PREPRINT

Early Career Engineers' Advice for Civil Engineering Instructors

Kacey Beddoes
San Jose State University
kacey@sociologyofengineering.org

Hawaii International Conference on Education

Honolulu, HI, January 3-6 2023

Abstract: There is a growing interest in engineering education research on school-to-work transitions and early career engineers. Much of this work documents misalignments and gaps between engineering education and engineering practice. Contributing to that growing body of research, this paper presents findings on the advice that early career engineers would give to engineering instructors. The research question addressed in this paper is: *What is the most important advice that recent graduates have for civil engineering instructors?* Data came from interviews with civil engineers in the United States. Sixteen early career civil engineers were asked what advice they would give instructors in civil engineering programs. Open coding methods were used to identify and categorise themes in the responses. In contrast to the other interview questions, for which participants' answers differed to a large degree, the uniformity with which participants answered the "advice" question was striking. Nearly all participants said that instructors should have a better understanding of real-world engineering work practices and/or experience working in industry. Their reasoning and explanations are elaborated upon in this analysis. Programs and suggestions on how this could be accomplished are discussed.

Introduction

While industry advisory boards provide guidance meant to better align school and workplaces, there are few opportunities to learn directly from the experiences of recent graduates. With that in mind, the question addressed in this paper is: *What advice would early career civil engineers give to civil engineering instructors and why would they give that advice?* Answering this question contributes to the body of literature on understanding the school-to-work transition (Stevens et al., 2014), and better preparing engineering students for what they will encounter in the workplace, which is of perennial concern (Trevelyan, 2007, 2010, 2019).

When recent graduates were asked what advice they would give to their professors, nearly all of them said that professors should have spent (more) time working in industry prior to teaching. Therefore, the literature review section summarizes research on faculty members' industry experience and how it affects their teaching. Following the literature review and a description of the interview methods of this study, the findings present a typology of the three reasons that recent graduates believed civil engineering faculty members need to have real world experience. The discussion connects these findings to findings on the challenges participants experienced and makes recommendations for engineering education stakeholders.

Literature Review

Relative to some other topics in engineering education, research on instructors' industry experience is relatively scarce. However, the research that has been conducted has shown that work experience in industry affects instructors' course decisions and practices. Specifically, differences have been found between instructors with industry work experience and those without in terms of instructional strategies, course content and curriculum, textbook decisions, and how material is contextualised and linked to real-work practice and settings through examples and stories (Burns, 2012; Davis et al., 2013; van Barneveld & Strobel, 2017). Even though traditional university reward structures do not necessarily value industry experience (Gasper & Lipinski, 2016), and in fact industry work requirements for construction faculty hires have been decreasing (McCuen, 2007), many researchers and educators believe it is important for engineering instructors to have industry experience because it improves their teaching (Lin et al., 2010; McCuen, 2007; Shaaban, 2013; van Barneveld & Strobel, 2017). Trevelyan (2019) suggests that misalignments between school and workplaces may be less problematic if more faculty members had work experience outside of academia. A related study found that the second most common reason transportation engineering instructors make changes to their courses was because they wanted to incorporate more real-world applications (Peters et al., 2016). For instructors who come to university positions without substantial industry work experience, engineering firms that offer opportunities, such as internships, can help bridge the gap to some extent. For example, the Kiewit Faculty Scholars program provides an opportunity to spend 10-12 weeks working on a Kiewit project. Examples of other programs that provide instructors industry experiences and recommendations for how to go about finding and successfully participating in such opportunities are discussed in Gasper & Lipinski (2016), Hynds (2000), and Lin et al. (2010).

Methods

In 2020, semi-structured interviews were conducted with sixteen civil engineers who worked at different firms in the United States. The participants were all early career engineers who began their careers in 2017 and 2018. Their work spanned a wide range of specialities, including structures, transportation, geotechnical and wastewater specialties. This interview was the third in a series of longitudinal interviews that are on-going (at the time of this writing interviews had been conducted five times), and other findings are reported elsewhere (Beddoes, 2019, 2021, 2022, Under review; Grajdura & Beddoes, 2022). One question asked in this interview was, "What advice would you give to professors in civil engineering programs?" Responses to that question were analysed with an open-coding approach to determine if any themes emerged. One predominant theme emerged with fourteen of the sixteen participants giving very similar responses. Presenting and discussing that theme is the purpose of this paper. Participants are quoted at length in order to present interviewees' reasoning as thoroughly as possible in their own words. Quotations were edited for readability and text in square brackets was added by the author.

Findings

More so than any other question asked in any of the series of interviews, participants answered this question with uniformity. Fourteen of the sixteen participants said that the advice they would give to civil engineering professors would be to have more real-world experience and incorporate more real-world content into courses. The reasons behind their answers generally fell into one of three categories as summarised in Table 1.

Table 1: Typology of reasons given

Characteristic of information from school	Meaning	Examples
Misleading	Things taught in school were not the correct way to do them in practice or not reflective of workplace realities	Bolted connections, selecting pipe sizes
Absent	Things used in workplace never taught in school	Software, manuals, different views
Decontextualised	Things taught in school with no sense of how they would be applied in practice	Equations, diagrams

The first reason was that some things they were taught were actually misleading in the sense that they are not done that way in the real world, or not reflective of workplace reality. For example, one participant explained that:

> One example is they are doing things less precisely but more conservatively with the understanding that at some point someone else is going to have to look at and understand the work that you did, be able to check it or be able to expand on it or modify in some way. So, sometimes things can to be too in depth and then not really able to be understood, or documentation is poor first time around, and then it has to be redone. In the simpler more conservative method anyways, then clients or someone else can understand what was done. But I think a lot of times in school, it's doing things like the correct way and sometimes the more complicated way is stressed more than the practical way it will actually be used in industry. A very specific example of that is bolted connections. There's a simple connection design and a more complex connection design and the more complex one is taught, but in my experience isn't really used because it's too complex for most situations.

This is similar to a quote from the first interviews where another participant shared the following story conveying that it "is really important" for "professors to distinguish between what you're doing in the real world and what you're doing in school":

> I would probably advise professors to put effort into giving real world examples and comparing like, 'This is how we're going to learn it now, but If you go do it in a job, this is how you're going to do it'. And for professors who don't have real world experience, to talk to professors that do have that kind of experience or to ask other working engineers for advice with their class, I think is a really good idea…I definitely had a couple of professors and one comes to mind in particular, my hydraulics professor, who had like never worked in the industry at all, so he… taught things very, very theoretically. And I actually work in drainage, so I use a lot of hydraulics, and I pretty much don't see anything I learned in that class and the way he taught it. And because I was already an intern at the time when I took that class, I kind of already knew that that was the case, but I could see a

> student who didn't already have a job or didn't work in a drainage industry taking that class and being so overwhelmed by all the formulas that you don't actually have to memorize or take to your job with you.

The second reason was that tasks that constitute a large part of what they do, they were never exposed to or taught at all. This included software, different types of views, standards/manuals, and understanding a project scope in its entirety. One participant wished that her courses had incorporated:

> …more of the things I see at work, such as… we have drawings, so we have plan views, section views, and profile views. So kind of differentiating between section and profile and learning those and seeing those just to gain exposure while in college that would be beneficial. Just visualizing it, understanding it, that would truly be beneficial.

Another participant gave an example related to the use of manuals:

> I took a class in college that was on the MUTCD [Manual on Uniform Traffic Control Devices], which is like the signing manual, it was an elective class…but a lot of classes don't reference the standards or manuals that professionals use and then you get in the real world and you're looking at this manual you've never seen before. You're not expected to know everything about the manual, but just seeing it in college, like, 'oh, okay…like how it's set up and like what I'm looking for… then when you're handed it at work, you're like, 'Oh, I know what this is' versus being like 'uhh, where do I start'?...[In school] they would always give us the values versus us having to search in the manual…Whereas if you had to like search through the manual I think you would learn a lot more as realistic.

Another explained that more real-world projects should be included so that the scope of a project is understood:

> Projects that included how you're going to procure the materials. We had to design a building in New York City in midtown Manhattan, and we had to do a transportation plan to figure out how they were going to get the steel beams into the city considering a lot of the roads don't allow trucks or the bridges have weight limits and it's just like, 'oh, wow, when I become a construction engineer, I'm going to need to know that'. And then we had to do a cost analysis and actually go and like calc out what the all the beams would cost and all the labour and everything…I feel like one of the first things that most entry level engineers do is a cost estimate. So, if you have a little bit of understanding from a project in college, it would be easier to explain what it is in the real world.

In the following excerpt, a participant explained why software used in industry should be taught in school:

> Industry is constantly evolving, but if the education system is not evolving according to changes in industry then the divergence between what is taught in school and what is used in industry starts growing and there's this disconnect and then you have engineers who are not going to be as productive or effective because they're having to learn all of this very quickly in a short amount of time…just so that they can be up to speed with what the industry is doing…Finite element analysis is a type of analysis that has…become fundamental for our use in industry because, of course, nowadays it's all computer generated…In the course I learned the fundamentals for the basis of what the finite element method is and the different techniques that are utilized by the computer. But I think that I

> learned that in probably three weeks out of a sixteen-week course. So there's these thirteen weeks of just repetition and time wasted in my opinion because… the fundamentals don't change… And I completely agree that the fundamentals need to be taught. However, I think that the course could be modified such that it is more applicable to today's standards. For example, when I first walked into work, that first year I had to do, a lot of learning on my own time, as well as on the job of 'how do I utilize some of these software's?' …Once you've picked up the instruments of what the software can do and how to do it, then you start getting into the more complex things [such as] now I need you to produce a whole bridge model with all these little details and all this analysis needs to be done and I need it done in a week. And you're like, holy crap, I've only done a simple bridge model very, very rudimentary... But when you're asked to do something where you spend weeks creating a model , fine tuning it, validating it, checking to make sure the results it's spitting out are correct…when it takes weeks and you are barely familiar with the software, that's a problem because now you have a lot of learning you have to do on your own to be able to effectively execute the tasks you're given at work, which are pretty much standard expectations at this point in industry….so I see that as an opportunity for the course [to start including more software].

Echoing that, another participant elaborated that employers too wished software was taught in school:

> What you do in classes is not what we do on a daily basis. You have to understand the math and you have to understand the physics and why things do what they do, but when it comes down to it, it's totally different…And we never used the software. [This state] is very heavy in MicroStation, which is where we do all our design. We never got to use that in college… Having gone to a state school, it would be awesome if they could kind of educate themselves on the field and how we can be successful. That is something that has been talked about with the [state] board of professional engineers. I know one of my professors told me that the [state] board of professional engineers is very upset that people are leaving college and they're not necessarily prepared for the positions that they take on They understand how to read a book and how to do math and how to do problems, but they don't understand how to apply that to the work that we're doing.

The third reason was that theoretical content needed to be contextualised with real work applications because how things they are taught are applied in the workplace. As one participant explained:

> Professors just kind of focused on like theories and equations, but they were never like 'oh so for instance, when you get into the workforce, you might have to use this equation for this situation and you might have to use it for the situation'. So yeah, I would just say like maybe try and put in the bigger picture for people that aren't going to like continue their education and aren't going to be worrying about the theories and the equations themselves.

Others similarly said that instructors should "throw some diagrams at us, the kind we see at work", and "Try to deal in more concrete world examples". Emphasizing this difference, one participant said that there was a "distinct difference" in the "practicality of the information that was learned" between classes taught by PEs and classes taught by non-PEs.

Several participants commented that the best instructors they had were those with significant industry experience. One said: "I had quite a few professors who had never ever worked a day in the field. And it was a very different atmosphere, like the classes were very different from the professors who did work in the field. They had a lot different advice to offer." Interestingly, however, several other participants had the impression that even when their instructors had industry experience the instructors were not able or willing to use that experience in their teaching because they felt too tied to the theoretical curriculum. For instance, one recalled:

> I had a professor who just took… a really basic approach to subject matter. And it just made everything really boring and not many people were interested in it. And he had a lot of construction experience. And so people were always trying to ask about that and relate the subject matter to his experience and he just kind of stuck to his PowerPoints that he'd been using for at least 10 years and I felt like if he had refreshed content a little bit, it would have really improved student engagement.

Another likewise said:

> Generally I think all of my professors were in the industry at one point. Most of them, some were, some weren't. I think maybe they kind of get too involved in the curriculum, or they kind of just get too involved with like tackling tasks and what we need to know, rather than, like, say, 'Oh, well, I did this task when I was an entry level [engineer]. Maybe I should give them something similar'. I wouldn't know how that would be incorporated in terms of teaching, but just throw like some diagrams at us that we see at work.

The quotations presented in this section are representative of the fourteen responses that emerged as this theme. The two remaining participants outside this theme said that professors should not place such high value on homework and that they should incorporate more teamwork into courses.

Discussion

Examples of problems and challenges caused by these gaps surfaced throughout the various sets of interviews. For instance, in the first interview, one participant recounted a time when she had done something incorrectly because of the first type of gap (misleading). She recalled the following problem in which what she had learned in school was not the correct thing to do in her job, but her instructors had never told her that:

> Just because something… *could* be used, that doesn't mean it *is* used, or cost effective, or possible for what we're particularly reviewing or working on…We were reworking on a pump station, which takes waste water and helps move it to the waste water treatment plant, and I was told to size something based on a diameter of pipe… usually you're trying to figure out the pumping capacity of the pipe and then you size the pipe – that is how I was taught to do it. So I had started confirming that the size of pipe was acceptable for the pump station, and I did all these calculations, and it generally confirmed that that size was OK. But I didn't need to do that. It was already provided to me that 'yes, that is the size of the pipe, that is what you are supposed to use, that is how you are supposed to design it'. So I spent all this extra work that I didn't need to do and obviously the person who directed me to do [that task] was not happy with me...I didn't know that we can just say 'Ya, we're going to make that pipe [this size].

As discussed elsewhere, encountering new practices and technical knowledge (the second gap) was one of biggest challenges many participants experienced in their first year (Beddoes, 2019). Further, not having accurate expectations of the workplace and never being exposed to software was a contributing factor to participants' dissatisfaction with their jobs and feeling that they were not real engineers once they got into the workplace (Beddoes, Under review). Similar conclusions about "value conflicts" created through educational structures that conflict with workplace practice have been identified by Trevelyan (2019). These gaps are not trivial then. They directly shape early career engineers' experiences, particularly their challenges and (dis)satisfactions. Combined with the fact that this was the only interview question answered so uniformly, these findings suggest a real need to address at least the first two gaps.

Moreover, these gaps may be more problematic for some newcomer engineers than others. Those who have the privilege of the presumption of competence, in this context white men, may be less disadvantaged by the gaps than women or people of color who do not have that privilege. For example, some women participants reported not being seen as engineers in the same way as men because they were not given the same presumption of competence by co-workers and clients (Beddoes, 2021, In press). Instances like the pump station pipe described above may therefore be more detrimental to women newcomer engineers than men newcomer engineers.

Prior research cited in the literature review provides evidence that industry experience for instructors could help address some of these gaps. In particular, the findings that instructors with industry experience make different decisions in terms of course content, textbooks, and how material is contextualized and linked to real-work practice and settings through examples and stories (Burns, 2012; Davis et al., 2013; van Barneveld & Strobel, 2017) suggests that all three gaps could benefit. However, the present study also raises questions about willingness and ability to use knowledge gained in industry even when they have it. Several participants had the perception that instructors were not able or willing to draw on their experiences when teaching. Why that might be the case, and what factors support or constrain their ability and willingness to do so, is a research question that could be explored in future work.

The findings presented in this paper suggest that deans and department chairs should support opportunities for their civil engineering faculty members to gain industry experiences. As noted, there are engineering firms that offer such opportunities. The findings also identify specific things that faculty participating in those programs should try to get out of them and incorporate into their teaching. In particular, they should seek out understandings of when and where things taught in school are not correct in the workplace, and try to find ways to incorporate more of the tasks students will see in their jobs.

Short of being able to provide or require faculty to have industry experience, the findings also point to three ways in which civil engineering education could be improved upon by individual instructors or curriculum committees (from the perspective of newcomer engineers). The gaps identified are areas that could be addressed even without industry experience through continued learning or research. One step would be to ensure that what they are teaching is an accurate representation of how students should perform a task when they begin working. A second would be to broaden the topics covered in courses to better align with realities of work that early career engineers perform. The third would be to more often and thoroughly contextualize what is taught with real world applications.

Of course, even though in the interviews this data emerged as advice for instructors, not all course content decisions are entirely up to individuals who teach the courses. National accreditation bodies, licensure requirements, and testing all play a role in engineering curriculum, and each of those factors is very much informed by national histories and boundary work around what constitutes engineering. These findings therefore also have implications beyond individual faculty members.

Conclusion

This study identified a common belief among newcomer civil engineers that their instructors should have had more real-world experience. It also identified three reasons why they thought that. The three reasons were: 1) so that students would gain correct understandings of how to do the tasks they faced as newcomer engineers, 2) so that students would gain experience with those tasks prior to encountering them in the workplace, and 3) so that students would understand how what they were learning would (and would not) be applied in the context of engineering practice. Identifying these reasons highlights areas that instructors, curriculum committees, and administrators can use to make changes that would better prepare graduates for their careers.

Acknowledgements

I sincerely thank my participants for sharing their time and experiences with me to make this work possible. This material is based upon work supported by the National Science Foundation under grant EEC #1929727. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

References

Beddoes, K. (Under review). Accounting for Occupational Identity Work in the Turnover of Newcomer Engineers.

Beddoes, K. (2022). Gender as Structure in the Organisational Socialisation of Newcomer Civil Engineers. *European Journal of Engineering Education*, 47(1), 102-116.

Beddoes, K. (2021). Examining Privilege in Engineering Socialization Through the Stories of Newcomer Engineers. *Engineering Studies*, 13(2), 158-179.

Beddoes, K. (2019). First Year Practicing Civil Engineers' Challenges. Paper presented at the Australasian Association for Engineering Education Annual Conference, Brisbane, Australia.

Burns, T.J. (2012). Does the instructor's experience as a practitioner affect the purpose and content of the undergraduate Systems Analysis and Design course? *Information Systems Education Journal*, 10(1), 37-46.

Davis, S., Brown, S., Dixon, M., Borden, R., & Montfort, D. (2013). Embedded knowledge in transportation engineering: Comparisons between engineers and instructors. *Journal of Professional Issues in Engineering Education and Practice,* 139(1), 51-58.

Gasper, C., & Lipinski, J. (2016). Industry Experience: Enhancing a Professor's Ability to Effectively Teach in Higher Education. *Journal of Education and Human Development*, 5(3), 63-67.

Grajdura, S.A. & Beddoes, K. (2022). What early career civil engineers wish they had done differently: Lessons for students and faculty. Paper presented at the American Society for Engineering Education Annual Conference, Minneapolis, MN.

Hynds, T. (2000). Professional Development/Internship Opportunities for Construction Faculty: A Win/Win Outcome. *Journal of Construction Education*, 5(2), 97-103.

Lin, K-Y., Kim, Y-W., & Dossick, C. (2010). Repositioning the Faculty Internship Experience in Construction Management. Paper presented at the Construction Research Congress, Banff, Canada.

McCuen, T.L. (2007). Industry Experience: An Important Requirement for Construction Faculty. Retrieved June 11, 2021, from http://ascpro0.ascweb.org/archives/cd/2007/paper/CEGT143002007.pdf

Peters, A., Beddoes, K., Brown, S., & Chang, K. (2016). Transportation Engineering Instructors' Decision-Making Process for Course Changes. *ASCE Journal of Professional Issues in Engineering Education and Practice*, 142(3), 1-7.

Shaaban, K. (2013). Practical teaching and its importance in teaching civil engineering. Paper presented at the Global Innovators Conference, Doha, Qatar.

Stevens, R., Johri, A., & O'Connor, K. (2014). Professional Engineering Work. In A. Johri & B. M. Olds (Eds.), *Cambridge Handbook of Engineering Education Research* (pp. 119–137). New York: Cambridge University Press.

Trevelyan, J. (2007). Technical Coordination in Engineering Practice. *Journal of Engineering Education*, *96*(3), 191–204.

Trevelyan, J. (2010). Reconstructing Engineering from Practice. *Engineering Studies*, *2*(3), 175–195.

Trevelyan, J. (2019). Transitioning to Engineering Practice. *European Journal of Engineering Education, 44*(6), 821-837.

van Barneveld, A., & Strobel, J. (2017). Engineering educators' perceptions of the influence of professional/industry experience on their teaching practice. Paper presented at the Canadian Engineering Education Association Conference, Toronto, Canada.