of students from which CE can recruit. The enrollment in this FY CE course was: 58 in 2018, 59 in 2020, 33 in 2021, and 57 in 2022.

It should also be noted that in 2020 the course was unusual since it was taught fully online for the first time, due to COVID.

FWV integration in FY Course

The integration of FWV into the FY course in 2020 to 2022 is summarized in Table 1. In 2020 and 2021 there was only a small incorporation of FWV and in 2022 FWV was integrated at multiple points during the semester. In all 3 years, a FWV video was shown on the first or second day of class.

Table 1. Topic outline and comparison of FWV integration

Week	Topic / Goal	2019	2020	2021	2022
1 or 2	Scope of CE Spark interest in CE	N/A	FWV video	FWV video	FWV video
2	Homework: understanding of CE	N/A	1 of 2 options	1 of 2 options	1 of 4 options, select 2
3	Homework: CE design process	N/A	N/A	N/A	Required to select scenario
8	Homework: Data science	--	--	--	Required scenario
7-9	Homework: Creativity	N/A	N/A	N/A	Option
15	Reflective essay	N/A	N/A	N/A	Mentioned

N/A = FWV not integrated into assignment; -- = topic not integrated into the course

Overview of Civil Engineering Homework

In 2020 and 2021 on the first significant homework assignment of the semester, students were given a choice of learning about civil engineering via either readings or the Future World Vision website and videos (see Table 2). In 2020 and 2021 a small percentage of the students chose the FWV option (28% in 2020, 20% in 2021). The low FWV selection may have been largely due to the framing of the options, which directed students to the traditional readings based on their self-rated level of knowledge, the primacy in order of the choice, and the higher 'cost' to answer four questions for the FWV option versus two questions for the traditional choice. However, there were a number of students who had family members who were civil engineers and/or reported taking civil engineering focused courses in high school and perhaps welcomed the opportunity to 'stretch' their learning. The FWV option of gleaning information from the website may have been more appealing than a reading (since the web is a familiar way students gain information) or less appealing (less clear and defined, seems less 'official' versus a book chapter). Among those who explored FWV, the Floating City scenario was the most popular in 2020 (80% of the students) and the Mega City in 2021 (67%). This mirrors the focus of the materials available on the ASCE website itself, which changed over this time. The initial 2019 launch focused on the Floating City, and by 2021 they were gearing up for the release of the interactive app for the Mega City.

The assignment was reframed in 2022 to be more encouraging toward the selection of FWV, as shown in Table 2. Students were asked to select two of four resources, and for all four resources answer the same two questions. FWV was listed second (in case students with primacy bias just selected the first two options). Among the three readings, the book chapter would be the longest, followed by the Vision document, and finally the Grind Challenges (only 3 pages and a 3-min video). The FWV option is the least "defined". It is also worth noting that the information in the book chapter (2012) and ASCE Vision document (2007) were beginning to feel outdated. FWV

was selected by the most students (59%). Most of these students referred specifically to the Mega City (n=22) with far fewer describing ideas related to the Floating City (n=4), Off-Planet City (n=3), Frozen and Rural cities (n=2 each). One student briefly mentioned all five (included in the previous counts). The strong focus on the Mega City is not surprising given that in August 2022 the website was largely devoted to promoting the newly released app on the Mega City, and that scenario was also the most fully developed.

Table 2. Overview of Civil Engineering Assignments in 2019 to 2022

2019 Traditional	2020 and 2021: FWV option	2022: FWV option on equal footing
Read Chapter 1 [52] and ASCE's "Vision of Civil Engineering in 2025" the chapter "The Vision for Civil Engineering" and chapter "2025: The Civil Engineers World" (pg 9-21) [53]: (a) What did you read related to a problem, need, or challenge facing society that inspires you to be a civil engineer (cite relevant part of reading; e.g. "As described on page 6 in Penn and Parker....") (b) What is something new that you learned in the reading. Again, be specific (e.g. "In the ASCE Vision document I was surprised to learn....")	**OPTION 1** if you don't already know a lot about civil engineering: {2019 assignment} OR **Option 2** *If you feel you already know a moderate amount about civil engineering:* Read about ASCE Future World Vision (web links) [31] Select one of the 5 cities: Floating city, Mega City, Rural City, Frozen City, or Off Planet City. (a) Briefly describe this context. What personally excites you about this context? (b) What elements of the four scenarios seem to apply? Give a few specific examples. (resilient cities, progressive megacities, dispersed settlements, unequal enclaves) (c) What specific civil engineering roles are involved in your context? Which civil engineering sub-disciplines? (d) Are there any additional trends that you can imagine that don't appear to have been considered but are relevant to civil engineering in your context? {include a reference if you add a trend}	**READ or Watch 2 of the following**: (1) READ Chapter 1 [52] (2) Read / watch videos about ASCE Future World Vision (URL link provided) [31] (3) READ in ASCE's "Vision …" [53] (4) READ The Grind Challenges, Guru Madhavan [54] and watch associated 2.5-min video [55] **Answer the following two questions**: (a) What did you learn from 1 or both of the above that you read/watch related to a problem, need, or challenge facing society that inspires you to be a civil engineer (cite relevant source) (b) What is something new that you learned in **each** of the videos / readings. Again, be specific. {Note: write above in such a way that the 2 items you read/watched is clear; and/or add an introductory sentence that states this}

Design Process Homework

In 2022 additional integration of FWV occurred in homework 3 about the design process (see Figure 2 below). This topic and a very similar assignment were previously integrated into the course in 2020 and 2021; the integration of FWV into the assignment is highlighted in red in Figure 2. The course included one main team project focused on bridge design, and this early assignment developed a foundation for the assignment. Qualitatively, the instructor believes that the FWV framing helped improve the quality of students' problem statement and background information responses. The most popular FWV scenario was the Floating City (n=22), followed by the Mega City (n=15), Frozen City (n=8), Off-Planet City (n=4), and Rural City (n=3). Five students did not identify a specific FWV scenario.

Design and teamwork

Read pages 1-26 of Penn and Parker Chapter 9 Engineering Design from the Infrastructure book [52].

Think about designing a bridge in one of the 5 ASCE 'future world vision' (FWV) conditions: Mega City, Floating City, Frozen City, Rural City, or Off-Planet City. [link to FWV website]

Discuss the process to design a bridge in one of the 5 FWV conditions.

Provide a problem statement that could motivate the design of a new bridge - be as specific as you can (clearly state the FWV context; include if it is for pedestrians / bicycles only, cars, rail, and/or multi-modal; etc.)
List at least 10 types of background information that should be gathered prior to designing the roadway bridge that solves the need that you identified in part (a) {hint: pgs. 7-9 and 18-22}
Describe the process that you would use to compare and evaluate multiple alternative bridge designs {hint: see pgs. 12-16}
Reminder: your response should be 250 to 500 words.

Figure 2. Design homework assignment

Data Science Homework

In 2022 a new topic was added to the course to highlight the application and importance of data science in CE. The assignment is shown in Figure 3 below. The most popular scenario was the Mega City (n=26), followed by the Floating (n=16), Off-Planet (n=7), Frozen (n=3), and Rural (n=1) cities. There were 22 students who discussed the same FWV scenario in both the design and data science homeworks.

Homework: Data Science / Big Data and Civil Engineering

Data Science is being increasingly applied in civil engineering. Thus, all civil engineers should have some proficiency in data science. Learning outcomes typically associated with proficiency in data science that will be helpful to civil engineers include (https://www.wittenberg.edu/academics/data-science/learning-outcomes):

- Programming abilities (such as creating algorithms to solve problems and code them in a language appropriate for data science work, e.g. Python, SQL, R, Java)
- Statistical analysis of data, including use of statistical software (standard data visualization, choose appropriately from range of exploratory and inferential methods for analyzing data, and interpret the results contextually)
- Ability to build and assess data-based models
- Data management (acquire and clean data, transform variables to facilitate analysis)

To learn about an example of data science in civil engineering read the online story where Transportation engineers working at Arcadis share experience using Big Data: Planning Louisiana's Bridges: 3 Big Data Case Studies. By Thomas Montz and Luis Alvergue, July 12, 2018. [Link to resource]. [56]

Other resources to learn about data science and civil engineering are provided below.

Answer each of the following 3 questions:

1. What did you learn about data science and civil engineering that was new to you (cite specific relevant sources)
2. Given the 4 'realms' of data science skills in the bulleted list above, discuss those that interest you the most (or least) and those that you feel confident that you can learn (or not)
3. Give an example of a data science related application that you think is relevant to one of the 5 'Future World Vision' scenarios (Mega City, Floating City, Frozen City, Off-Planet City, Rural City)

Reminder: your response should be 250 to 500 words.

Figure 3. Data Science homework assignment

Creativity and Innovation Homework

The goal of this homework was to allow students the freedom to explore topics on the cutting edge of civil engineering practice. Creativity and innovation will be important skills to realize the vision of the future shown in FWV. These importance of these skills is recognized within the *ASCE Civil Engineering Body of Knowledge Third Edition* [57] in the professional attitudes outcome ("explain professional attitude relevant to the practice of civil engineering, including creativity…") and professional responsibilities outcome ("explain professional responsibilities relevant to the practice of civil engineering, including… innovation."). The 2022, students were provided the opportunity to read / watch one of a series of eight website options, or explore the Mega City via the desktop app (see Figure 4). In 2020 and 2021 the assignment did not include the FWV option, and some of the website options differed. There were 20 students who explored the Mega City app in 2022. Popular topics to comment on included sustainability elements and building on historic buildings / sites. Another two students discussed FWV but it seemed that they based their discussion on videos on the ASCE website rather than personal explorations in the Mega City app. Note also that students were given options in the format for completing the assignment (aligned with tenets in Universal Design for Learning, UDL, and self-determination).

Creativity and Innovation

Select **one of the three** options below to document your learning:
(a) Visit me during office hours for individual meeting or by appointment
OR (b) submit to Canvas as 3-5-min video
OR (c) 'normal' document, 250-500 words total.

Select between two types of exploration:

(A) ASCE Future World Vision (https://www.futureworldvision.org/future-worlds)
Explore the Mega City of 2070 (via the desktop app)
In your write-up/video: Identify 5 elements in the city that are new innovations that are not common in today's cities. (maybe include a 'screen shot') Discuss which you think are more likely to occur sooner. Which might not be limited to a 'mega city' (population 10M or more people)? Which are highly dependent on local conditions (locate in Alaska vs. Hawaii, for example)?

OR

(B) Read / watch ONE of the following
• https://www.constructionplacements.com/construction-technology/#gsc.tab=0
• https://www.raconteur.net/business-innovation/top-ten-construction-innovations
• https://online.norwich.edu/academic-programs/masters/civil-engineering/resources/articles/5-innovations-in-civil-engineering-aimed-at-improving-sustainability
• https://www.autodesk.com/redshift/innovation-in-civil-engineering/
• https://www.activesustainability.com/construction-and-urban-development/the-evolution-of-innovation-in-civil-engineering/
• https://www.quora.com/What-are-the-latest-innovations-in-civil-engineering
• https://www.ennomotive.com/4-new-techniques-in-civil-engineering/
• https://www.asce.org/cemagazine/originality-built-in/
• Video: youtube.com/watch?v=vfZ7ToBvwn4 10 futuristic construction technologies, 2018

Your write up / video should:
a) Identify the reading you selected or video you watched
b) Summarize what you learned – Yes/no aware of these? Think it will work? Why/why not?
c) Dig a little deeper into 1 area of interest discussed in the article (will need to cite 1 or more references you consulted). What did you learn?
d) Cite reference(s).

Figure 4. Creativity and Innovation homework assignment

The instructor had some concern about requiring use of the desktop app in case students encountered technical problems. However, given the success among the students who tried it, next year the assignment can require all students to explore the Mega City via the app. Students can use personal computers and the department can also load the app into the computer lab. In general, the majority of the innovations described in the website options were embedded in the app.

Results: Across the Semester

First, the inclusion of FWV in the different course assignments across the semester are summarized in Table 3. Literature indicates that selecting FWV among options may provide evidence of student interest in the topic. When interpreting the results it is also important to note that because students could drop two assignments during the semester not all students completed the specific assignment (two to three students opted not to complete the design, data science, and creativity assignments). In addition, some students did not follow the instructions, so even when explicitly instructed to include a FWV scenario some did not.

There were not statistically significant differences in the percentage of students from different demographic groups who included FWV in the assignments. The largest difference is that a higher percentage of the students not declared as civil engineering majors opted to explored FWV on the overview assignment where students selected two of four resources. Fewer URM students explored FWV on the civil overview and creativity assignment. More male than female students explored FWV on the creativity assignment. However, more female students discussed FWV in the final essay.

Overall, the percentage of students who opted to explore the FWV Mega City app in the creativity assignment was somewhat low, but there were many other options available which may have seemed more straightforward (e.g., read an article on a website versus needing to install an app on personal computer).

Table 3. Number and percentage of students who included FWV in various course assignments

Group	*n*	Civil overview	Design	DataSci	Creativity	Final essay
All students	*59*/57*	35 (59%)	52 (91%)	52 (95%)	22 (41%)	31 (54%)
Female	*19*	11 (58%)	17 (94%)	15 (88%)	5 (29%)	13 (68%)
Male	*40*/38*	24 (60%)	35 (90%)	37 (97%)	17 (46%)	18 (47%)
URM	*18*/17*	9 (53%)	18 (100%)	15 (94%)	5 (31%)	9 (53%)
Civil majors	*36*/34*	20 (56%)	32 (91%)	30 (91%)	15 (47%)	18 (53%)
Non-civil majors	*23*	15 (65%)	20 (91%)	22 (100%)	7 (32%)	13 (57%)

* *2 male students (1 URM, both civil majors) withdrew before the Data Science homework*

Across the five assignments with an option to include FWV, there were 7 students who included FWV elements in all five and 12 students who included FWV in only two assignments (see Table 4). Note that the theoretical minimum was two given that two assignments required FWV integration to earn full credit; no students had fewer than two assignments with FWV. It is interesting to note that none of the students who only included FWV in two of the four homework assignments discussed FWV in the final essay. This may indicate that requiring the

students to integrate FWV in three or more assignments in future semesters would have a greater impact.

There were not significant differences among demographic groups in the total number of assignments that included FWV (most clearly evident based on the average number of assignments, the far right column in the table).

Table 4. Percentage of Fall 2022 students who included FWV in 2 to 5 course assignments

Group	Number of assignments including FWV				Average n assignments
	5	4	3	2	
All	12%	28%	39%	21%	3.3
Female	11%	26%	37%	26%	3.2
Male	13%	29%	39%	18%	3.4
URM	18%	18%	35%	29%	3.2
Civil majors	9%	35%	32%	24%	3.3

Results: End-of-Semester Student Interest in FWV

In 2022 on the last day of class of the semester an iClicker poll was used to quickly gage student opinions about FWV integration into the course. Polls in the class are used only to award attendance points. Attendance on the final day of the semester was unusually low (only 63%). The students were invited to 'select all that apply' among four poll options; results are shown in Table 5. Responses about FWV were more positive than neutral, with more female and URM students having positive responses about finding FWV interesting (the most common 'dual responses' were for the first two choices).

Table 5. In-class poll results for student interest in FWV

Response options	n	% of n=36	% Male (n=23)	% Female (n=13)	% URM (n=10)
FWV was interesting	17	47	61	77	80
FWV encouraged my interest in civil engineering	12	33			
FWV was not significant to my feeling during the course	10	28	43^	23	30^
I don't remember FWV	3	8			

^ one student indicated both 'encouraged interest in civil' and 'not significant'

An optional extra credit survey was distributed on the last day of the semester and included an open-ended item inviting students to identify their most and least favorite topic in the course. FWV was listed as a favorite by four students (among 23 students who provided a response), and none mentioned FWV as their least favorite.

The course included a final culminating essay assignment. The first part of the assignment asked students to define civil engineering, describe what they find inspiring about civil engineering, and discuss the importance of ethics and sustainability in civil engineering. They were also told to cite specific assignments and readings in the class that were impactful. The second prompt was slightly modified in 2022 asking students to think about FWV, although not requiring them to discuss it.

Discuss something about civil engineering that you find inspiring. Be specific. A problem? An opportunity? Any of the Future World Vision scenarios? [6 pts]

On the final essay in 2020 and 2021 (without specific prompting), one student (2%) and four students (13%), respectively, talked about FWV as something that excited or inspired them about civil engineering. This increased to 18 students (32%) in 2022, although it is uncertain if this change was due to the altered wording ('nudge') in the prompt or the more robust integration of FWV into more elements in the course. FWV was described as an inspiration by a higher percentage of female students (47%) than male students (24%), and 24% of URM students. These responses often focused on the innovative elements and/or sustainability focus of FWV. In 2022 there were 13 additional students who discussed FVW elements in the earlier description of civil engineering or other portions of the assignment. Thus in total 54% of the students in 2022 discussed FWV as they reflected on their semester in the course (68% of the female students, 50% of the male students, 53% URM students). Most students discussed or mentioned the Mega City (n=16), followed by the Floating (n=9), Off-Planet (n=7), Rural (n=4), and Frozen (n=4) cities, with some including more than one scenario. Example quotes from the student essays are provided below:

> Something I found honestly really inspiring while working throughout this course was when we took a look at the Future World Vision and had to explore what cities in the future would look like made by engineers. This was because they took a whole new approach on even what a city means, designing them for the arctic, to float on water, as a mega city, and even an off planet city. It was so hopeful to see that at least somewhere out there people were designing cities to prepare for the reality of what our world may look like in 10-20 years. And it really was the moment where I felt fully confident in my choice for civil engineering as those were exactly the types of interesting projects that I have always dreamed of working on. *Female student majoring in civil engineering*

> What has really drawn me into civil engineering is that we are the generation that may have to design a completely new way for our society to live. The Future World Vision scenarios have all been extremely inspiring to me, because it's a glimpse into what I could help make a reality in my lifetime. My favorite scenario is definitely the floating city. For me, it inspires almost childhood wonder, but it could be a very plausible solution to many issues that coastal cities will experience from climate change in the coming years. Having the honor to work on a project that could help so many people live safer lives is a major life goal I want to set for myself. *Female student, started semester open option but planning to declare mechanical engineering due to her experiences in CAD and projects course*

> I am inspired by the ability to leave something valuable for people, and to enjoy seeing design or constructed works turn into reality. … Pointedly, the "Mega City" caught my attention; described as a transformed world combining Virtual reality and Real life, with the addition of innovations like personal transport pods and drone deliveries. As the world continues to grow and change, implementing engineering design and innovation will help society adapt to our needs. The Mega City, along with future worlds like the Floating city and Rural City will do just that. Our future is bright with the amount of qualified and intelligent students coming out of Universities, and I want to be one of them to make an

impact or become involved with projects as immense as them. *Male student majoring in civil engineering*

One thing that I found extremely inspiring about Civil Engineering was how much power they have to change the world. Civil Engineers can design cities that encourage communication and collaboration within a community by breaking down the blockers that are present today in our cities. One of the things I really find interesting and have a lot of hope for, is a future where cities aren't divided and destroyed by cars. Civil Engineers hold a lot of power to help break down this divide and replace it with better systems of public transit, walking and biking. Thus, making new cities that are cleaner, safer and encourage connection and play. This is part of what made the Mega City so exciting to me. The emphasis on public transportation. *Male student majoring in civil engineering*

As we grow into a more and more advanced society, we need the right civil engineers to facilitate our growth and the sustainability of our man-made environment. For example, in the ASCE (American Society for Civil Engineering) Future World Vision, a community of engineers collaborate to brainstorm possible megacities in the future and solutions to the problems that arise from these types of urban areas. This project is remarkably inspiring, involving a great amount of profound innovation, such as the concept of each building in a city being responsible for its own footprint. This would involve the production of renewable energy, recycling of the building's own waste, and even the collection of rainwater. …. Creative solutions such as this are the future of not only our country, but the entire world as we grow more and more painfully aware of the detriments of climate change. I personally feel very passionate about this aspect of engineering, as our generation will be the ones to see these effects play out on our earth, and it is up to us to do something about this. *Male student, started semester open option and declaring major in architectural engineering*

The aspect of civil engineering that fascinated me the most was by far the "Future World Vision" scenarios…. I think that it would be incredible to be a part of the designing and construction processes of these futuristic worlds just because they seem so advanced and so complex compared to our modern-day cities. The city that interests me the most would be the Off-Planet City because it combines my interests in space and civil engineering. I'd love to be able to combine both civil and aerospace engineering in a single project and it would be an amazing accomplishment to begin building colonies on other planets and satellites. *Male student, started semester open option, ended semester planning to declare civil engineering*

I find Civil engineering to be inspirational because of the simple fact that I will always be working to make my community and other communities around me more advanced… While in this class we also looked over what possibilities could happen in the future. We are so close to finding new ways of living. This includes other planets, new city structures, floating cities, etc. Like I have told my friends in aerospace engineering, "You may find a new planet, but I will be the one to build a city on it." I cannot wait to see what the future holds for me in the future. These are some of the inspirational things that have inspired me to continue my elevated level of education. *Female student majoring in civil engineering*

The above are just a few of the examples of students' excitement and enthusiasm for civil engineering. It is hopeful that many students had their interests in civil engineering confirmed, and perhaps FWV helped attract some of the open option students to declare civil engineering. The final quote contrasting civil and aerospace engineering suggests that the student found themselves defending the prestige of the CE major, reminiscent of the literature on high-status jobs. However, the power of FWV integrated into the 1-credit course is limited, as illustrated by the student who found FWV inspiring (the second quote) but ultimately felt more drawn to mechanical engineering due to other introductory classes in their first semester (likely first-year engineering projects and/or CAD) and perceptions that mechanical was more 'hands-on work'.

Limitations

This paper discusses the integration of FWV into a course aimed at introducing first-year students to the civil engineering profession. The results are from a single institutional context and could easily differ in other implementations. The student demographics were predominated by "traditional" students who were coming direct from high school and attending college full time. There were also fairly small numbers of students enrolled in the course, making it difficult to identify differences among demographic groups. In particular, it was not even attempted to explore intersectional identity groups and some demographic groups were not represented among the students enrolled in the course. For example, there were no Black / African American female students in the course in 2022. The author also acknowledges that other methods to stimulate student interest could be equally or more effective, such as the Engineering Grand Challenges [58], [59].

Future Ideas

For more robust integration of FWV in the course next year, the bridge design project will be modified. Teams will be assigned to one of the FWV scenarios. This will allow students to explicitly consider how the different environmental and site conditions should impact bridge design. Given the typical size of the course, students will see a couple of examples of bridges for each scenario when the teams present their best design to the class. Comparing and contrasting these bridges will add another dimension to the assignment.

Students will also be required to use the FWV Mega City app for one or more assignments. The creativity / innovation assignment is an obvious choice. But given the elements students keyed in on during their use of the app, it appears that sustainability could also be well supported (as environmental and social elements are clearly evident). The current version of the FWV Mega City app (which was updated after the end of the semester in December 2022) has 'sustainability' pre-populated into the search dropdown menu, yielding 47 results. Resilience is another pre-loaded search topic, which yielded 48 results. Ethics and equity is another pre-populated topic in the search and yielded 42 results including a 'public safety and restorative justice center' and 'socially-weighted algorithms'. There is plenty of breadth on these topics to allow students the choice to explore what interests them in the Mega City app.

In addition to this first-year course designed specifically for civil engineering students, FWV elements could be integrated into general engineering courses. FWV appears to be an excellent illustration of the importance of interdisciplinary and multidisciplinary collaborations to solve societal challenges related to infrastructure. The author is testing integration into a materials

course in spring 2023. There were 46 search results for materials, including many that should capture student interest including graphene-laced materials, transparent wood, and automated road maintenance (including self-healing asphalt).

Conclusions

Simple modifications to integrate FWV were made in an introductory civil engineering course for first-year students. In this pilot effort, FWV was integrated as a requirement into two homework assignments and as an option for students to select in two additional homework assignments (of 12 assignments across the semester). FWV was supportive of achieving learning goals in the course related to the breadth of civil engineering, the need for civil engineering to contribute to the well-being of society, design, data science, and creativity / innovation. FWV appeared to interest and inspire many of the students in the course, including students from groups traditionally underrepresented in engineering. This type of course may help attract students to civil engineering, conveying the exciting possibilities and prestige associated with CE, and recruiting students from a breadth of demographic groups. In the future there are opportunities to use FWV to achieve additional learning outcomes related to diversity, equity, and inclusion (DEI) and sustainability. Overall the integration appeared to go well, and the instructor plans to expand FWV integration in the next offering of the course in fall 2023.

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