HOW FINE ARE THE EMPEROR’S CLOTHES? – MOTIVATING CRITICAL AND ETHICAL DESIGN PRACTICES BY DECONSTRUCTING ENGINEERING CODES AND STANDARDS

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Abstract – At the University of Toronto, Engineering Science students are typically introduced to the engineering codes and standards that they are expected to incorporate into framing and responding to engineering design challenges in their first year of study. In our experience, however, students do not always appreciate that these codes and standards may not reflect the interests of key (and potentially under-represented) stakeholders, and thus may not be appropriate for their engineering context. To encourage our students to adopt a more critical perspective when working with codes and standards, we exposed them to case examples of contentious regulations, and highlighted the objectives, people, and processes behind the development of these works. Our examples focus on common products to which first-year students can relate, such as handrails and stairs. By exposing our students to the people and processes by which codes and standards are developed, and to the controversies associated with contentious policy decisions, we expect that students will adopt a rigorous approach to using engineering codes and standards in their design activities.

Keywords: Codes and Standards, Engineering Design, First-Year Initiatives, Engineering Ethics

1. INTRODUCTION

The “Praxis” course series provides grounding in engineering design and communication for approximately 250 first-year Engineering Science students at the University of Toronto. The courses expose students to building codes and product standards that they are expected to consider when framing and responding to design challenges throughout the year. This aligns with the Canadian Engineering Accreditation Board’s (CEAB’s) graduate attributes for design, which states that students must be able to “integrate[e] standards, codes of practice, and legal requirements relevant to the activity” [1] when undertaking engineering design.

Our experience is that students rarely appreciate that codes and standards are themselves designed artifacts. As such, these artifacts may exclude important stakeholders in their development process, and often involve compromise, power, history, and context. For example, the National Building Code of Canada (NBC) allocates votes equally between policy officials (e.g. building inspectors), industry representatives (e.g. tradespeople, engineers, architects) and “general public interests”, which may include combinations of homeowners, public health representatives, insurance personnel, and others [2, 3]. One consequence of this allocation is that policy decisions do not always reflect the interests of cohorts with less or no representation in the decision process.

To counter the potential limitations of existing design standards, Praxis students are expected to go beyond including or targeting the minimum design requirements necessary to “meet code”. Instead, they are expected to incorporate research and practice as they develop requirements that are appropriate for their context and stakeholders. To support this goal, the Praxis teaching objectives related to codes and standards are to enable students to:

1) Critically consider how the composition of – and processes followed by – the committees that develop codes and standards could influence the standards these committees produce;
2) Evaluate the appropriateness of existing codes and standards for guiding design, given the needs of key stakeholders and the students’ design objectives and values; and
3) Derive appropriate design requirements for their projects that not only meet code, but also more strongly consider key stakeholder interests, based on the literature, standards or guidelines from other jurisdictions, direct evidence from stakeholder interactions, or other sources.
We scaffolded these skills with case examples that illustrated controversial code and standard decisions, and discussed the corresponding implications for public health and safety. The examples focused on stairway and handrail design – common, mundane products to which a diverse class of first-year Engineering Science students can relate, and for which students can evaluate the physical reasonableness of related codes and standards without requiring advanced skills or equipment. This paper shares a selection of our case examples, and how we used these examples to teach critical analysis and the appropriate incorporation of codes, standards, and guidelines into design practice.

2. APPROACH TO TEACHING CRITICAL ANALYSIS AND USE OF ENGINEERING CODES AND STANDARDS

Our lessons in encouraging critical analysis and use of engineering codes and standards consisted of three key components:

1. An overview of the objectives, people and processes associated with the National Building Code of Canada (NBC), and the analogous Canadian Standards Association (CSA) standard (“Accessible Design for the Built Environment” – CSA B651-2012)
2. A facilitated critique of select building code and care facility guideline provisions related to stairway and handrail design
3. A case history of the evolution of handrail graspability provisions in the NBC and the International Building Code (IBC)

The overview lesson introduced students to important elements of code and standard development, and encouraged students to think critically about how the development process could plausibly affect the codes and standards that these committees produce. The facilitated critique then enabled students to evaluate code and guideline provisions, which we selected to highlight a range of limitations, including being insufficiently-conservative when considered with epidemiological and biomechanical data, and being overly-conservative when considered with the expected physical abilities of prioritized stakeholders. Finally, the case history of the evolution of handrail graspability provisions in the NBC and the IBC served as a concrete example of how (and the extent to which) research, history and stakeholder considerations were incorporated into regulatory decisions.

Our examples emphasized safety and accessibility, particularly as they related to reducing the risk of a fall and falls-related injuries. This decision was motivated by two major reasons. First, we can reasonably expect that all of our students have experienced falls themselves, and many are likely to know somebody who has been injured from a fall. Accordingly, we expected that students would be more likely to perceive falls risk reduction as an important consideration in both ‘safe’ and ‘accessible’ design. Second, all of our students engaged in building design through an introductory structures course in their first semester; however, their course focused primarily on exploring safety from the perspective of reducing risk of structural failure, over human factors. We therefore sought to broaden our students’ perspective on key safety considerations in the context of building and product design.

2.1. Overview of the Objectives, People and Processes Associated with the NBC and CSA B651-2012 (“Accessible Design for the Built Environment”)

We juxtaposed the objectives, people and processes involved in developing the NBC versus the analogous CSA standard governing accessible design for the built environment [2-5]

2.1.1. Objectives. This lesson focused on the accessibility objectives of the NBC, to appropriately contrast with the CSA B651 accessible design standard. We asked students to review these objectives, and make inferences about the priorities of these regulatory works based on the language in the objectives. For example, the NBC objective to “limit the probability that, as a result of the design or construction of the building, a person with a physical or sensory limitation will be unacceptably impeded from using the building or its facilities” [4] suggests that the NBC targets a minimum set of requirements, with a potentially-fluid definition of what constitutes an “unacceptable imped[iment]”. In contrast, the CSA B651 standard is more proactive about accessibility, with a stated purpose of “specifying] technical requirements on how to make buildings and the exterior built environment accessible and safely usable by persons with physical, sensory, or cognitive disabilities” [5].

By exploring the objectives of these regulatory works, and inferring the priorities that likely follow from these objectives, we expected that students would come to see: 1) that these works are fundamentally different in their purpose, and 2) that the different mandates should be considered when applying these works to engineering problem framing and solving.

2.1.2. People. We walked students through the composition of NBC committees versus CSA accessible design committees, and asked them to consider the implications of committee composition for the design of codes and standards. For the NBC, we focused on how voting members “represent[ed], in a balanced way,
regulatory authorities, general public interests, and industry from all regions of Canada” [2], and the potential consequences to Code design with public health representatives (as members of the “general public”) not being guaranteed a vote. We similarly discussed the potential consequences of excluding industry or regulatory authorities in code development, and why their presence on these committees was warranted. Conversely, the CSA B651 accessible design standard includes a substantial presence of representatives from groups that advocate for people with disabilities [5], which students noted as enhancing the likelihood that interests of these communities were reflected in the standard.

2.1.2. Processes. We considered the processes that committees follow when developing codes and standards, emphasizing the NBC process. In particular, we highlighted the potential benefits and consequences of the “consensus-based process” adopted by the NBC [2, 3], for which code change requests are generally scrutinized by multiple sub-committees and a public review before being considered by the Canadian Commission on Building and Fire Codes (responsible for the final review of all code change requests before they are passed, or otherwise) [2]. Two key implications were highlighted. First, the NBC process likely favors regulatory inertia, as implied by the multiple committees through which code change requests must pass, and the NBC’s position that “if a strong consensus is not possible, the proposal will normally be withdrawn so as to not create disharmony” [2]. Second, the feasibility of “consensus” among NBC committee members is contingent on the composition of these committees. Accordingly, code change requests that are important to cohorts with limited representation in the decision process may not pass if those on the committee – perhaps representing groups with different interests – are not convinced of the value of these requests.

2.2. Facilitated Critique of Select Building Code and Design Guidelines

We invited our students to critique a miscellany of provisions from building codes and design guidelines. The goal was to encourage students to more seriously consider the appropriateness of these provisions for users of these buildings, and to reinforce the importance of thinking critically about the codes and standards that they are using. Our examples focused on building codes established for the general population, as well as long-term care facility design guidelines that focus (in principle) primarily on older adults who are no longer able to live independently in the community. We included select care facility guidelines because of their explicit intent to privilege a specific stakeholder group (i.e. residents), which positioned students to evaluate the appropriateness of select provisions for their focal population. This context also prompted the students to consider how they could credibly assess the impact of the guidelines on, or in a broader context “speak for”, a community (care facility residents) of which they were neither members nor had significant direct experience.

To support their design activities, we discussed strategies that students could use to credibly consider codes, standards and guidelines of interest, including:

- considering the range of solutions that are possible with that requirement (and evaluating the physical reasonableness of those solutions);
- comparing provisions to other codes, standards and guidelines; and
- reviewing the literature to find support for or refutation of focal provisions, with particular consideration for the needs of important and potentially under-represented stakeholders, such as older adults and children.

Some example guidelines and codes that were discussed include:

1) Example of guidelines that may have preserved too much flexibility in design: the installation height requirements for handrails in corridors in a few long term care home design manuals [6, 7]. After considering the range of solutions permitted with this provision, students realized that the absence of an upper boundary meant that a handrail could technically be installed near the facility ceiling and still comply, though its function as a reachable balance and walking aid may be undermined.

2) Example of a Code provision that is not sufficiently conservative: the minimum run length requirements for stairs in private homes in the Ontario Building Code [8]. We asked students to perform a quick “sanity check” by estimating if they could fit their entire foot on a step designed to the minimum Code requirement (run length of 210 mm). Most expected that they could not (especially if wearing a shoe) – a predictable outcome when taken with the average North American adult Caucasian male foot length of roughly 263 mm [9]. To emphasize the importance of checking design requirements with research, we noted epidemiological [10] and biomechanical [11] data that supported longer step run lengths to reduce the risk of falls, as well as codes and standards from other jurisdictions that had adopted more conservative provisions (e.g. [12, 5, 13]).

3) Example of a guideline that may be too conservative: the handrail structural strength provisions in a set of design guidelines for Continuing Care facilities [14]. While Praxis students are expected to prioritize safety as fundamental to the engineering profession, they cannot simply ignore other considerations, such as cost, ease of installation, and enforceability of a requirement. Students generally noticed quickly that requiring handrails to resist 1000 lbs in all directions
(as noted in [14]) may be excessive. We reinforced the possible inappropriateness of this requirement by noting that it was more than double the world record for weightlifting with the ‘clean-and-jerk’ method (474 lbs) [15], and that expecting care home residents to apply handrail forces that exceed the lifting ability of a world-record weightlifter may not be realistic – even when considering a standard safety factor of 1.5 [16]. Finally, we discussed the possible consequences of conservative requirements, such as the potential for products to become unaffordable for target users.

2.3. Case History of the Evolution of Handrail Graspsibility Requirements in Canadian and International Building Codes

We walked students through a case history of the handrail graspsibility provisions in the Canadian and International Building Codes, as an example of a common, mundane product for which substantial controversy has erupted in the associated regulatory development. This involved using source documents to:

- Highlight and critique research over the last 35 years, which aimed to evaluate how the cross-sectional design of a handrail is likely to influence the ability of a user to grasp the rail effectively after balance loss, and avoid a fall (e.g. [17-21]).
- Illustrate where this research was contended among various stakeholders (e.g. trade associations such as the US-based Stairway Manufacturers Association and the American Society of Home Inspectors [22]; other researchers in the field [23]).
- Examine the breadth of research and stakeholder considerations that entered Code discussions on graspsibility, and the extent to which these considerations were reflected in actual policy decisions. (Some key stakeholders include: public health representatives and ergonomists advocating for stricter handrail cross-sectional requirements that would enhance grasping for children and users with arthritis; wooden rail manufacturers concerned with how stricter regulations could threaten their livelihoods; and regulatory officials concerned with how requiring smaller rail cross-sectional perimeters that enhance grasping could threaten the rail’s ability to meet structural strength requirements) [24, 25].
- Explore how political considerations and interactions among building code committee members could influence the research and stakeholders who are privileged in policy decisions [24-26].

We concluded this lesson by discussing the consensus among Codes Canada and NBC committees that stronger evidence on the relationship between handrail design and falls risk would be invaluable to the decision process [3], and that some industry representatives even donated handrail cross-sections to researchers for study purposes – despite the possibility that this research could result in their products being deemed ‘unsafe’. Through this discussion, we aimed to convey that the Code development process should not be simplistically interpreted as “good versus evil” or “safety versus money”; instead, it comprises an ongoing negotiation between many stakeholders with often-conflicting but legitimate interests in the outcomes. We also emphasized the value of strong, compelling evidence in guiding decision-making and in persuading a stakeholder to support a request to change a code or standard – even if the change were to disadvantage the cohort that the stakeholder represents on the regulatory committee.

3. CONCLUSION

We aimed to encourage Praxis students to more critically consider codes and standards when framing and responding to design challenges. By exposing our students to the people and processes by which codes and standards are developed, and to the controversies associated with contentious policy decisions, we hope to have engendered in them a healthy critical perspective. This perspective will improve their understanding of both the value and the limitations of existing codes and standards, and help them to appreciate that even common, mundane products can involve controversy.

Anecdotaly, students appeared to more judiciously incorporate regulatory works into framing design challenges: while many teams in previous years attempted to circumvent reading of regulatory works by writing “solutions must meet all relevant codes and standards” into their design requirements, student submissions after this activity more strongly considered guidelines that targeted their focal communities, supplemented by the literature. Our teaching team also commented that the role of direct research in design challenge framing appeared to increase, with students incorporating findings from stakeholder discussions into their requirements.

To that end, we expect that this activity motivated and empowered students to adopt a critical and rigorous approach to using engineering codes and standards in their design activities within and beyond Praxis.

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