

A Preliminary Review of Building Information Modeling (BIM) Tertiary Education in the Province of Ontario

Christopher J. Willis, Ph.D., P.Eng, MCSCE and Tulsi Regmi, Ph.D., MCIOB
George Brown College
Toronto Ontario
Canada

BIM education is almost non-existent in Ontario university undergraduate built environment programs, being more established in Ontario's community colleges and polytechnics. Ontario's education of architecture technicians and technologists focuses on BIM's technical competency, that is, the use of software for 3D modeling, whereas the province's only BIM graduate certificate program offered at George Brown College, exposes built environment students to a wider spectrum of competencies such as managerial, functional, operation, and implementation. Ontario's built environment graduates lack competencies associated with BIM support and BIM administration giving rise to the likelihood of construction organizations meeting these requirements by hiring additional specialized human resources or possibly through outsourcing. In order to further investigate the effectiveness of BIM education in Ontario, a series of research studies, such as exploring ways in integrating BIM in Ontario's university undergraduate built environment programs and developing built environment courses that address the competencies BIM support and BIM administration, are recommended. Due to the strict regulation of engineering in Canada, undergraduate construction engineering and management (CEM) programs are non-existent. With this in mind, approaches to BIM education as utilized at various universities in the United States may not be readily transferable to Ontario, Canada.

Key Words: BIM, Built Environment, Canada, Education, Ontario

Introduction

During the past five years, there have been significant advances in the development and adoption of BIM by construction industries throughout the world. Notably, in the United Kingdom (UK), BIM has been mandated by the UK government in the design and construction of publicly funded projects (BIM Task Group (2013), RIBA (2016)). Similarly, in the United States of America (USA), the General Services Administration (GSA), the public entity responsible for the procurement and facilities management of federal government buildings, requires the use of BIM in the design of new federal government facilities (FCW 2006). Fostering this adoption of BIM technologies and processes is the continuous development of BIM software and BIM-related technologies such as mobile technologies, laser scanners, virtual reality headsets, and unmanned aerial drones. In addition, the actions of various governments, e.g., the UK government, has not only resulted in an increase in the development and adoption of BIM by architects, engineers, and contractors, but has also resulted in significant changes in the way construction professionals are educated and trained with respect to new competencies in BIM technologies and processes (NATSPEC, 2015). Unlike the UK and the USA, in Canada, there has been no significant government intervention at both the federal and provincial levels with respect to the adoption of BIM. As such, the adoption of BIM technologies and processes in Canada lags behind both the UK and US (Kissoon *et al.* 2015). In addition, it is believed that the approach to educating and training Canadian built environment professionals has not evolved to include new BIM-related competencies. Unfortunately, there appears to be a dearth of general understanding with

respect to approaches in formal tertiary education that construction industries could adopt to effectively build their BIM capabilities. This situation appears to be pronounced with respect to Canadian approaches to BIM education of built environment professionals, as to-date, there is no clear understanding of how Canadian tertiary built environment education programs should be structured, accredited, and delivered in order to develop BIM competencies in graduates. While research studies done in the area of BIM education relative to other countries are useful in many regards, they do not provide insight with respect to approaches that can be adopted in the delivery of BIM education in Canada, in particular, the Province of Ontario. Recent studies in the area of BIM education include a study by Badrinath *et al.* (2016) that reviewed and analyzed global BIM education research trends and identified six conceptual categories of BIM research, including needs assessment, identification of skill sets, developing education framework, developing BIM curricula, piloting BIM courses, and developing strategies for continual improvement. Interestingly, Abbas *et al.* (2016) analyzed the current state of BIM education in Construction Management (CM) programs in universities of Pakistan and other developing countries through the use of a questionnaire survey, and discovered that the current status of BIM education in Pakistan is unsatisfactory, with the greatest barrier to the successful integration of BIM in CM programs being a lack of BIM-trained faculty (Abbas *et al.* 2016). While the Abbas *et al.* (2016) study is useful in the context of Pakistan, its findings cannot be extended to the Province of Ontario given the differences in both education expectations and the structure of the construction industry in both regions. Interestingly, Lee and Hollar (2013) investigated current BIM trends and practices in the US construction industry in order to propose an approach to leverage BIM within construction education. While the Lee and Hollar (2013) research study is useful in the context of US construction engineering and management (CEM) programs, it is unclear as to whether their findings may be transferrable to colleges and universities in the Province of Ontario. At the crux of Lee and Hollar's findings is the need to integrate BIM into mainstream CEM courses. At present, it is unclear if Ontario's built environment education programs have begun to take this approach or even have the capacity to do so. In summary, there is no clear understanding of the preparedness of Ontario's tertiary education institutions to educate and train built environment graduates in a way that equips them with BIM-related competencies. With this in mind, this research study represents a first step to proposing a roadmap to integrate BIM competencies in Ontario's tertiary built environment education programs. This is important as it will not only serve the increasing demand for BIM-capable professionals but would also produce new opportunities for students in their professional careers by providing them with skills and competencies to deal with new occupational challenges through the application of BIM (Wong et al. 2011). As such, the goal of this research study is to document for the first time, the current state of BIM education and training in Ontario's tertiary built environment education programs.

The objectives of this research study are: 1) complete an environment scan to document Ontario's tertiary institutions with built environment programs that are engaged in various forms of BIM education as well as their current approaches to BIM education; 2) analyze Ontario's single stand-alone BIM education program to highlight its structure and delivery; and 3) provide initial recommendations on the next research steps to better guide the development of BIM education in Ontario. It is expected that this paper will be useful to both built environment academics and Ontario's post-secondary education policy makers as it will provide a useful understanding of the current state of Ontario's approach to BIM education. This understanding will provide a basis on which to plan for the evolution of BIM education and training at the tertiary level.

Research Method and Data Collection

This investigation's data collection and analysis were done in three steps as highlighted in Figure 1. In the first part of the investigation, the websites of universities and colleges were mined to identify built environment programs. This was done by visiting the websites of Ontario universities and colleges, and scanning their undergraduate and graduate programs. Secondly, the curricula and course descriptions of Ontario's various built environment programs

were accessed and reviewed to determine the presence of courses that were likely to include BIM-related content. Thirdly, these courses were tested against a set of educational competency criteria to determine if they qualified as contributing to BIM education.

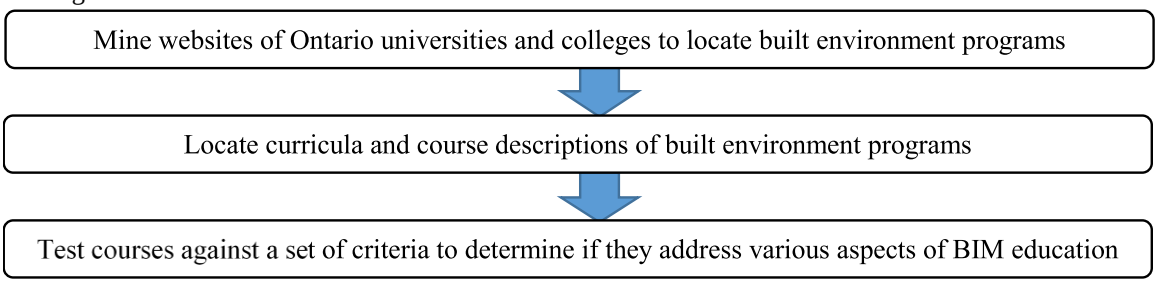

Figure 6: General steps used for the research study's data collection and analysis

Table 1 provides the criteria framework that was used to determine if a university or college-level built environment course qualified as being a course that contributed to educating a built environment student in BIM. This framework was adapted from the BIM competency hierarchy proposed by Succar *et al.* (2013) that identified primary and secondary competency sets associated with an individual's professional abilities in the practice of BIM. The description of courses listed as being part of university and college curricula for identified built environment programs were compared to the descriptions in Table 1 to determine the degree of their contribution to BIM education by exposing students to various BIM competencies. A course was deemed to be a BIM-related course if it satisfied any one of the competencies provided in Table 1.

Table 4: Criteria framework used to determine if a course contributed to BIM education (adapted from Succar *et al.* 2013)

Competency	Description and Example
Managerial	Content and activities that expose students to leadership and organizational management with respect to BIM. *For example: 'understanding and analyzing business benefits and risks associated with implementing BIM technologies and workflows'*.
Functional	Content and activities that expose students to non-technical competencies, such as BIM project management. *For example: 'understanding and being able to facilitate a BIM meeting as a part of project management'*.
Technical	Content and activities that expose students to modeling, drafting, model management etc. *For example: 'using BIM software tools to generate 3D models'*.
Supportive	Content and activities that expose students to information and communication technology systems. For example: *'being able to troubleshoot basic software and hardware issues'*.
Administration	Content and activities that expose students to the administration of a construction organization when adopting and implementing BIM. *For example: 'establishing metrics to measure the financial performance of BIM projects'*.
Operation	Content and activities that expose students to practices required to deliver a project using BIM. *For example: 'using a building information model to generate a quantity takeoff or schedule'*.
Implementation	Content and activities that expose students to introducing and implementing BIM in an organization. *For example: 'developing modeling protocols'.*

The second part of this study, that is, the analysis of Ontario's only stand-alone built environment education program in BIM currently being delivered was done by extracting information from that program's website. In particular, course outlines associated with the program's curriculum were reviewed to determine their focus in terms of BIM competencies and the number of contact hours that students receive with respect to those competencies. The authors believe that this research method is appropriate for initial investigations into new approaches to education and training that have not been investigated before.

Approaches to BIM Education in Ontario

The Province of Ontario's tertiary education system consists of 20 public universities and twenty-four colleges (Ministry of Advanced Education and Skills Development 2016), of which six colleges are classified as polytechnics (Polytechnics Canada 2015). Out of Ontario's 20 public universities, 11 of them have accredited civil engineering programs (Engineers Canada 2016) and four of these universities also have accredited architectural programs (Royal Architectural Institute of Canada 2016). A survey of these universities' websites reveals that four of these universities can be considered as presently offering BIM-related courses as part of their civil engineering programs and/or architecture programs. Table 2 is a listing of these university programs along with a description of the way in which BIM is introduced and taught, and the level at which BIM is taught. Two universities, i.e. the University of Waterloo and Ryerson University teach BIM at the undergraduate level as part of their architecture degree programs. In these two programs, the teaching of BIM is restricted to the use of computer software for 3D model development and visualization purposes. The University of Western Ontario and the University of Toronto each offer a single course in BIM at the graduate level as part of their civil engineering programs. Unlike the other two universities that offer courses that focus on the technical competency of BIM, i.e. the use of BIM-related software for 3D modeling, these two programs, according to the course outlines that are present on their websites, appear to each offer a course that introduces students to the application of BIM in construction practices. It appears that at the graduate level, these two universities each offer a single course that equips students with limited functional competency in BIM and no apparent technical competency.

One possible reason for the lack of BIM education in Ontario's undergraduate university built environment programs, particularly civil engineering programs, is that these programs are not construction engineering and management (CEM) programs, neither do they allow students to specialize in CEM. In fact, Ontario's undergraduate university civil engineering programs focus on the traditional aspects of civil engineering, such as geotechnics, structures, and transportation, to name a few. Based on this, the course offerings in these programs are significantly grounded in the areas of math and applied science, as opposed to the practices of construction engineering and management. This is a noteworthy difference compared to universities in the USA which offer separate and distinct degree programs in CEM and CM and the evidence suggests that they may be ahead in integrating BIM into their curricula.

Table 5: List of Ontario University programs & the way in which BIM is taught

Name of Program	Description of BIM Education within Curriculum	Level of Education
University of Western Ontario – Civil Engineering Program[1]	BIM is taught in CEE9518 – Building Information Modeling[1]	Graduate[1]
University of Waterloo – Architecture Program[2]	BIM is taught in ARCH113 – Visual Communication, where students are exposed to the use of 3D modeling software[2]	Undergraduate[2]
Ryerson University – Architecture Program[3]	BIM is taught in ASC520 – Integration Studio 1, where students apply BIM in the preparation of a feasibility study and schematic design[3]	Undergraduate[3]
University of Toronto – Civil Engineering Program[4]	BIM is taught in CIV1298H – Special Studies in Civil Engineering – BIM, where students are introduced to the basic principles of BIM throughout the project cycle[4].	Graduate[4]

[1](University of Western Ontario 2016), [2](University of Waterloo 2016),[3](J. McArthur, personal communication, December 09 2016), [4](University of Toronto 2014)

The above-mentioned is supported by the fact that Ontario universities with built environment programs in civil engineering are accredited by the Canadian Engineering Accreditation Board (CEAB). At present, CEAB's present listing of graduate attributes and minimum curriculum components does not identify or promote the use of BIM

technologies and processes concomitant with construction management as being requirements in civil engineering education (see Engineers Canada 2015). A direct consequence of this is that Ontario universities with civil engineering programs are not motivated to include courses in BIM and develop requisite delivery capacity as part of their undergraduate curriculum.

A review of Ontario's 18 community colleges' programs reveals that at present, only those colleges with architecture technology programs offer training in BIM as part of their CAD courses. These courses are limited in scope as they introduce students to 3D-modeling and do not extend to the implementation of BIM processes and technologies in construction project management. In this regard, Ontario's community college architectural technology programs provide a low level of BIM education where students become proficient in the use of BIM-related drafting technology for 3D modeling and therefore have only technical competency in BIM. This is expected as graduates from Ontario's community college architecture 2-year technician and 3-year technology programs are expected to meet general curriculum requirements as set by the Canadian Council of Technicians and Technologists (CCTT), which emphasizes competency in the use of computer hardware and software to perform tasks within their discipline (CCTT 2016). This means that at present, Ontario-trained architecture technicians and technologists are not required to demonstrate extensive competencies in BIM identified by Succar *et al.* (2013) as part of their requirements for graduation and certification as architectural technologists.

The current situation with respect to BIM education in Ontario's six polytechnics is slightly different from the situation in Ontario's public universities and other community colleges. Table 3 is a list of Ontario's polytechnics that offer built environment education programs and brief descriptions of their approaches to BIM education. All six of the polytechnics provide some level of BIM education by offering a stand-alone course or courses in 3D-modeling as part of a larger education program such as architectural technician/technology diploma. In addition, three of the polytechnics offer software training, more so, Revit training through their schools of continuing education. Interestingly, one of the polytechnics, George Brown College, has established a stand-alone graduate certificate program in Building Information Modeling Management (BIMM) that has a study duration of 12 months. In addition, BIM education has been integrated to a very limited extent in Ontario's only 4-year Bachelor of Technology (B.Tech) degree program in construction management that includes two stand-alone BIM courses, that is, Introduction to BIM and BIM Management.

Table 6: List of Ontario Polytechnics and descriptions of their approach to BIM education

Ontario Polytechnic	Description of approach to BIM education
Algonquin College[1]	BIM is taught in CAD/drafting courses in Architecture Technician and Technology programs
Conestoga College[2]	BIM is taught in individual CAD/drafting/computing courses in Interior Design, & Architecture Technician & Technology courses.
Humber College[3]	BIM is taught as stand-alone courses in the following programs: Engineering Software Skills Enhancement, Revit education in the School of Continuing Education, Architecture and Technology.
Seneca College[4]	BIM is taught as stand-alone courses in the following programs: Civil Engineering Technician and Technology, & Revit education in the School of Continuing Education
Sheridan College[5]	BIM is taught as stand-alone courses in the following programs: Architectural Technician Program
George Brown College[6]	BIM is taught as stand-alone courses in the following programs: Construction Management Bachelor Degree, Architectural Technician, and Technology, Revit Education in the School of Continuing Education. BIM is taught in a graduate certificate program in Building Information Modeling Management.

[1](Algonquin College 2016) [2](Conestoga College 2016A, 2016B) [3](Humber College 2016A, 2016B) [4](Seneca College 2016A, 2016B) [5](Sheridan College 2016) [6](George Brown College 2016A, 2016B, 2016C, 2016D)

The above review has highlighted that currently tertiary education in BIM in Ontario is prevalent predominantly in Ontario's community colleges and polytechnics, and is almost non-existent in Ontario's university built environment programs. It appears that in most instances, built environment students at the architectural technician and technologist levels are exposed to and become proficient in BIM-related 3D modeling software. It is apparent that these students are not educated in BIM processes, such as BIM planning and execution, BIM workflows, BIM-enabled project management processes and organization implementation processes. As such, these built environment graduates will require some form of on-the-job training to become better competent in BIM. A direct implication of this state-of-affairs is that it is unlikely that the Ontario construction industry's uptake of BIM will become widespread in the near future owing to the lack of structured BIM training and education. At the graduate level, George Brown College's BIMM Graduate Certificate program appears to provide students with a wider scope of building information modeling competencies. This unique approach to BIM education in Ontario is discussed in the proceeding section of this paper.

Analysis of Ontario's Stand-alone BIM Education Program

In the province of Ontario, there is a single tertiary education program in the form of a graduate certificate program that is exclusively devoted to BIM education. This program is offered by George Brown College and commenced in January 2015. Table 4 is a list of courses that are part of George Brown College's Building Information Modeling Management (BIMM) graduate certificate program, the semester in which they are offered and the contact hours associated with each course. At present, students are required to complete 11 in-class courses over two semesters, followed by a work practicum. In semester 1, students are introduced to different types of software and learn about the capabilities of those software. In semester 2, students apply the skills and competencies learned in semester 1 to real-life projects, in addition to learning how to plan and implement BIM in organizations and on projects. Finally, in semester 3, students complete a work practicum which provides hands-on industry learning and practice.

Table 7: List of courses that are part of GBC's BIMM graduate certificate program, semester offered and contact hours (Source: George Brown College 2016D)

Course ID & Name	Semester	Contact Hours
BIM 1002: BIM Management	Semester 1	56
BIM 1003: BIM Software Integration	Semester 1	56
BIM 1071: Workplace Preparation	Semester 1	28
BIM 1004: Revit Architecture 1	Semester 1	21
BIM 1005: Revit Architecture 2	Semester 1	42
BIM 1006: BIM Preconstruction Practices	Semester 1	42
BIM 1010: BIM Implementation Strategies	Semester 2	56
BIM 1011: BIM Project Planning	Semester 2	56
BIM 1012: Building Energy Modeling	Semester 2	56
BIM 1013: BIM Capstone Project	Semester 2	42
BIM 1014: Work Practicum Preparation	Semester 2	14
BIM 1020: BIM Work Practicum	Semester 3	560

Figure 2 is a mapping of the program's in-class courses according to BIM competencies identified by Succar *et al.* (2013) and shown in Table 1. It is apparent that the program's first semester focuses primarily on the BIM competency sets: *operation* and *technical*. The BIM competency sets: *implementation* and *functional* are not addressed until the program's second semester, building on the competencies imparted during the first semester.

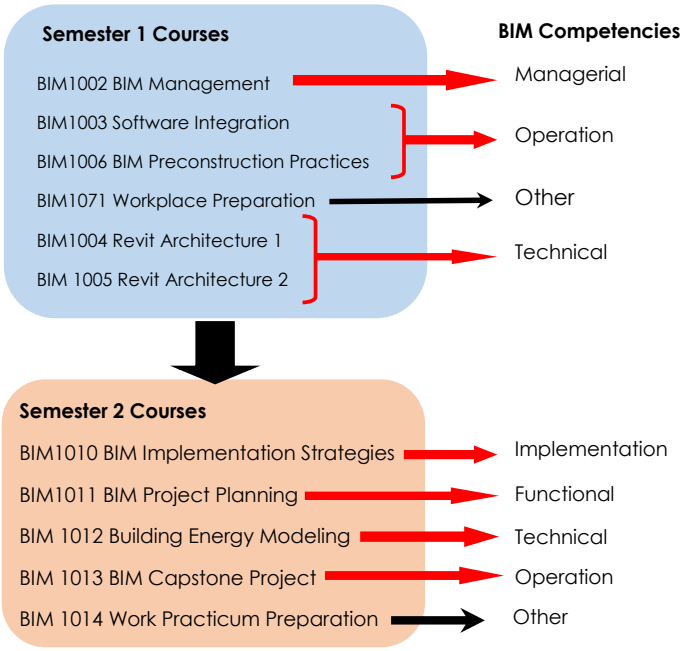

Figure 2: Mapping of program's in-class courses according to BIM competencies

Figure 3 is an analysis the GBC BIMM program's contact hours according to BIM competencies as identified by Succar *et al.* (2013). The contact hours for in-class courses in semesters 1 and 2 were assigned to the BIM competencies: *managerial, functional, technical, supportive, administration, operation, implementation,* and *other*. The *other* competency accounts for the skills and knowledge gained from the courses 'workplace preparation' and 'work practicum preparation'. Contact hours associated with the program's work practicum were excluded from the analysis as the work practicum was a mix of all competencies, the breakdown of which would be different for each student. The *operation competency* is addressed the greatest through the program's in-class courses and accounts for 140 contact hours. The *technical competency* is second, accounting for 119 of the program's in-class contact hours, while the *managerial*, *functional*, and *implementation* competencies each accounted for 56 of the program's in-class contact hours. Noteworthy is the observation that the program's in-class courses do not address the competencies *supportive* and *administration*. The major implication of these findings is that built environment graduates of GBC's BIMM program have significant competencies in technical and operational aspects of BIM management, but have no competencies in the supportive and administration aspects of building information modeling. This means that Ontario construction organizations that are engaged in the utilization of BIM are likely to have to hire separate individuals to provide services with respect to the support and administration of building information modeling in their organizations and on their projects.

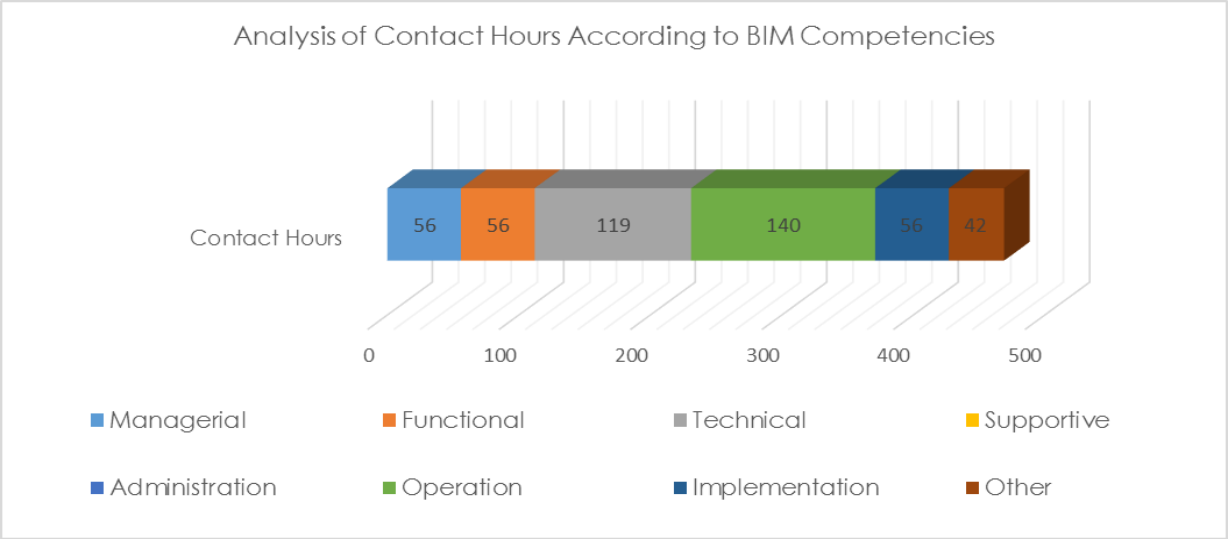

Figure 3: Analysis of program's contact hours according to competencies

Conclusion

This investigation is the first to assess the current state of BIM education in the province of Ontario. It was discovered that BIM education of built environment students in Ontario exists mainly in built environment programs offered by the province's community colleges and polytechnics, whereas BIM education is virtually non-existent in university built environment undergraduate programs. It appears that architecture technicians and technologists educated in Ontario are competent in technical aspects of BIM, but it is still unclear as to the extent of their technical competency. While graduates of George Brown College's BIMM graduate certificate program appear to possess a wider spectrum of BIM competencies as proposed by Succar *et al.* (2013), it is uncertain as to whether these built environment graduates are effectively meeting the construction industry's needs for BIM-enabled construction practices. With this in mind, the following are potential research studies that should be implemented to better guide the development of BIM education in Ontario:

1. Determine BIM competencies required by Ontario's construction organizations.
2. Explore ways of integrating BIM in civil engineering curricula in Ontario university programs and reformulating construction management programs in Ontario polytechnic programs.
3. Develop courses to impart BIM competencies such as *BIM support* and *BIM administration* competencies in built environment graduates.

It should be pointed out that this research study focused on BIM education as offered by public education institutions and did not consider unaccredited private career colleges and training centers. As such, the authors recommend that a separate environment scan is done to determine the current state of BIM education in private career colleges that may be engaged in built environment education and training. The authors would also like readers to be cognizant that at present there is no industry or government body that is actively accrediting BIM education in Ontario Canada.

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