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Back to the future: is the Canadian AEC education adapting to the new needs of its industry

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Abstract: While the US architecture, engineering and construction (AEC) industry has undertaken a radical transformation toward new more sustainable and collaborative approaches to building construction design and delivery, the Canadian industry is adapting relatively slowly to these innovations in technologies and practices. One of the reasons for this lack of enthusiasm to improve existing practices is the slow pace of public clients in driving the changes, another potential reason is the inertia of AEC education in adapting their curricula to better prepare students for the new construction paradigm. This paper presents the preliminary results of a longitudinal research aimed at benchmarking the evolution of the Canadian versus the US AEC education in Building Information Modeling (BIM), and sustainability. It builds on a previous study conducted in 2010 that examined 101 programs in the US. The same questionnaire was adopted and sent to 11 architecture and 29 engineering schools in Canada. The preliminary results highlight the widening gap between Canadian and US AEC education programs regarding the integration of technological innovations.

1 Introduction

A rapidly evolving construction industry, constant reassessment of parameters of sustainability, and continuing technological and information advances-including Building Information Modeling (BIM)-are changing the design process of buildings from conception to operation. Having recognized this shift and the challenges it poses, architecture, engineering and construction (AEC) associations and university programs in the US have joined forces to rethink the training required, introducing the teaching of BIM processes and technologies, new Integrated Project Delivery (IPD) approaches and integrated design for sustainable construction within the curricula. New programs, like BIM studio courses, and new ways of training students in AEC can already be found in the curricula of major universities (Forgues, Staub-French et al. 2011).

Canadian industry is following these developments, albeit at a somewhat slower pace: BIM and Leadership in Energy and Environmental Design (LEED) certification are becoming the instruments of choice in a number of new projects commissioned by governmental bodies and agencies. Whether Canadian higher education is also adapting fast enough to these new trends is another matter. As asserted by Becerik-Gerber, Gerber et al. (2011) "*AEC education should be setting the pace rather than keeping the pace with the industry. AEC education should be adapting, and structured to evolve to address present and future challenges. What is clear is that the AEC profession can no longer be focused on a single discipline. In concert, the AEC education should acknowledge the collaborative nature of the multidisciplinary AEC design and construction process".*

"Setting the pace" to address present and future challenges entails a deep questioning of present AEC curricula, and highlights the inability of current reform efforts to adequately respond to them. That is so, because of the fragmented nature of university faculties and programs, which tends to be the mirror opposite of the integrating direction the industry is taking through Integrated Project Delivery.For example, the design process has ceased to be the exclusive domain of designers and encompasses all types of related sub trades and professions with the development of the construction aspects of the model.

The integration of BIM by the client and supply chain is not only a technical or technological challenge. It also requires addressing the processes and the organization dimensions that are inherent to successful BIM deployment (Dossick and Neff, 2010, Jung and Joo, 2011). The change is radical, since it entails moving away from breaking a project into a linear set of related work and activities that are divided between specialties in design or construction, to managing the workflows and data flows for the whole project. It implicates a redefinition or integration of professional practices and changes in power and influence among the members of the supply chain (Blackler and McDonald 2000, Carlile 2004).

Sustainability is a major issue for our society, and the development of a sustainable built environment is much more than a technical problem. It is recognized that the linear and fragmented design and construction process results in buildings that are sub-optimal in their performance. The design of sustainable buildings and communities requires a multidisciplinary, iterative and integrative approach (Zimmerman 2006, Larsson 2002). Moreover, optimal building performance cannot be achieved without valuing and responding to inhabitant knowledge and agency new conditions, new experiences, and new types of interactions between inhabitants and building systems and unfamiliar technologies. Design professionals have to learn to establish dynamic dialogue with future occupants and users not only at a building but also at a community scale (Cole, Robinson et al. 2008).

The problem is that architectural and engineering research and education replicates the compartmentalized patterns found in the industry of the 20th century through university and faculty structures. The main shortcoming of the current research and educational systems is that they cannot adapt to such a transformation. Therefore, academic research is lagging behind industry as far as generating new knowledge for BIM-driven integrated practices or for the production of sustainable design through an integrated design process. Students acquire design skills that may be outdated when they join the practice. They lack interdisciplinary knowledge or skills, and they are not trained to perform within integrated digital environments (Iordanova, Forgues et al. 2010).

The objective of this paper is to provide a first stepping stone for rethinking AEC education in Canada by providing a picture of the evolution of AEC curricula. It builds on a similar research conducted in 2010 by Becerik-Gerber, Gerber et al. (2011) for measuring the pace of technological changes in the US AEC curricula. The aim is to develop, by providing longitudinal data every two years on the evolution of US and Canada curricula, a benchmark on how well AEC education is performing to respond to the industry emerging needs.

2 Methodology

The methodology developed by Becerik-Gerber, Gerber et al. (2011) was reused with their permission to measure the "current level of integration of recent trends including BIM, sustainability and virtual learning applications into AEC higher education curricula" in Canada and "the status of research in AEC education, and integration of multidisciplinary approaches to the research and teaching" (Becerik-Gerber, Gerber et al. 2011: 412). The original survey was *"designed to elucidate the core question, that of the level of recent trends and topics of technology integration within the disparate curriculum of architecture, engineering, and construction management… and to benchmark and quantify trends of current and future integrations of the key topics and technologies for academic programs to parallel and set the pace for the needs of industry"* (Becerik-Gerber, Gerber et al. 2011: 413). The authors analyzed 101 programs in the U.S., with a 21% response rate".

In the Canadian context, respondents answered this survey between June 2011 and February 2013. The objective was to benchmark how well AEC higher education in Canada stood against their US counterpart. As in Becerik-Gerber, Gerber et al. (2011), this survey also targeted the deans, heads of schools, departments and programs of 39 accredited architecture, civil engineering, and construction engineering programs throughout Canada for a total of 16 responses (64% of accredited Architecture schools and departments, and 31% of Construction and Civil Engineering). These were provided from the Canadian Engineering Accreditation Board (CEAB), the Canadian Architectural Certification Board (CACB) and the Royal Architectural Institute of Canada (RAIC). Although the Canadian response rate was higher than in the US study, the sample is much smaller, therefore subject for more important variations. Also, we solicited faculty members since we did not have much success in getting answers from program executive administrators.

This survey addressed the three key domains “of innovation in the AEC curricula” that Becerik-Gerber, Gerber et al. identified, namely, the levels of: “BIM integration,” “sustainability integration” and “research and collaboration in support of BIM and sustainability”.
The first seeks “to determine the level of BIM integration for programs that already offer BIM courses, and to understand the future integration plans for programs that don’t currently offer BIM courses but plan to offer them in the future”. The second identifies “means of integrating sustainability into the curricula, course requirements and AEC educational areas that sustainability is taught for.” The third looks at “level of research and collaboration” in AEC education (Becerik-Gerber, Gerber et al. 2011: 413). This paper is based on the same methodological framework and structure of the survey and is a preliminary analysis. It presents the most important findings of the research.

3 Preliminary results

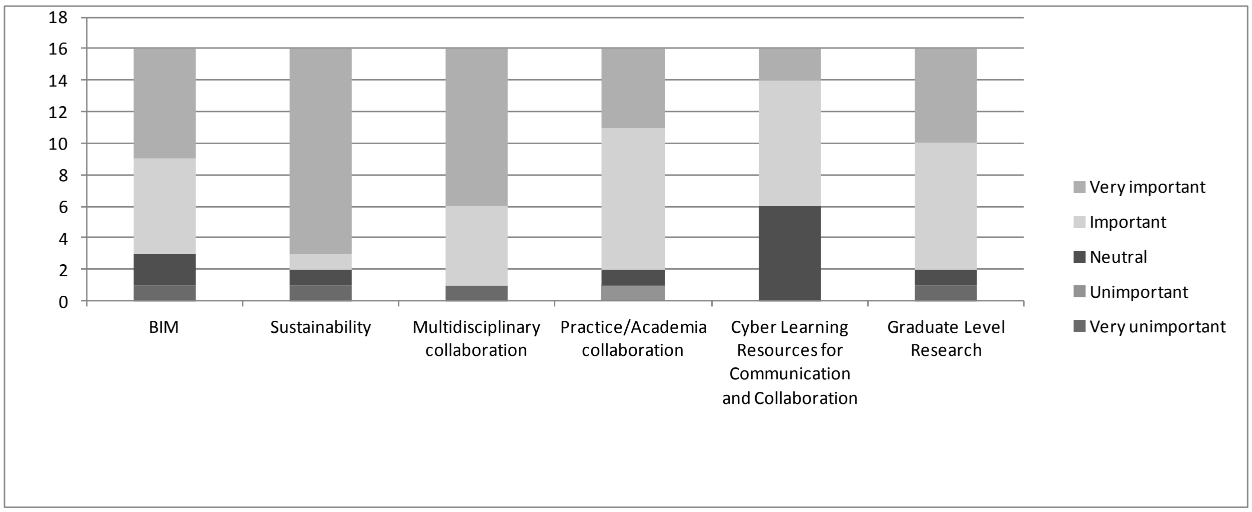
3.1 Context and vision

While the industry structure in relatively similar, the context in which the construction industry evolve is quite different between Canada and the US. In the US, large national public organizations, professional or construction associations played a key role as drivers of changes into BIM and sustainability. This is not the case in Canada where the industry context varies from province to province. For example the requirement for BIM in the US Construction industry starting in 2006 triggered a series of paradigm shifts collapsing the industrial and information revolutions into one. It pushed professional associations to question the underlying foundations of their practices (Broshar, Strong, et al. 2006). In the US, professional and industry associations reacted to new BIM related procurement rules by working together in redefining and integrating practices. There was already an underlying structure that started to take place after the CICE report (1983) with the creation of the Construction Industry Institute (CII). CII, among others, built this learning space between industry and research, a fertile ground to develop the learning workspace necessary to build practice knowledge around BIM. It stimulated exchanges within education and industry about rethinking the curriculum.

Two examples of pioneering use of BIM technology are noteworthy. One of them is Stanford University’s 1993 Computer Integrated Architecture, Engineering and Construction course, which brought together higher educational institutions from the US, Europe and Japan to develop synergistic, multi-disciplinary and organizational approaches to A/E/C design with a focus on developing a team-based environment and methodology (Fruchter 1999). The other is Penn State University’s CIC construction research program, financed by the Charles Pankow Foundation and CII among others, which developed bodies of knowledge summarizing industry best practices regarding the integration of BIM by owners and the preparation of a BIM execution plan. It also provided BIM-related training and served as a launching board for the university’s plans to integrate BIM courses throughout its five-year course program (Forgues, Staub-French et al. 2011). Similar initiatives can now be found in various universities in the US (Barison and Santos 2010).

At the same time, the Canadian research, design, education and construction landscape continued to remain fragmented, and as a result, BIM and sustainable practices are requested less by clients, and taught less by educators.
How AEC education oversees the future? Figure 1 presents what should be its focus in the coming years. Sustainability and multidisciplinary collaboration score high in perceived priorities, a vision that is shared by the US AEC education. The difference of vision regards BIM and Practice/Academia collaboration that are perceived as less important in Canada. This may be explained by way of BIM still not being required by most public clients, hampering BIM adoption by the industry and the pressure on AEC education. Also there is no equivalent to CII, Fiatech or CIFE in Canada to promote collaboration between Practice and Academia.

Figure 1: The importance of trends in the future of the AEC industry



3.2 Building Information Modeling in Canadian AEC education

To the question “Do you offer BIM courses as part of this Program?” only 19% of respondents answered yes. This is far below the rate observed in the US, where the overall proportion was 56% (Becerik-Gerber, Gerber et al. 2011: 414). Like in the US, in Canada, we identified that the pace in which Architecture programs integrated BIM was more than twice as high as in Engineering programs (28% and 11% respectively), while in the US, over 80% of architecture programs offered BIM courses and slightly more than half that number of engineering programs integrated BIM to their courses. In Canada, the earliest introduction of BIM mentioned in the survey occurred in the 2000-2003, while this adoption started earlier in the US (Becerik-Gerber, Gerber et al., 2011: 414).

As shown in figure 2, the majority of architecture-related program respondents who did not offer BIM courses in their curriculum answered that they were planning to integrate BIM to their program (80%) while less than 40% of Engineering respondents had the same answer. Overall, 38% of all engineering and architecture programs were not planning to offer BIM courses in the future, a percentage twice higher than in the US, as only 19% had no plans to include BIM (Becerik-Gerber, Gerber et al., 2011: 414).

Figure 2. Are you planning to offer BIM Courses as part of this program?

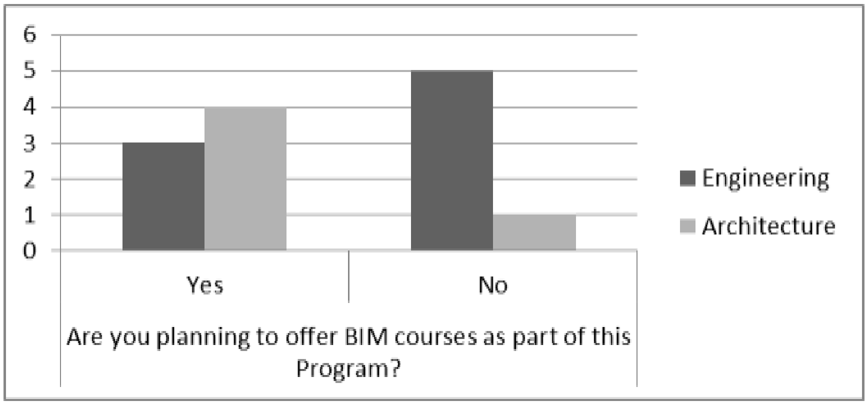
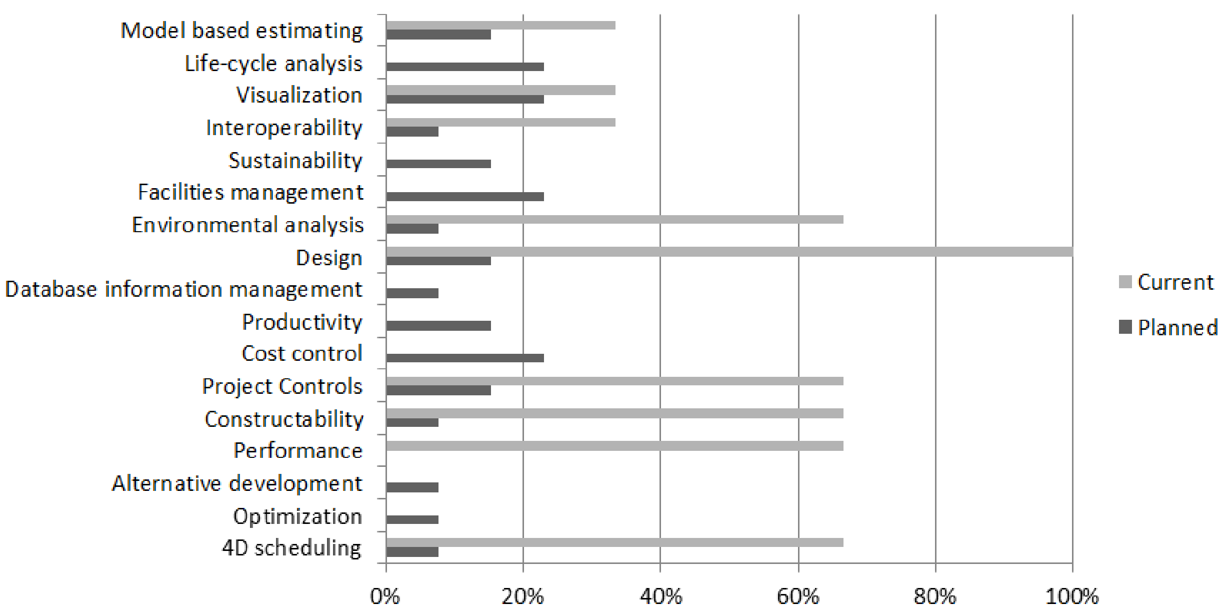


Figure 3 shows the current and planned teaching-related areas in Canada. Based on what was currenlty taught, design led followed by environmental analysis, project controls, constructibility, performance and 4D scheduling, further, these were followed by model based estimating, visualization and interoperability. Interestingly, sustainability, life-cycle analysis, facilities management, database information management, productivity, cost control, alternative development and optimization were identified as planned to be taugh. In 2009, in the US, design was also identified as a leading area that was being taught, however, while sustainability and life-cycle analysis were part of the curriculum and were planned to grow, in Canada, according to the survey, these were not taught with the use of BIM, but there were plans to develop that aspect. In addition, while constructibility, model based estimating and 4D scheduling were identified as an area of growth in the US (Becerik-Gerber, Gerber et al. 2011), in Canada, they were not. The canadian figures may be misleading as only 25% of the respondants answered this question.

Figure 3. Areas in which programs are planning to teach BIM



3.3 Sustainability in Canadian AEC education

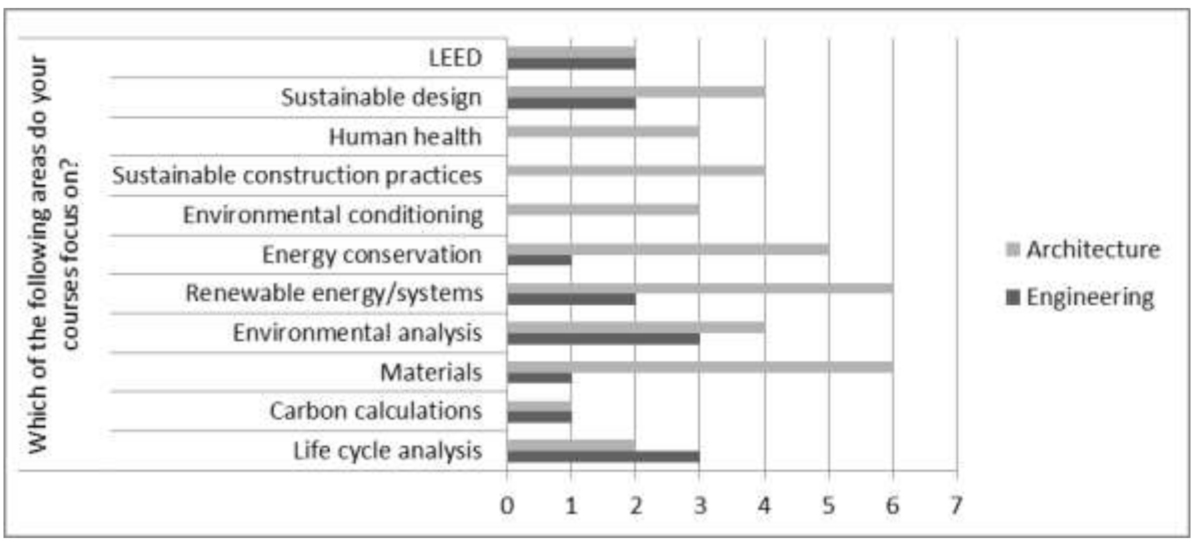
The results of this survey show that 69% of the Canadian AEC programs offer courses in sustainability. While all architecture programs surveyed responded that they included sustainability in the curriculum, less than half of the engineering programs surveyed responded positively.

This is a trend that has also been identified in the US, with a clear lead in architecture programs, however, Canadian engineering programs are lagging behind the ones offered in the US (with 44% in Canada in comparison to 74% in the US) (Becerik-Gerber, Gerber et al., 2011).

All architecture programs responded that they teach how to use sustainability on projects in class.
While over 70% of the architecture programs in the US had sustainability specific courses in 2009, in Canada, this percentage is lower with only 57%. Surprisingly, 56% of Engineering program respondents skipped this question.

As shown in figure 4, while in architecture programs, the emphasis on environmental sustainability is primarily related to the selection of materials, renewable energy/systems, energy conservation, sustainable construction practices, environmental analysis and sustainable design; in Engineering, the emphasis is on life cycle analysis, environmental analysis and to a lesser extent LEED, sustainable design, energy conservation, renewable energy/systems, materials and carbon calculations.

Figure 4. Which of the following areas do your courses focus on?



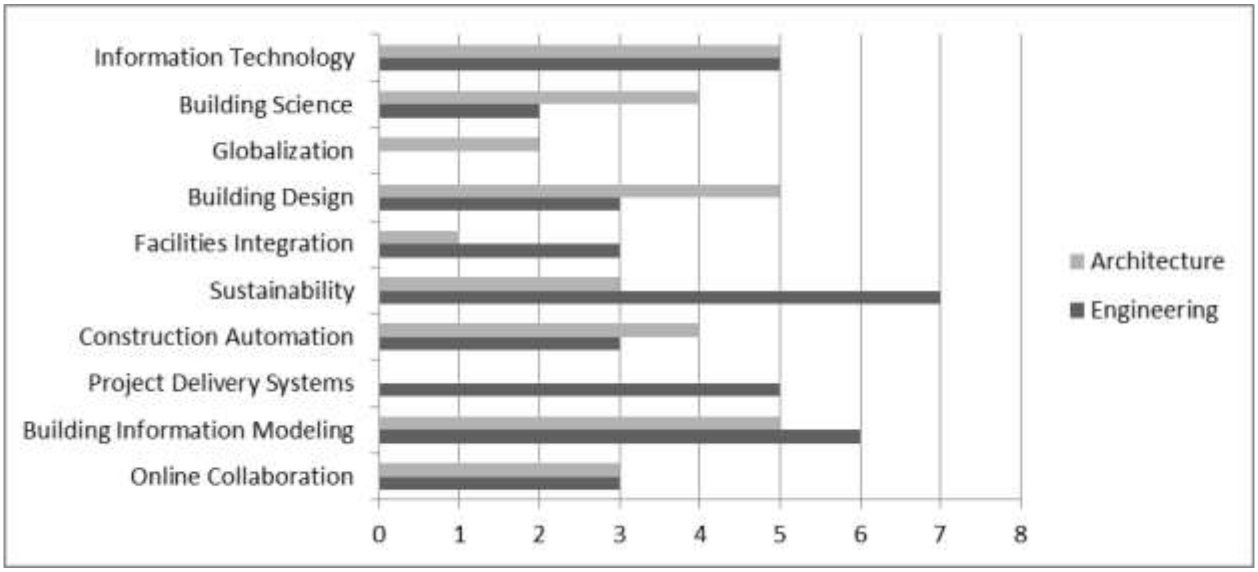
While there are similarities with programs in the US, like the areas of sustainability covered in the courses, and the overall lead architecture programs have over engineering ones, there are also differences, for example, in the US, over 70 % of both architecture and engineering programs incorporate LEED to their courses, in contrast, in Canada, the percentage is lower (with 43% in architecture and 33% in engineering). Further, none of the engineering programs included sustainable construction practices in the Canadian context, while over half engineering programs surveyed in the US mentioned that particular aspect (Becerik-Gerber, Gerber et al., 2011). This gap may be due to the limited number of respondents (44% of the engineering programs who responded to the survey responded to this question).

3.4 Research and collaboration in Canadian AEC education

In Canada and in the US, faculty members responded that they advised their graduate students in a variety of areas including information technology, building science, building design, facilities integration, sustainability, construction automation, building information modelling and online collaboration. As shown in figure 5, in Canada, globalization is taught in Architecture programs, while in the US, it also figures in

Engineering programs; also, project delivery systems is taught in Engineering programs in Canada while in the US it was emphasised in Architecture programs (Becerik-Gerber, Gerber et al., 2011).

Figure 5. Areas of research in which faculty members advise Master's and PhD level students.



All respondents mentioned that they used a virtual learning environment. Like in the US, the majority of Canadian AEC programs use blackboard (50%), followed by Moodle (25%), desire2learn (19%) and WebCt (also 19%). Further, 19% of the respondents used another virtual learning environment (including Second Life, Jump and Aurora as well as a "custom wiki style website") and in four cases, they used a combination. Again, this varies from the US where over 60% of all programs used blackboard and 16% responded they did not use virtual learning environments in their classrooms in 2009 (Becerik-Gerber, Gerber et al., 2011: 425).

Further, 25% of all surveyed programs offer distance education courses, where off campus students can participate in the classroom. Architecture leads as 43% of the respondents answered that they offer distance education courses, while just 11% of engineering programs offer this option. These results are inversed with US where proportionally 37% of engineering and 11% of architecture programs offered distance learning in 2009 (Becerik-Gerber, Gerber et al., 2011).

4 Discussion

"*If the AEC educational community is to set the pace rather than trailing industry, necessary resources need to be allocated to support this change in curricula"*. (Becerik-Gerber, Gerber et al., 2011).

This assertion applies also for the Canadian AEC educational community, especially for the integration of BIM in the curricula. Not surprisingly, AEC education in Canada, as in the US (with some exceptions), is not leading, but trailing the industry on the topics of technological innovations (Becerik-Gerber, Gerber et al., 2011). What is surprising in Canada is engineering education that, as opposed to the US, is moving much more slowly than in Architecture, especially regarding BIM. Only 33% of engineering schools have BIM training, and 66% are not planning to add BIM training in the next two years to their curriculum. This is serious considering that, on the technological drivers of changes, BIM could be considered as the one having the strongest impact on existing professional practices.

The gap could be much wider considering that the survey does not measure the extent of BIM integration in the curriculum. According to our knowledge, there is no equivalent in Canada to Penn State, Stanford, Georgia Tech and Virginia Tech BIM programs and research.

While there is no research in Canada that can help explain the very low level of BIM integration in the AEC education, we can anticipate the issues to be similar to the ones identified in the US (Sabongi 2009, Becerik-Gerber, Gerber et al. 2011) which could be summarized as follows: saturated curriculum, lack of qualified resources and material to teach BIM , and not an accreditation criterion (Becerik-Gerber, Gerber et al., 2011).

What is most striking is the fact that BIM is not considered a revolution in professional practice which undermines the very foundation of programs, but rather a new topic to cover in training. This view contrasts with the observation made in the report of the American Institute of Architects (Broshar, Strong, and Friedman, 2006: 3) the impact of BIM on the practice and teaching:
« These new representational technologies clear a space for teachers and practitioners to re-examine the underlying principles of professional education… So the question is: How might we reformulate the curriculum in view of emerging technologies that allow owners, architects, contractors, and subcontractors to virtually manipulate construction in real time, with exacting precision, earlier in the process… In other words, if this technology stimulates the reformation of architectural (and engineering) services around emerging diagrams of integrative practice, what would a correspondingly integrative curriculum look like? »
Both in the US and in Canada, the fact that BIM is not formally identified in the accreditation criteria also adds to the challenge of not having a more unified and comprehensive BIM adoption approach in the AEC curricula.

In summary, changes in the industry through the adoption of BIM and sustainable construction are mainly industry driven. As asserted by the American Institute of Architects' BIM panel (Broshar, Strong et al. 2006), there is a need to redefine professional curricula to fit the new context of integrated practices. That is, because BIM is a disruptive technology that forces the rethinking both of the practice and the way is it being taught. However, the core problem is the lack of recognition in AEC research and education that existing approaches to improve the curricula will not be sufficient. Knowledge inertia is very strong and modifying curricula is a long and complex process. There is little incentive for academics to make these changes. Moreover, boundaries between specialties are not only about knowledge, but also about physical separation. Teaching AEC disciplines under the same roof is more the exception than the rule.

5 Conclusion

The paper aimed to shed some light on the challenges facing AEC education in Canada. Design, research and construction are becoming increasingly complex. This degree of complexity will keep increasing, and will demand greater proficiency in using these new tools, as well as stronger collaborative skills in applying this new knowledge and in managing the interaction and motivation it requires. The US is quickly adapting its educational programs to these changes. Becerik-Gerber, Gerber et al (2011) and Sabongi (2009) surveys demonstrate the challenges of bringing BIM and integrated practice into the curricula, such as a lack of BIM experts to teach the courses and a lack of resources.

For Canada to catch up to these evolving US industry and education practices, it needs to swiftly update and reform its university curricula to reflect this innovation and integration. Some encouraging signs have appeared in the rising number of large governmental bodies that now request BIM, but this trend needs to continue and turn into a standard requirement. The present paper hopes to contribute to this discussion on the pace and direction of this reform.

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