

THESIS

INTEGRATING BIM AS A TEACHING TOOL IN EXISTING CONSTRUCTION
MANAGEMENT CURRICULA: A CASE STUDY

Submitted by

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In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Fall 2021

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ABSTRACT

INTEGRATING BIM AS A TEACHING TOOL IN EXISTING CONSTRUCTION MANAGEMENT CURRICULA: A CASE STUDY

Building design and construction delivery methods are becoming more complex while construction durations are simultaneously being reduced. Today the construction industry is leveraging technologies including Building Information Modeling (BIM) to improve project delivery. BIM applications are used in the construction industry as the platform on which design build and integrated project delivery (IPD) is practiced to complete construction task such as: lift and shop drawings, cost estimating and cost management, generation and analysis of project schedules, logistics analysis, and project marketing. BIM technologies are also used to facilitate more clear communication between all members of a building project development team. Literature review and professional experience reveals that the construction industry needs graduates with some aptitude for BIM. Further, an experiential understanding of BIM applications is imperative for construction management graduates to navigate the growing complexities of project delivery to meet industry demand.

This study investigated the integration of BIM within an existing graduate-level construction management course at Colorado State University (CSU). An exploratory sequential case study approach was implemented to conduct a cross-sectional study of quantitative and qualitative data. The investigation is grounded in the researcher's ongoing professional work in facilities management at CSU, and a review of literature to establish the need for BIM exposure, experience and aptitude in the construction industry. This study initially explored BIM integration and teaching methodologies in the architecture and engineering disciplines. The researcher applied the expanding use of BIM in architectural engineering education to inform technology integration within construction management

curricula. A survey was distributed to gather data on the student experience with BIM as well as their pre- and post-class perceptions of the learning opportunities and outcomes of BIM integration in a graduate construction management course. After compiling the data from quantitative Likert scale items, the researcher conducted paired samples t-tests: comparing the same people on one variable, at the pre-test and post-test intervention for students taking the CON 571 class. The objective of running the paired t-tests was to determine if student perceptions of their experience with BIM and associated development planning assignments were significantly different before and after taking CON 571. A significant difference in the mean at pre-test and post-test was observed and results suggest that the students were learning the technology and the course materials at the same time.

The study leveraged the researcher's work as University Architect and Manager of Capital Design and Construction at Colorado State University coupled with a parallel appointment to teach the Facility Planning and Management (CON 571) course. The researcher has taught CON 571, each fall, for eleven years, and this case study focuses on three semesters where BIM was fully integrated into the existing curricula. The course used actual projects in various stages of development on Colorado State University's campus and sequentially taught the project development process. The content and teaching used BIM to align assignments directly with the development process, starting with master planning, building, programming, project marketing, conceptual building design, building code analysis, cost estimating, scheduling with logistics planning and concluded with construction documentation. Through the integration of three-dimensional technologies, the building information models evolve through the duration of the course and result in a detailed facility that was originally identified on the student's conceptual master plan.

An exploratory case study approach was implemented to conduct a cross-sectional study of quantitative and qualitative data through literature review research, professional experience and interactions, surveys and analysis. The investigation is grounded in the researcher's ongoing professional

work, and a review of literature to establish the need for BIM exposure, experience and aptitude in the construction industry.

The study provides evidence that BIM can be successfully integrated into existing construction management curricula to promote the critical thinking, planning and problem solving required of successful construction management graduates and practitioners. BIM was successfully used as a tool to teach the existing curriculum in CON 571 which focuses on the project development process at Colorado State University. The results revealed that the students learned the existing course material, emerging delivery methods, and the BIM technologies simultaneously. This study suggests that BIM can be integrated into existing curriculum and that separate classes focusing on the technology itself may not be needed. The study also illustrates teaching methodologies developed in the subject course that can be utilized in other courses to support the integration of BIM across existing AEC curricula.

Identified in the literature review and supported by the researchers work experience, this research builds on current educational and professional practices using BIM technologies in design, construction and development. The results are helpful for professionals involved with both the teaching and practice of integrated project delivery, specifically, design-build. That said, continuing efforts to integrate BIM into Construction Management education is needed. Further research should focus on teaching methodologies, more mobile and site-based technologies, and the adaptation of this parametric, data driven tool to encourage discovery and innovation in both project documentation and delivery. BIM is rapidly changing the way buildings are procured, constructed and delivered. Preparing construction management students to leverage BIM applications, while still obtaining a solid foundational CM knowledge base, is paramount for preparing students to enter a quickly advancing Architectural Engineering and Construction (AEC) industry.

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LIST OF KEYWORDS

AEC Industry	Architecture, Engineering and Construction Industry.
Building Model	The virtual or electronic representation of the construction project to inform the physical development.
Design Build	Construction project delivery method where the Owner holds one contract with the design builder. Due to project bonding requirements, the design builder is usually the general contractor who contracts with the architect, engineer and required subcontractors to complete the contracted scope of work. Design Build often allows for fast track project delivery.
Discipline	As related to a specific body of study or practice.
Fast Track	Developing a project with an accelerated design and construction schedule. Construction work is started while the design work is still in progress.
Parametric	In reference to the Building Information Modeling database, the capacity to change data in one model view and have the change reflected in all other model views.

Pedagogical	Educational parameters that influence instruction often based in theory.
Virtual	A computer generated representation of a physical object
Gantt Chart	A mechanism to graphically schedule and review construction activities with a horizontal and vertical axis. Horizontal duration of construction activity over the vertical inclination of time. The chart shows work done or production in certain periods of time in relation to the amount planned for those periods.
Null Hypothesis	A hypothesis that states there is no significant difference pre-test to post-test or no significant difference between identified study participants.
Alternative Hypothesis	A hypothesis that states there is a significant difference pre-test to post-test or a significant difference between identified study participants.

LIST OF ABBREVIATIONS

4D	Refers to the integration of construction cost estimating in BIM.
5D	Refers to the integration of schedule and logistics in BIM.
BIM	Building Information Modeling
CSU	Colorado State University
IDP	Integrated Project Delivery. Collaborative project delivery model with shared risk and reward. The owner, architect, contractor, subcontractors and suppliers work together from project inception through occupancy to develop best value in project delivery.
PDF	Portable Document Format – In working with BIM, often used as a printing driver to export information from the virtual model to two dimensional sheets which can be used in further analysis.
RFQ	As in project procurement, the Request for Qualifications
RFP	As in project procurement, the Request for Proposals

CON 571	Course Identification Code – Construction 571 Facilities Planning and Management
CM	Construction Management
O&M	Operations and Maintenance
N	The number of participants in a study.
M	The mean or average of the sample study results.
SD	The standard deviation is a statistical measure of the distribution of a data set when compared to the data set mean.
t	The t-statistic or t-stat is the ratio of the departure of the estimated value of a parameter from its hypothesized value.
df	The degree of freedom is defined as the number of observations in a sample or data set that can vary when estimating statistical parameters.
p	The p-value is the probability factor, a number between 0 and 1 interpreted as a small p-value (typically less than 0.05) supports the alternative hypothesis and a large p-value (typically greater than 0.05) supports the null hypothesis.

Chapter 1: Introduction

Building information Modeling (BIM), without any proprietary reference, can be defined as developing a project virtually prior to, and perhaps during, actual physical construction (Becerik-Gerber & Kensek 2009. Technology in the Architectural, Engineering and Construction (AEC) disciplines is an ever-evolving interface and BIM is currently being used for building design development (Azhar, 2011). Further, BIM applications are rapidly changing the way building projects are procured, built and managed (Clevenger & Rush, 2011) and students and professionals embrace the opportunity for continued learning and integration of these technologies throughout their careers (Hardin, 2015; Bryde, 2013; Clevenger, 2010; Azhar, 2011; Huang, 2018). Therefore, preparing students to leverage these tools when entering the AEC industry is paramount. Yet, while the incorporation of BIM applications in existing curricula within Architectural and Engineering coursework is robust (Lee, Ponton, Jeffreys, & Cohn, 2011), the integration of BIM within the construction management (CM) educational discipline is limited (Uddin & Khanzode, 2014).

Given advances in BIM integration throughout the AEC industry and limited evidence of implementation within CM education (Huang, 2018), this study investigated teaching methodologies to deploy BIM as a parametric, data driven tool to deliver curricular materials in an existing graduate-level construction management course entitled CON 571: Facilities Planning and Management. The researcher, who was the instructor of record in the course, implemented a case study approach in course development and curricular adaptations were documented over a three-semester timeframe to explore BIM integration as a teaching tool. A survey of students was deployed to collect quantitative and qualitative student perceptions of BIM exposure and learning during the three-semester case study duration.

Professional Experience

Evidence for the proliferation of BIM in the construction industry and the associated need for graduates with experience using BIM, was gathered through literature review and the researcher's experience in developing highly complex projects over the last decade at CSU. While this research is anecdotal, it did encourage the researcher to empirically explore the implementation of BIM technologies in the classroom to prepare student for entry into the industry upon graduation. From the researcher's experience, construction companies developing projects at CSU are using some form of BIM technology and/or software. On large and complex projects, we see BIM being used on site. Construction trailers are now outfitted with a BIM based virtual construction interface that is directly informing trade communications, sequencing of operations, schedule management and impacting the physical construction of the project itself. While not an exhaustive list of BIM technologies being used, the researcher commonly observed the use of Adobe, Bluebeam, AutoDesk Revit, BIM 360, and Navisworks on site by AEC stakeholders participating on CSU projects.

Research Question

The use of BIM in a classroom setting can emulate real world problems and associated solutions (Huang, 2018). This research builds on the educational and professional use of BIM and explores a pragmatic method to integrate BIM into existing construction management curricula. The aim of the study is to integrate BIM as a teaching tool and simultaneously assess student learning, perceptions of the technology and course material. The goal of the case study was to integrate BIM into an existing CM course and determine if the technology could be learned at the same time as the course materials without the need for a separate course focused only on the technology. Therefore, the case study investigated the following overarching research question:

1. Can Virtual Design and Construction (VDC) applications be used to effectively teach BIM technologies and CM course materials at the same time?

A case study approach was implemented to conduct a cross-sectional study of quantitative and qualitative data through literature review research, professional experience and interactions, student surveys and analysis. The investigation is grounded in the researcher's ongoing professional work, and a review of literature to establish the need for BIM exposure and learning theory to support BIM integration within existing CM curriculum. The student survey results included both qualitative and quantitative data. After compiling the data for quantitative Likert scale items, the researcher conducted paired samples t-tests: comparing the same people on one variable, pre-test and post-intervention for students taking the CON 571 class. The objective of running the paired t-tests was to determine if student perceptions of their experience with BIM and associated development planning assignments were statistically and significantly different before and after taking CON 571.

Researcher Background

The researcher is an instructor, graduate student, licensed architect, ICC certified building official, former builder and currently the University Architect and Chief Building Official for Colorado State University (CSU). With highly capable teams, the researcher has engaged in the delivery of nearly \$1.6 billion in capital development projects at Colorado State University over the last fifteen years. These various experiences have formed the basis for the research, and they impacted the development of the case study and the graduate course under study.

University Development Process as Course Development Basis

Over the last fifteen years, CSU has been revitalized to promote teaching, research and discovery for the next century. Practical and pragmatic experience suggests the integration of technology has been a critical component of successful project delivery not only at CSU but in

professional practice. This foundation and existing knowledge of BIM deployed through actual building development significant in the ability to leverage BIM in the classroom.

While this study was formalized over several years, and deployed in a three-semester case study, the integration of BIM in the CON 571 course began in 2009. Figures 1.1a and 1.2a represent the virtual model and completed Behavioral Sciences Building (BSB) occupied in 2010 at Colorado State University. Figure 1.1b and 1.2b show the new Health and Medical Center (HMC) occupied in 2017. Both projects, and many others, have been used as course materials in CON 571. These projects illustrate the evolution of a BIM, e.g., in-house design development, procurement, project acquisition and delivery strategies.

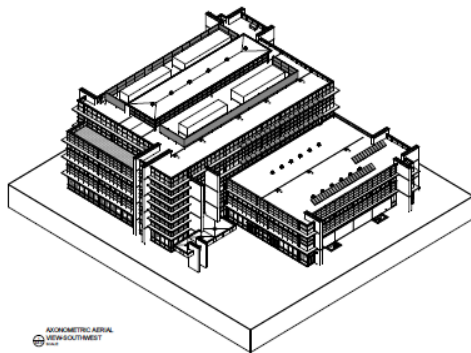


Figure 1.1a BIM MODEL – BSB 2008



Figure 1.1b Built Project – BSB 2010



Figure 1.2a BIM MODEL – HMC 2015



Figure 1.2b Built Project – HMC 2017

The building development process at CSU (Figure 1.3) has evolved towards the exclusive use of a highly collaborative, team-based Design Build Lump Sum (DBLS) project delivery method. CSU develops very explicit and detailed bridging documents using BIM applications. These bridging documents integrate highly refined performance specifications, a comprehensive site survey and geotechnical report to accurately inform a project-specific Request for Proposal (RFP). The researcher, as part of his employment responsibilities, develops an initial BIM depicting the project's design, aesthetics and component makeup as a part of the capital fund raising effort. At the same time, the BIM is utilized as a tool for developing the total development cost model. Once a plan of finance is secured, the native model is then used to create the DBLS RFP document.

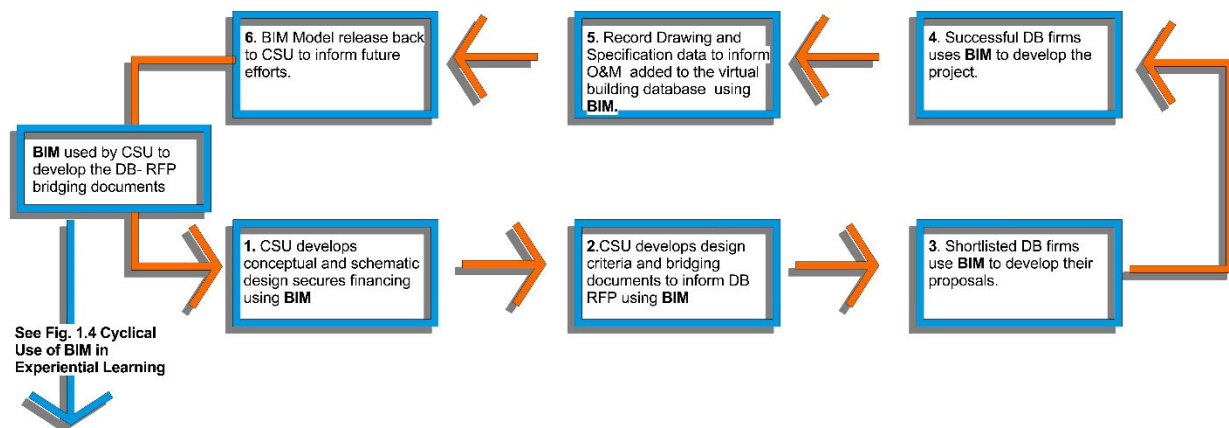


Figure 1.3 – Working Path of the BIM Model in the Development Process at CSU

The products of the BIM are released to three selected or shortlisted design-build firms for reference. The competing Design-Building firms further develop and refine the BIM through a series of stakeholder pre-proposal meetings to inform their lump sum cost proposals. The selected design build firm continues to use the BIM developed through the procurement to finish the contract and construction documents and as the base for subcontractor shop, lift and other associated drawings. On larger, more complex, projects the same model is used both internally and externally for logistics

studies, scheduling and sequencing during construction and through project occupancy. As the project is constructed, the BIM is kept up to date and populated with supplier, operation and maintenance data. Upon occupancy the BIM is released back to the owner (CSU) as a contractually required record document. The model will eventually be used to operate and maintain the facility. Over the duration of this study the DBLS project development process at CSU has evolved from a highly prescriptive DBLS acquisition strategy with heavy bridging documents to a target value based DBLS process with performance specifications. The target value-based acquisition strategy allows more industry innovation. It also reduces risk for the Owner and requires less time and resources invested in the bridging document development. This real time evolution and associated discussion informed many of the CON 571 class sessions.

As illustrated in Figure 1.4, the most current on-campus buildings projects and the related development process informed the CON 571 course content. For example, in 2015 the DBLS acquisition strategy evolved from the traditionally used highly prescriptive bridging documents to a more performance-based document development approach under a new target-value based DBLS methodology. Both acquisition strategies were leveraged in the course as an opportunity to discuss the merits of these project delivery methods. This allowed the students to consider the most appropriate approach from the perspective of the Owner, and the DB Firm in terms of quality, efficiency and risk management. Both the prescriptive bridging document and target value-based Design-build RFP development require master planning, logistics planning, site planning, building programming, building design, building code analysis, cost estimating, specification development, construction standards development, operational expectations, and life cycle cost analysis.

The initial and overarching concept for CON 571 requires the students actively prepare the component parts of DBLS RFPs using BIM to help prepare them to respond to the same documents in professional practice. The procurement and contracting methods are also studied with opportunities to

discuss challenges and opportunities in real time on real projects. All of these project attributes are learning objectives of the course. Figure 1.4 illustrates that professional practice at CSU builds to teaching materials for CON 571, builds to the integration of technology in CON 571 using methodologies from actual practice. We use the actual design-build projects to inform research, practice, teaching and delivery.

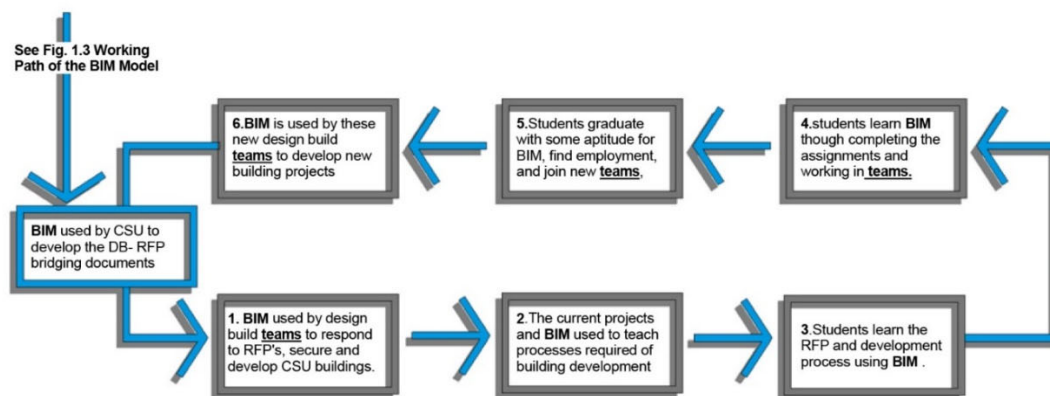


Figure 1.4 Cyclical Use of BIM in Experiential Learning

CON 571 was a dynamic course in that it changed each year to align with the actual projects in development. The course is grounded in the existing framework of CSU project development process that promotes the solving of actual, building development and industry-specific problems through experiential learning. In CON 571, the integrated and experiential teaching process is intentionally cyclical and mirror CSU's project development processes (See, Figure 1.3 and 1.4):

1. The instructor describes how BIM is used by design build teams to develop the buildings currently in development on campus.
2. BIM is used to teach the materials and learn the processes required of building development using the actual building projects.

3. BIM is used by the students in teams to complete the course assignments, the components parts of a Design-Build RFP.
4. The students learn BIM technology through completing the assignments and working in teams.
5. The students obtain aptitude for BIM while learning the course materials.

Description of the Course

During CON 571 students participated directly in the processes of master planning, building programming, conceptual building design, building code analysis, cost estimating and creating construction documents through the course exercises and assignments. The course used actual projects in various stages of development on Colorado State University's campus and sequentially taught the project development process. The curriculum utilized BIM on existing projects to directly align teaching with the development process; master planning, development planning, programming, project marketing, conceptual building design, building code analysis, cost estimating, and scheduling with on-site logistics planning. The course concluded with, student-created, BIM-generated documents. Through the integration of three-dimensional technologies, the building information models evolve through the duration of the course and resulted in a detailed facility that was originally identified on the student's conceptual master and development plan.

In analyzing the relationship between instructor, student and practitioner, graduate student education presents an ideal opportunity to explore integration with a vast sampling of experience levels and with students from various AEC disciplines. Graduate students often arrive in the classroom with professional work experience and can readily reflect on industry needs and opportunities. This experience informs robust discussion and motivates innovation, discovery and attention to instruction.

Emulating design and construction practice in the classroom to solve problems requires student to complete research and implement new processes in order to meet the development planning-based course requirements.

We can readily ascertain that effective communication is critical in the building development process (Aspin, 2007; Azhar, S. ,2011). Today's fast paced, technologically driven AEC industry requires clear and concise communication. In practice, construction cost estimating and cost management are commonly referred to as 4D and is enhanced by the database driven information derived from the use of BIM (Kim, 2012). Effective use of BIM can help accommodate communication and is often critical in fast-track schedule management. Schedule management and the associated communication with building owners, subcontractors and suppliers often utilize BIM models and scheduling software to create virtual representations of how the building will be constructed over time. This process is commonly referred to as 5D schedule management in the construction industry (Bryde, Broquetas, & Volm, 2013). Exploration and utilization of 3D, 4D and 5D BIMs are components of my work responsibilities in professional practice. In class instruction the researcher describes methodologies to use BIM as a teaching tool following a workflow similar to the BIM process used to develop buildings designs in practice. The course explored and exposed students the use of BIM in Integrated Project Delivery (IPD), Collaborative IPD methods such as design- build. Specifically, the class explores target value design build lump sum project delivery methods, as this prepares students for what has become the most prominent project delivery method utilized in new project builds by the facilities department at Colorado State University. Under the design-build delivery method, the architect, engineer and contractor are part of a design build team under a single contractual agreement with the owner (Songer, 1996; Lopez del Puerto, 2008). The course development is further explained in chapter 3 and syllabi can be found in the Appendix IV.

Significance of the Study

The results of this study inform BIM integration within CM curricular development to better prepare students for professional practice. Industry can benefit from students that are not playing catchup upon initial employment but instead leading the charge with innovative strategies to leverage technologies having experienced the full BIM integration required to complete problem solving-based assignments. This research will add to the pedagogical body of knowledge in CM and provide an example of successful integration to help encourage and influence the preparation of construction management students for a career in a highly competitive industry where innovation has become more relevant, if not required, for success.

The integration of technology is a common focus of 21st century education. It requires experimentation, feedback, refinement and cyclical interventions over many years. The use of technology can encourage a greater understanding of the content while maintaining the need to retain critical thinking skills (Koehler,2007).

Understanding the emerging, team-based, collaborative structure of IPD was a critical component of the class. BIM was used as a communication tool in the course to teach workflow processes as well as document the workflow of each student-team. Students also embraced the value of their peers in a team setting as they struggled individually with the material but quickly gained understanding in a team setting. The team work and collaborative problem solving is considered efficient and effective in private practice (Tsay & Brady, 2010).

This course leveraged an opportunity to educate future industry leaders with immediate, actual and relevant content, regardless of which AEC discipline they ultimately reside in. The study sought to develop and further advance curriculum that will ultimately provide graduate students with an aptitude directly aligned with emerging industry demand. The course was adapted from existing pre-BIM CON 571 curricular material, with the major change being the use of BIM as a teaching tool that allowed

students to learn course materials and the BIM applications at the same time. The study describes one methodology that can be used to help student solve the construction and design problems using BIM. Ultimately the research investigated the use of BIM in the CON 571 course to explore student abilities and perception of their own BIM skills to learn the development planning process and BIM technology simultaneously. The intent was to introduce students to new technology and emulate AEC industry practice to encourage students to think critically and develop learning skills to help them lead and innovate. The researcher embraced positive reinforcement and the notion that learning to learn would help students utilize the most current and ever-changing technology throughout their career.

Conclusion

As described in detail in Chapter 3 and depicted in figure 1.5, this study sought to identify industry demand for construction management graduates with some aptitude for BIM, capitalize on the researcher's industry experience with BIM in practice, deploy BIM in a classroom setting as a case study and then describe the merits of integration, determining if the technology and the course materials could be taught at the same time. Deployment of BIM in the classroom included the development of BIM-based assignments and documentations of the student experiences with BIM in existing construction management curricula. The data collected in this study were used to explore student perception on their own experience and skill level gained through BIM as well as their perceived effectiveness of learning the course content simultaneously. Finally, the research examines the data and reported on the success of the process and provides a platform to inform future development on courses that expose student to BIM technology as a tool to deliver curricular content. This work and the associated area of study will be ongoing with modifications of approach based on the results of this and subsequent interventions (CON 571 course) as well as experience gained in professional practice. The research aims of this study directly align with the CON 571 course objectives and development strategies discussed later in this work.

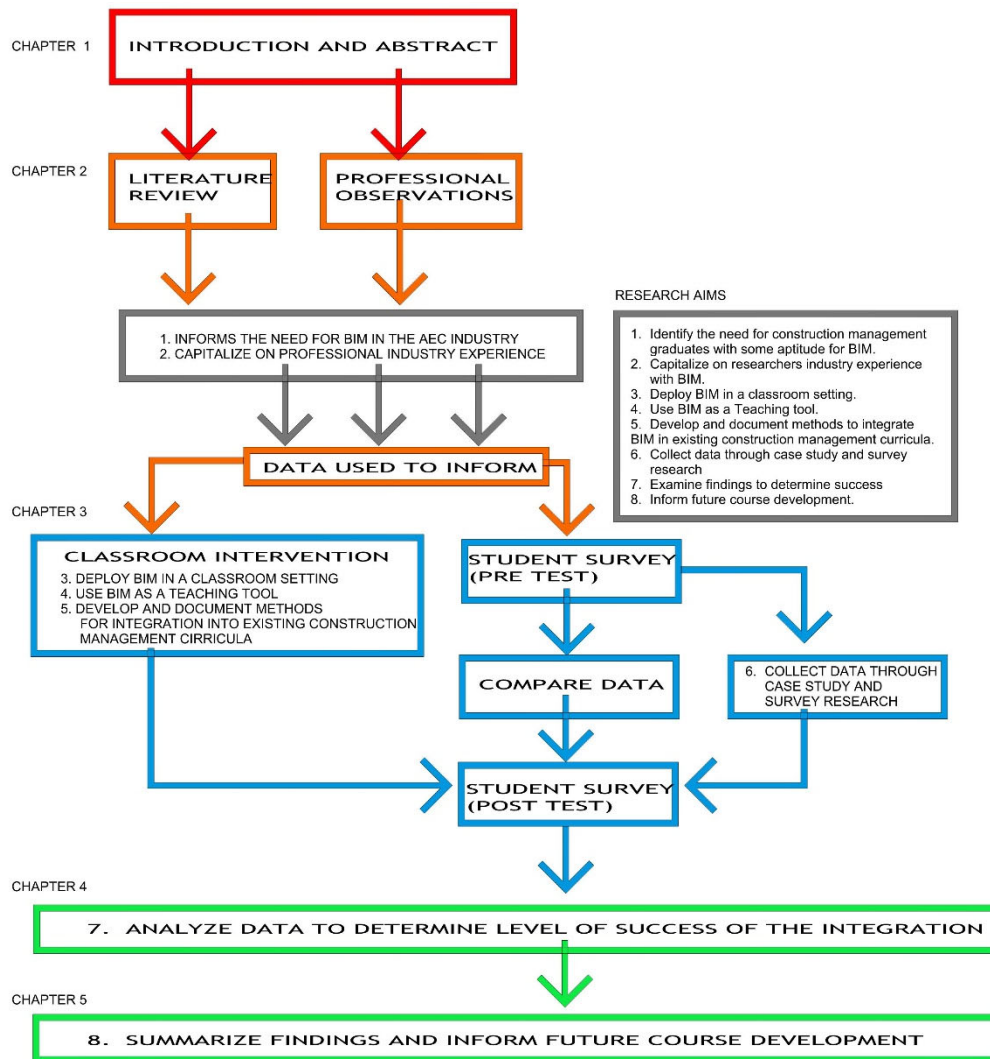


Figure 1.5 – Data Mapping to Research Aims

Chapter 2: Literature Review

The literature review initially describes the use of BIM in architectural and engineering education. Next, the chapter focuses on demonstrating the proliferation of BIM in the construction industry and establishing the need for BIM-focused construction management education. The review also documents the use of BIM in integrated project delivery and describes current industry trends and the influence of collaborative team approaches on instructional models. Existing teaching methodologies to deploy BIM in the classroom were studied from the architectural and engineering perspectives with the associated benefits and challenges. Finally, a description of educational theory, as defined by Gay (2011), Creswell (2014) and Fellows (2015), described in this chapter informed the research methodology and study design.

The Use of BIM in Industry and Integrated Project Delivery

The use of Building Information Modeling is blurring the lines between comprehensive architectural, engineering and construction management education while simultaneously providing platforms to enhance collaboration earlier in the design and delivery process (Mulva and Tisdell, 2007). Today we see the integration of BIM in Integrated Project Delivery (IPD). Integrated project delivery leverages early project delivery collaboration of all team members either under a single source contract or multiparty contracts where project risks and rewards are distributed across the AEC disciplines. (Kent, 2010). Most specifically, in the context of this work and in the practice of design-build at CSU, we describe both the prescriptive and performance, target value-based design, where both acquisition strategies are executed under a single lump sum contract as IPD.

Inherent to IDP, deploying, Integrating and leveraging BIM in Construction Engineering and Management classes can be effective by suggesting that learning BIM can improve process and enhance efficiencies (Leite, F. 2016). With an emphasis on process enhancement through the use of BIM as

opposed to the technology itself, the instructor can maintain instructional goals that align with industry practice.

The integration of BIM inherently promotes the IPD principal of collaboration among the AEC disciplines, adds a competitive edge in securing work and provides additional value to the owner. (Furst, 2010 & Marshall-Poiting, 2005). The student of the future may be educated without specific focus, and rather in a comprehensive way using technology that blends the AEC disciplines. (Becerik-Gerber 2011). In AEC education, the researcher imagines a single building project shared between the colleges of architecture, engineering, and construction management at a single or multiple universities to aid in teaching real world collaboration and charrette based methodologies. Just as in professional practice, Building Information Modeling can help facilitate this collaboration and by definition refers to the collaborative management of a component building system database (Denzler and Hedges 2008). BIM can be leveraged with augmented reality to promote interdisciplinary study and collaboration (Zamora-Polo, F 2019).

BIM is used by architects, engineers, contractors and owners. Through integrated practice, we all collectively collaborate in the eventual delivery of a facility. BIM was initially used primarily in the design process but today is seamlessly integrated through construction and most recently, in the management of facilities, (Livingston, 2008; Gordon, 2009). Through the use of BIM, a virtual model of the building is developed. The process of creating and using the BIM model is often referred to as Virtual Design and Construction (VDC). Designers, contractors, owners and suppliers work hand in hand in resolving potential conflicts between building systems before construction commences. The ability to work through these potential problems proactively and the ability to represent the building geometries in three dimensions in the construction documents allows for more efficient delivery (Eastman, 2004). When compared to more traditional two-dimensional document delivery methods, these more closely coordinated documents produce tighter bidding, fewer change orders and schedule efficiencies that increase value for

the owner. Further, the use of BIM saves time in construction and may result in more cost effective, energy efficient buildings of higher quality while establishing a platform to work collaboratively on a global stage (Burr, 2009; Becerik-Gerber and Kensek, 2010). BIM technology tools currently used in industry include but are certainly not limited to Autodesk REVIT, Bentley MicroStation and ArchiCad with AutoDesk REVIT being used by the majority of the AE industry in the design of buildings (Raphael, 2009). AutoDesk REVIT is the BIM platform used in the development of buildings at CSU.

Google Sketch-Up also represents a platform for the initial study of conceptual design work for marketing and quantity take-offs for cost estimating but does not have the parametric data base driven capacity of other Building Information Modeling platforms (Taylor, Liu, and Hein, 2008). In building design through the use of BIM, parametric capabilities can be defined as the use of interconnected data including parameters, figures and characteristics. These are used to determine the conduct of a modeled entity. The term parametric can further define relationships between model components that eventually result in a coordinated, database driven representation of building systems (Denzer, 2008). In this discussion we determined that the simplistic and non-parametric nature of Google Sketch-Up results in an ease of use. Further, in regards to teaching with BIM, starting with Sketch-Up may offer an initial launch pad for students to begin to understand the three-dimensional characteristics of BIM without being overwhelmed in preliminary instruction by the significantly more complicated parametric capabilities of the BIM tools, specifically Revit.

BIM: A Need to Know

There is a high demand for BIM training from companies in the construction sector (Zamora 2019). The advantages of using BIM in the collaborative development of buildings are numerous and thus the technology is now in wide use across the AEC industry (Sharag-Eldin and Nawari 2010).

BIM is used in construction today and construction management graduates with some aptitude for BIM technology are needed in the construction industry (Hardin, 2015; Bryde, 2013; Clevenger,

2010; & Azhar, 2011). BIM professionals are not only being hired by contractors but also subcontractors and material suppliers. The demand for construction professionals with BIM experience is growing and schools should embrace this demand and prepare students accordingly (Hardin, B., & McCool, D. 2015).

The current body of literature is sufficient to generate the conclusion that the construction industry needs candidates with some aptitude for BIM. BIM technology, as an interface, lends itself to interdisciplinary study and IDP (Azhar, 2011; Clevenger, 2010). Even with limited exposure, integration can provide a foundation for further individual exploration in other courses. Further, teaching with BIM may enhance the ability to communicate, coordinate, sequence and develop project constructability analysis through a more robust understanding of building systems, structure and component integration (Kim, 2012; Shapria, 2010; & Sacks, 2010)

Experiential Learning and Integrating BIM

The process of students using BIM as a tool for completing existing assignments represents a compelling example of experiential learning and aligns with recent programs that promote a learning ecology (Siemens, 2003). Experiential learning, transformation of experience, was originally defined by John Dewey 1938, and simply describes learning by doing in the most pragmatic sense. (Kolb, A. Y., & Kolb, D. A. 2005). Learning theory as a basis for case study research is promoted by Lorraine Gay (2011). The theories of Experiential Learning will be deployed to inform the proposed case study and redevelopment of CON 571 to fully implement BIM. A University may be the ideal setting for such experiential learning. (Sanders, M. J. 2013).

Experience working with diverse groups, mentoring and guiding students will be directly applicable in developing methodologies for BIM integration in existing curriculum. BIM can serve as a tool for the educator to emulate professional practice and current industry trends towards interdisciplinary, integrated project delivery and collaborative development methodologies (Mulva and Tisdell 2007).

This work commenced in 2009 with the initial integration of BIM in CON 571 but only at the very end of the course to capture the products of the class in three dimensions as an initial introduction to the parametric tool. In 2010, the majority of peer reviewed literature on the integration of BIM was focused on architectural and engineering undergraduate programs. Recently, research and professional experience reveals that BIM the integration of BIM in existing construction management education should be a priority. (Clevenger, 2012; Uddin M.M. 2014; Ahn Y. H. ;2013; Kim, J; 2012 and others).

BIM as a Teaching Tool

Through initial research, we find that BIM can inform instruction and be considered a teaching tool (Ahn Y. H. ;2013; Kim, J; 2012 and others). BIM can be a tool for interdisciplinary study (Zamora, 2019). BIM enables the study of component building system assemblies that might begin to bridge the gap for those undergraduates with little or no hands-on construction experience. To further illustrate the need for integration, we reflect on the current state of the academic programs across the country. Today, we see diminished state funding and limited academic budgets, many construction management programs have been required to eliminate, or put on hold, the costlier lab classes (Glick, S., Porter, D., and Clevenger, C.; 2010). These labs have traditionally provided an introduction and platform to study hands-on construction. While it is difficult to replace hands-on construction experience, BIM may help fill an ever evolving gap through data base driven, parametric modeling that helps illustrate in three dimensions, component assemblies. (Glick, S., Porter, D., and Clevenger, C.; 2010). In response to industry and ongoing research, the construction management department at Colorado State University added a VDC studio in 2013 (Ufberg, 2018). The studio was entirely funded by local industry to enable students to implement the most current technology in completing existing assignments just as they would in job site trailers where the same technology is being fully integrated.

The integration of Building Information Modeling into architectural curriculum has been evolving for the past decade (Eldin and Nawari, 2010). The architectural discipline, both in academic and

professional practice, has led the way in integrating BIM technologies. This proliferation coupled with the availability of research literature at architectural academic institutions makes curriculum integration in the architectural discipline a prime source for gaining information regarding the integration of BIM across all AEC disciplines. The findings in architectural education, including the challenges and benefits of integration, can then provide guidance for integration of like technologies in construction management discipline. Where similarities exist in the undergraduate coursework of each discipline, we simply need to teach how a building goes together. (Hedges and Denzer, 2008). BIM is the ideal technology to do this.

For the last twenty-five years, we have experienced a paradigm shift in construction industry practice that needs to be assigned to education. This shift is described as the move away from two-dimensional computer aided design (CAD) to BIM. Two-dimensional design traditionally presents building information as abstract relationships to be interpreted. In contrast, we are seeing the rapid evolution of three-dimensional platforms that represent database driven, systematic and component assembly relationships. These are further illustrated in real time through the use of virtual models that represent virtual construction. (Denzer, 2008). Professional practice is leading the advancement of the technology, construction practitioners are anxiously waiting for academic institutions to fully embrace BIM and thus prepare students to not only use the technology but also advance it. These students will be well positioned to capture employment opportunities and continue to move the industry forward. Advancement of the technology is a rapidly moving target especially in professional practice. This ever evolving platform is one of the most challenging aspects of integrating it into existing AEC curriculum. (Livingston, 2008)

Additional challenges associated with integrating the technology are often presented and challenged by time. The time it takes to grasp the unparalleled complexity in the technology; finding instructors who have the experience with the new tools, the time it takes to prepare existing instructors,

and aligning all this with an academic calendar (Weber and Hedges, 2008; Yan, 2010). These challenges are especially taxing when weighed against existing accreditation mandates and implications on often long established and successful core curriculums. The cost of integration weighed against resource allocation is also a factor but it appears to be of limited degree where educational versions of the software are available to students at greatly reduced costs or free . Also of consideration is a perception that the use of BIM may hamper creativity and impair critical thinking and problem solving skills if not properly and carefully integrated.(Ching,R.; 2008)

Impacts and Benefits

Impacts and benefits in undergraduate AEC education with BIM are described with remarkable similarity across research topic sampling and professional industry discussions. These benefits include proliferation of integrated design, an accelerated design process, added initial concept complexity, a more robust exploration of concepts, and an overarching gravitation towards more collaborative and coordinated teamwork. (Denzer, 2008; Hedges and Denzer, 2008). CM students appreciate and are motivated by the opportunity to study BIM (Adhikari, 2020). In instruction, using Building Information Modeling as a tool appears to ease the transfer of knowledge. The study of sustainable design and building concepts as facilitated through the use of BIM can inform new coursework moving forward and ultimately result in more energy efficient buildings (Burr, 2009; Kim, 2011). Instructors are losing less information to translation when compared to more traditional and two dimensional methods of instruction. (Berwald, 2008). It is also generally accepted that different students learn in different ways. Year to year, we see a variety of students in terms of ability and ways in which they learn; some have skills weighted towards a more a pragmatic, engineering type approach and some exhibit more artistic and creative skills. Ideally, as we evolve towards interdisciplinary practice, we hope to see a balance of both. The integration of the BIM is helping these diverse students successfully investigate more complex design ideas in unrealized ways when compared to traditional two-dimensional platforms. BIM allows

instructors to teach an integrated process geared towards collaboration involving all the AEC disciplines where we see a greater opportunity to visualize how building systems go together (Berwald, 2008). The Integration of BIM technologies was perceived to be successful when the coursework emulated interdisciplinary professional practice (Sotelino, 2020).

Several underlying recommendations for integrating the technology into AEC curriculum have been echoed across several articles. Early integration in the initial semesters appears to be critical such that the technology can be used in more robust ways as the student progresses through upper level coursework and graduate studies (Gordin, 2009). The existing curriculum should not be abandoned, instead the technology should be integrated into existing coursework to the extent possible. Students should be encouraged to retain traditional skills but explore the possibilities of the technology through customization and investigation. Educators should closely monitor industry development and accreditation standards to ensure the integration of technology is aligned. Integrated curriculum requirements that focus on new technologies should be widely published such that primary and vocational educators might begin to prepare students prior to collegiate application. The curriculum and integration process should be flexible and nimble to attempt to parallel the often overwhelming pace of industry development (Denzer and Hedges, 2008; Eldin and Nawari, 2010; Taylor, Liu and Hein, 2008).

In ongoing conversations with AEC educators in regards to the rapid proliferation of technology in industry, many express concern that regardless of the tools used, instructors can no longer teach only to the curriculum but instead should spend the majority of the academic hour teaching students how to learn. Learning how to learn allows the student and eventual practitioner to embark on specialized investigation using the technological tools of their own choosing as supported by industry demand (Denzer & Hedges, 2008; Eldin & Nawari, 2010; Taylor, Liu & Hein, 2008; and Gordin, 2009).

Initial, high level, process concepts for integrating BIM in AEC curriculum are echoed to some degree across current literature. These overarching concepts include: Creating an atmosphere of acceptance and innovation that facilitates and rewards integration; developing a phased integration into existing curriculum without recreating it; creating industry partnerships to help advise the integration focus; managing the complexity of the tool itself while retaining the use of other media and tools; understanding and anticipating the time associated with gaining an aptitude for the tool; developing an appropriate prerequisite sequence with associated requirements; encouraging invention and collaboration; pursuing opportunities for cross discipline, collaborative study where BIM can be used as the platform of such integration (Denzer & Hedges, 2008; Eldin & Nawari, 2010; Taylor, C., Liu, J. & Hein, M.F.;2008; Gordin, C.;2009).

Educational Theory to Inform Case Studies and Research Methods

Transformative learning theory, experiential learning, the learning ecology and learning cities all describe theory embedded in lifelong learning and is directly applicable to graduate level education where we often see students of diverse demographics and varied levels of experience. Transformative learning theory draws on experience to promote critical thinking. (Taylor, 1998, & 2008, Mezirow, 1997). Thinking critically is essential to problem solving and innovation (Mezirow, 1997; Lee, 2011). Teaching with technology, using real world assignments, focusing on actual projects and gathering students into teams fosters critical thinking skills, motivates students and emulates the way the AEC industry delivers built projects. Transformative learning theory can inform research design where pre and post class surveys may reveal an understanding of existing materials through experiential learning, most simply, learning by doing.

Also of specific interest is the idea of using the technology to teach existing material in lieu of simply teaching the technology (Clevenger, 2010; Lee, 2011). Challenges associated with the use of BIM both in professional practice and education should also be illustrated. One such challenge is the

perception that the use of BIM may hamper creativity if not properly and carefully integrated. Perhaps a more critical hurdle to using BIM as a teaching tool is training existing instructors and engaging new ones that have some aptitude for BIM and the associated technology (Ching, 2008; Davies, 2013).

If we are to truly incorporate a teaching tool and if this initial study is to inform ongoing research, we must identify a teaching methodology to explore an educational theory. Identifying an educational theory will allow for testing the results of the initial study. Transformative, experiential learning and a learning ecology both prescribe that educators might be most effective if they teach to their strengths, identify their talents, gather their experiences and simply share. This promotes the idea that the students can solve the same problems in the classroom that they will be faced with in professional practice (Siemens, G. 2003). We reflect on, and contrast experiential learning with the more pragmatic and traditional verbal delivery of information including note taking, testing and repeat (Mezirow, 1997; Kolb, 2005,). The CON 571 course was originally founded in experiential learning and has evolved towards transformative learning theory. In a Learning Network, Siemens describes Connectivism as a learning theory for the digital age which embodies many of the tenants of transformative and experiential learning and most directly informs the prescribed exploratory descriptive case study research detailed here in. Connectivism finds its place in learning theory as informed by teaching innovation through the use of technology (Siemens, 2014) and is not dependent on a formal learning environment. Generally construed and graphically represented in Figure 2.1 connectivism theory prescribes a learning network. Connectivism learning theory suggests the following attributes of learning through the use of integrated technology:

1. Learning is a continual process, spanning the now many career engagements over the life of the learner;
2. Informal learning becomes more significant than formal learning;
3. The organization and the individual are part of the learning organism or learning ecology;

4. Learning and work are no longer separate;
5. Technology is altering our brains, the learning tools we use are changing our way of thinking;
6. Knowing what and knowing how is not as important as knowing where to find the information;
7. Knowledge management, (the organization of knowledge) is of emerging importance as the use of technology surges.

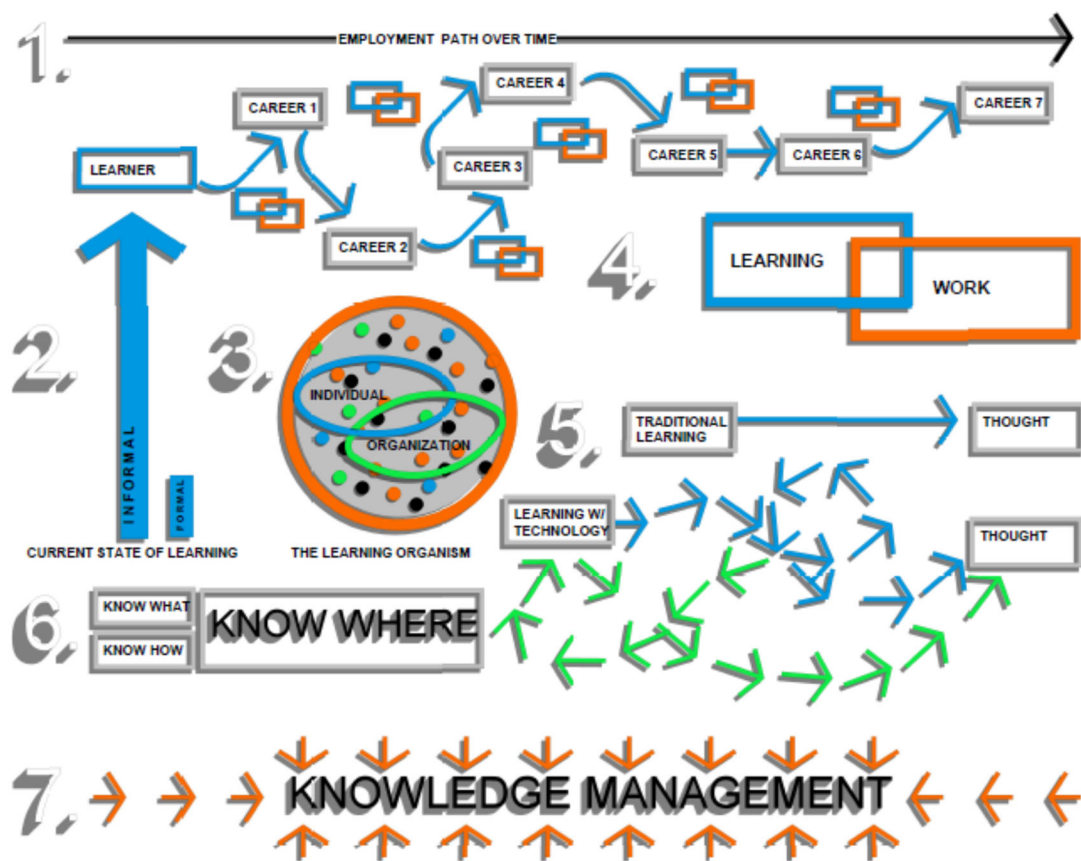


Figure 2.1 – Connectivism Learning Theory

Where information is readily available and accessible, Connectivism Learning Theory, not unlike the integration of technology into existing curriculum, establishes relationships between teaching modalities as we navigate the technologically driven digital age. Tenants of life-long learning,

experiential learning, informal learning, organizational knowledge management and the associated less structured path to innovation are all captured in Connectivism. The researcher embraced the work of Siemens as it closely resembled the emerging direction for the CON 571 class and seemed to consistently resonate with the students and AEC professionals. Aligned with connectivism theory and inherent to the construction industry; communication, teamwork, learning to learn and then learning throughout your career is critical to achieving professional objectives and moving the industry forward (Zamora, 2019).

Conclusion

The Literature Review provides support for the proliferation of BIM in AEC education, and it indicated the technology's evolution from Architectural and Engineering to the Construction Management disciplines. Research review also indicated that BIM can be used as a tool for teaching. It became apparent that BIM can be leveraged in the classroom. Further, these opportunities in education can be utilized to teach construction topics such as Lean Construction, Integrated Project Delivery and Design-Build methodologies. In each of these delivery methods we see the construction management professionals leading the AEC team. In light of this, students should have a working knowledge of the technology and the way it is used in AEC disciplines when entering the construction industry upon graduation.

Chapter 3: Methodology

Introduction

This research utilized the redesign of CON 571 as a multi-semester case study to document and explore the process of integrating BIM as a teaching tool to deliver an existing construction management course. The research focused on experiential and connectivism learning theories to promote evolving connections between technology, the workplace and learning. The literature provided an assessment of the following: 1) BIM use in development of design build RFP documents, 2) current industry practice to establish the need for CM graduates with aptitude for BIM, and 3) developing methods for integration and 4) deploying these methods through team-based study of projects derived from current and ongoing campus development at CSU. The CON 571 course was designed to emulate Design-Build and Integrated Project Delivery (IDP) methods using BIM in professional practice using current CSU building projects. The following chapter describes the case study methodology, the process followed for original course redevelopment, a description of modifications made after each semester offering, the development of the survey, the statistical tests/approaches used to address the research questions.

The researcher employed an exploratory case study using a mixed methods cross-sectional approach where a survey which contain both quantitative and qualitative items was distributed (Creswell, 2013; Gay,2000). Investigation of qualitative data to inform a survey tool is used in sequential explanatory educational research (Bassegy, 2003; Gay & Airasian, 2000). This research method was appropriate for this focused exploratory case study where a structured survey was administered to a limited number of participants (n of in total 33 students (2014, n = 9; 2015, n = 9; 2016, n = 14) over a relatively short duration (e.g. three-semesters) The researcher's professional observations of building projects at Colorado State University were used to inform the need for the study. Exploration of

collected data via a survey of student perceptions around their ability to learn the BIM applications during the course would be foundational.

The overarching research objective was two-fold: 1) can BIM be used as a teaching tool to convey course content, and 2) can students learn BIM technology and the existing course materials simultaneously. The students had various levels of experience with the BIM tool at the on-set of the class. Supported by collectivism learning theory,(Siemens, 2014), the researcher wanted to determine if using BIM to teach the existing material, integrating BIM in existing CM courses and learning by doing, would prove to increase retention of both the material and the technology. The pre- and post-class surveys were developed to focus on existing course materials before and after the CON 571 course. Collecting pre- and post- class survey data over three semesters provided a level of content validity. Collecting qualitative data offered the opportunity for a more in-depth examination through open-ended post-class survey questions. (Creswell, 2013; Gay, 2000). Redesigning a course, with the overlay of BIM technology over existing course materials and reporting the results of the redesign within a class context can be categorized as exploratory and descriptive research (Fellows, 2015).

A Mixed Methods Approach

A mixed methods approach (Creswell, 2013) was employed in this research. The researcher adapted the method as described in Figure 3.1 The implemented research process included five steps:

- 1) Literature Review
- 2) CON 571 Course Adaptation to Incorporate BIM
- 3) Students Survey Development and Deployment
- 4) Quantitative and Qualitative Survey Data Analysis
- 5) Results, Interpretation and Discussion

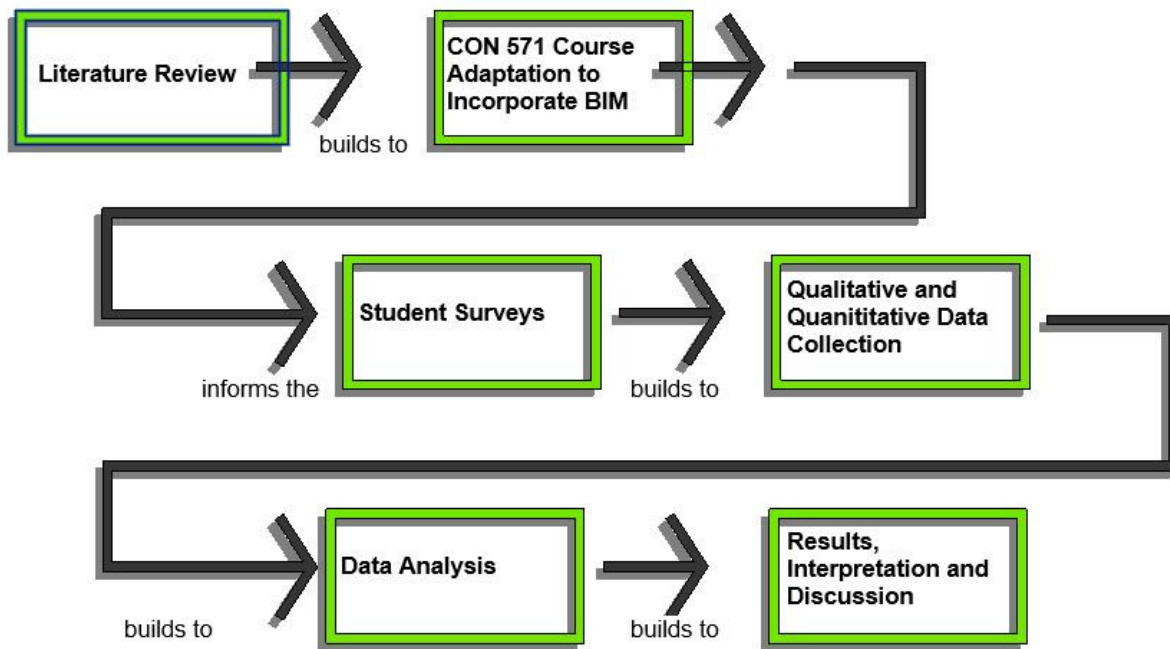


Figure 3.1 Implemented Research process

Literature Review

The Literature review and the researchers professional experience provided the foundation to complete the next steps in the study. The researcher conducted a focused literature review with the objective of not only finding examples of the integration of BIM in construction management education but also in the field of teaching with technology. Understanding the educational theory and its alignment with technology integration was an important step during the redevelopment of the CON 571 course to incorporate BIM technology.

The Literature review also investigated qualitative information related to the integration of BIM in existing AEC courses. The researcher then discovered methodologies and tools suggested by educators that could be implemented and tested in the proposed exploratory case study. The case study was developed around educational theory research review and deployed to determine if the redesigned course was successful. By comparing three investigations over three separate survey groups, similarities

began to appear. These findings are discussed with the survey results in the next chapter. The researcher used information gathered from literature review and professional observations to inform the case study, course redesign and develop the CON 571 student survey.

Con 571 Course Adaptation to Incorporate BIM

Con 571 was redesigned to incorporate BIM. Prior to 2011, the CON 571 – Facilities Planning and Management course provided students with an opportunity to develop a facilities plan, and learn about the sustainability, energy management, commissioning and operational considerations in project development. The evolution of the course syllabus is included in Appendix IV and graphically represented in Figure 3.2. Appendix IV is divided into the following sections based on level of BIM implementation.

- 1) 2010 syllabus prior to initial redesign and researcher as instructor
- 2) 2011- 2013 syllabi based on the initial course redesign.
- 3) 2014-2016 syllabi – the subject semesters of the current study
- 4) Post study 2017 syllabus (discussed in Chapter 5) that incorporate the results of this research and the continued integration of BIM into existing coursework.

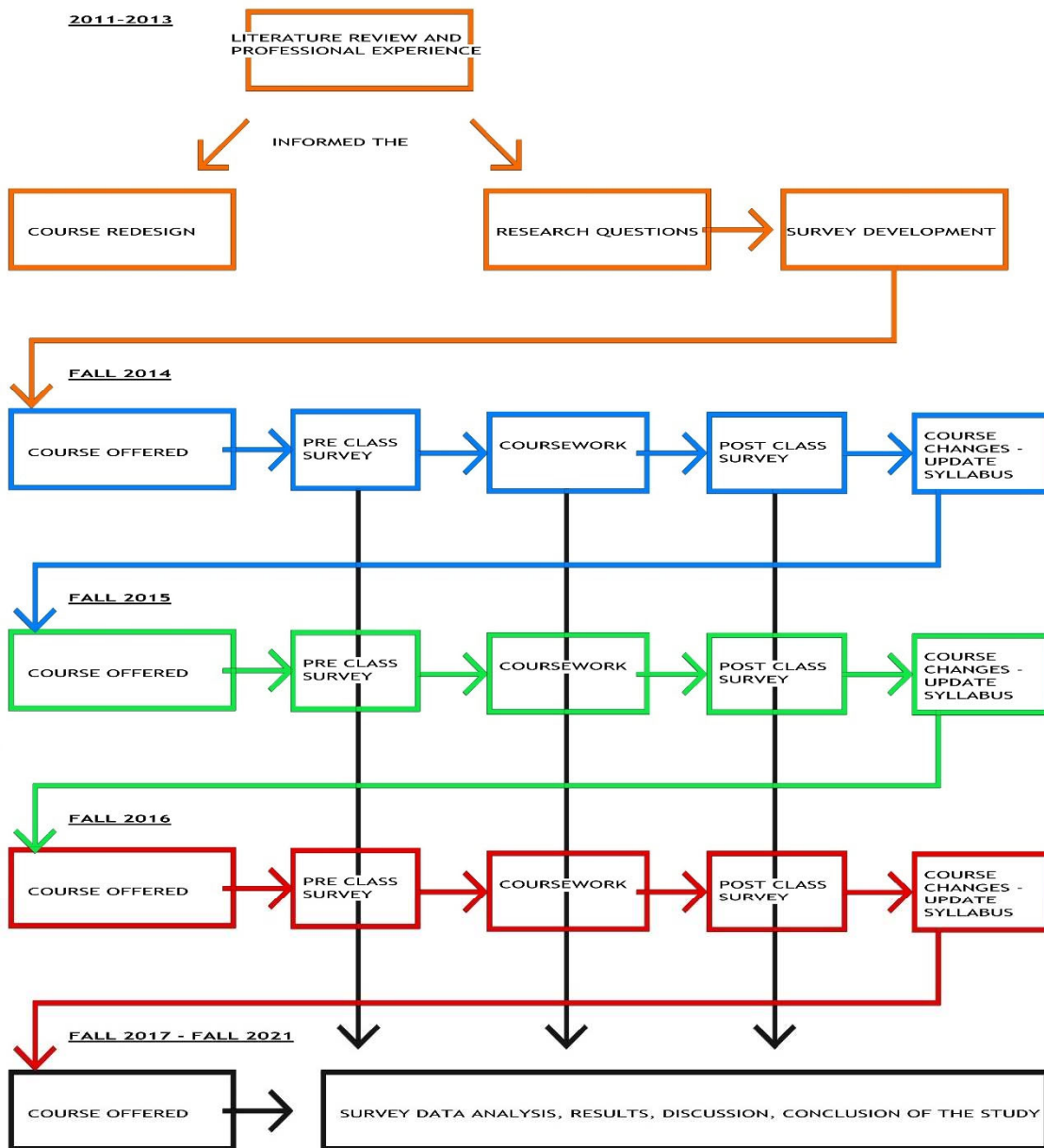


Figure 3.2 Case Study and Syllabus Evolution Timeline

Course Adaptation Summary

In 2011, the researcher began teaching the CON 571 course. As the primary instructor, the researcher, reorganized the course to integrate technology and emulate the current development processes being deployed by Colorado State University Facilities Management department at that time. The initial course redesign focused on creating an interdisciplinary learning experience that simultaneously taught the building development process specific to a campus environment. The adaptation aligned the course content and assignments with current design- build projects at CSU to provide students with experiences that would benefit them in professional practice. The course was developed in a dynamic way; that is, adaptations were implemented in subsequent semesters given changes in the technology itself and/or the processes used to procure projects at CSU. During the first semesters of teaching (fall 2011 – 2013), the course engaged industry widely in the form of guest lectures around professional construction and development practice. The alignment with industry practice and the incorporation of BIM into the course started in 2011, with the time dedicated to BIM instruction increasing incrementally semester to semester through 2013 and in preparation for the 2014 course session. To control the experiment, the 2014 content would remain the same during the three-semester duration of the study.

In the Fall 2014, Fall 2015 and Fall 2016 sections of the course, the researcher allocated less time for professional guest lectures and replaced this time directly with BIM-technology based instruction. To retain instruction around current professional industry practice, BIM instruction was coupled with the teaching of the design build lump sum development process. This procurement method, with the associated integration of BIM was being used almost exclusively for the development of large capital construction projects on CSU's campus at that time.

The CON 571 course was now set to emulate the project development process and project pursuit strategies with the integration of BIM in master planning, logistics planning, building

programming, conceptual building design, code analysis, cost estimating and schedule development. Master planning and site logistics planning is introduced and practiced at the beginning of the course and offers problems of limited complexity in which to initially introduce BIM as part of the experiment and intervention. Towards the end of the course, after delivering the required objectives, the students study the evolution of the construction documents required for each project. This study begins to explore the various systems required of a building which include the MEP system integration with the architectural and structural models. The emerging use of BIM in the operations and maintenance of completed projects is also discussed.

Student Survey Development

The survey items were developed to gain an understanding of student's BIM experience before and after the CON 571 course. The pre- and post-test surveys (See Appendix III) were used to collect qualitative and quantitative data on the effectiveness of BIM integration while retaining the existing course framework. Questions also considered student perceptions regarding the future use of BIM in current assignments in other classes. For example, BIM was used to solve mathematical and analytical problems and as a tool to complete analysis and projects. Finally, to align with industry needs, it was important to determine anticipated use of BIM after graduation to support the student's future employment.

A pilot test of the survey was conducted to ensure the questions were understandable, response options were appropriate, responses could be measured, and that the survey was efficient. The pilot was given to employees in the Planning, Design and Construction department, members of the Construction Management department at Colorado State University (CSU) as well as graduate and undergraduate students in the construction management program took the survey and offered comments in regard to the clarity of questions the native format and time to complete. Definition of terms were typically requested, and associated modifications of text were incorporated into the final

surveys for clarity. The students that pilot-tested the survey did not participate in the final survey population in order to prevent the study from collecting biased data.

The Research Integrity & Compliance Review Office (RICRO) at CSU reviewed and approved the surveys (Appendix I), and recommended an attached narrative requesting consent be submitted for approval from the Institutional Review Board (IRB) before proceeding with the research. The consent narrative (Appendix II) was completed by the participants prior to completing the survey. The consent narrative summarized the study and its researchers, reason(s) for the research, risks and benefits of participation, and indication of consent for participation. The survey was designed to take respondents ten to fifteen minutes to complete.

Due to the limited sample and varied background of the survey participants, the survey was intentionally simple and consisted of 15 pre-class survey questions (15 quantitative and qualitative) and 20 post-class questions (17 quantitative and 3 qualitative) . The first 15 questions in the post-class survey were replicated from the pre-class survey in an attempt to indicate if the integration was effective. In the close-ended questions, the respondents were asked to choose their responses from a 5-point Likert scale or provide a dichotomous (yes/no) response. The open-ended questions requested a short narrative response.

Rationale for Survey Items Included in both the Pre- and Post-Course Survey (Items 1-15)

The researcher determined that it was important to define BIM and describe the associated technology with examples before administering the survey. This was done to identify if BIM was integrated into, or used in other graduate or undergraduate courses. The use of computer aided design (CAD) is prevalent in the AEC industry and a question was asked to help establish student experience and understanding of the use of technology to develop construction projects.

The questions were developed to align with the course content and experiential learning theory. Next, does construction management education need to emulate professional practice and of equal importance was determining a baseline around the student capacity to learn the prescribed technology.

The survey sample seemed to represent a diverse demographic and age profile; this indicated a question may be of value in comparing responses to questions around technology integration and the associated age of the respondent. A question around master planning and site logistics planning was identified to establish an experience level around course teaching objectives and materials in which BIM was introduced.

Inquiry around building programming and conceptual building design were included to establish an experience level around course teaching objectives and materials in which BIM may be introduced. The building programming and conceptual building design builds on the master planning work, increases in complexity and allows BIM to be incrementally introduced based on the skills gained from the completed assignments.

Building code analysis and associated development strategies around the building codes is an integral component of construction and the development process. Establishing a baseline experience level with a building code related teaching objective of the course will help to establish time allocation around the introduction of code analysis and the associated use of BIM in the code analysis process.

Scheduling, sequencing and logistics planning are foundational in AEC education. When BIM is integrated, 4d terminology is often used to describe the time factor of the construction schedule as it relates to the parametric capacity in the 3D model (BIM). The term 5d, describes cost estimating when associated with the BIM. 5d adds the cost factor to the database nested within the BIM and allows the estimate to be updated real time as the plans and specifications are developed through the BIM interface. To establish experience with schedule development and cost estimating, questions were developed to determine capacity before and after the course and the use of associated 4D and 5D

terminology promoted in the assignments. The class, beginning in 2010, has been delivered with a focus on experiential learning, using the campus as our teaching lab and the development projects as our assignments.

Rationale for Survey Items Included in Post-Course Survey Only (Items 16-20)

The qualitative open-ended questions 16-20 were included in the post-class survey allowed the students to discuss the course subjectively with the intent of determining ways to improve the course over time. Opportunities to integrate BIM in other courses could be explored as well as challenges with the course materials and the associated time allocated to complete the modules. Also of interest was the students past and present integration of technology in their learning, determining if the course successfully emulated professional practice and the student's perception of the value of working in teams. The conclusion of the qualitative survey requests that the students discuss the future use of the BIM technology and if they feel it will allow for some advantage in seeking employment opportunities.

Qualitative and Quantitative Data Analysis

The survey collected both quantitative and qualitative data. Questions 1-15 on both the pre-class and post-class surveys were quantitative with questions 16-20 on the post-class survey open ended qualitative questions. The qualitative questions are subjective in nature, and the responses were analyzed using comparative methodologies (described below) for three semesters of data collection.

The pre-class data was captured through initial analysis of the, scanned, completed hard copy materials through input into a coded spreadsheet which also assimilated the post-class data. Items 1-15 are dichotomous (yes/no) questions and Likert scale-based questions. Items 2,3,4,5, and 9-15 were yes/no questions allowing for a frequency analysis of the response pre-class and post-class. Items 1,7 and 8 utilized a 5-point Likert scale, thus means comparison were completed before and after the course using paired-samples t-test.

All the quantitative survey data for the duration of the study was assembled into a coded and aggregated spreadsheet which allowed for importing into Statistical Package for the Social Sciences (SPSS) data analysis software. SPSS Statistics is the software tool used for the analysis of the quantitative questions 1-15. The associated survey analysis is included in chapter four with the results discussed in chapter five.

Questions 16-20 were included on the post - class survey to accommodate subjective perceptions of the course that might inform future study and course development. The qualitative raw survey data was collected in the form of hand written responses from the distributed hard copies. From the completed hard copies, the qualitative survey data was reviewed using thematic analysis approach with common responses grouped and summarized in chapter four.

Conclusion

The exploratory sequential case study research design coupled the quantitative and qualitative data collection to explore the research questions and address the study aim. The students surveyed were enrolled in CON 571 during the three-semester case study and researcher's professional experience used to first help determine the need for the study and then to add validity to the results.

The study included literature reviews and professional experience to determine a need for the study and then further literature review to understand how BIM had been incorporated into existing AEC curriculum at other universities and to determine an appropriate learning theory to inform course redevelopment. The existing CON 571, Facility Planning and Management, course was then redesigned to incorporate BIM and student surveys administered to determine pre and post class experience with the BIM technology and experience with the course objectives, learning the project development process. The study investigated the incorporation of and the use of BIM as a teaching tool through experiential learning that leveraged the current, at any given time, capital development program at Colorado State University. The following chapter provides the result of the data analysis.

Chapter 4: Results

The following chapter provides the results of the quantitative and qualitative data analysis. The completed surveys were recorded in a spreadsheet and the spreadsheets used to summarize the results of the Dichotomous items based on yes / no responses by year and then by mean over the duration of the study. Likert scale items were summarized for analysis by combining the no experience categories into one response and ranking the responses 1-5 for the analysis. The Likert Scale items were then analyzed using paired samples t-tests: comparing the same people on one variable, at pre- test and post- test intervention for the students taking the CON 571 Class. The analysis includes a tabular representation of the data for each question followed by a brief description of the results. The results and associated classroom discussions are documented for the case study in Chapter 5. Appendix III includes the survey questions.

Survey Participants

In total 33 students (2014, n = 9; 2015, n = 9; 2016, n = 14) voluntarily completed the pre-class survey. The 32 students completed the post-class survey yielding a 96.88% response rate. All students who completed the course also completed the survey, with the exception of one student. The high rate of participation may have been due to the sample composition of primarily graduate students. In total, 31 graduate and 2 undergraduate students completed the survey. The actual time required to complete the pre-class survey was averaged approximately 12 minutes and the post-class survey was completed in an average time of 15 minutes.

Demographic Items

One demographic question was included in the survey. This item asked students to report their age based on a given range of age in years. The majority of the students (84%) were between the ages of 18-30, with the remainder reporting an age 30-36 (16%). Table 4.1 provides this information:

Table 4.1 Participant Age

Year	Age in Years					
	18-24	24-30	30-36	36-42	42-48	over 48
2014	3	3	3	0	0	0
2015	4	5	0	0	0	0
2016	5	7	2	0	0	0
Overall	12	15	5	0	0	0

Quantitative Survey Results

The following section provides the pre- and post-test results for survey items 1 through 15. As noted previously, items 2-5, and 9-15 included dichotomous (yes/no) response options while Items 1, 7 and 8 included 6-point Likert scale response choices. The Likert scale responses were then modified to combine no experience “a” and no experience “b” into one response and the analysis changed to a 5-point scale to accommodate a paired samples t-test; comparing the same people on one variable, at pre-test and post-test survey intervention for the students taking the CON 571 class. Analysis of the dichotomous responses are presented first below; followed by the analysis of the Likert scale survey items.

Analysis of Dichotomous Items

Table 4.2 provides the wording of each question 2-5 and 9-15 and the frequency of responses separated by year of enrollment in the CON 571 course with a brief discussion of the results.

Table 4.2 Dichotomous Survey Items

	Year	n	<u>Pre-Test</u>		n	<u>Post-Test</u>	
			Yes	No		Yes	No
2) Was BIM used to complete assignments in any of your previous coursework	2014	9	11%	89%	8	63%	38%
	2015	9	11%	89%	9	88%	25%
	2016	14	71%	29%	14	50%	50%
	Overall	32	38%	63%	31	61%	39%

The results of question 2 indicate an increase in the use of BIM to complete assignments between pre-test to post-test.

	Year	n	<u>Pre-Test</u>		n	<u>Post-Test</u>	
			Yes	No		Yes	No
3) Do you have any Computer Aided Design (CAD) experience?	2014	9	78%	22%	8	88%	13%
	2015	9	100%	0.0%	9	89%	11%
	2016	14	86%	14%	14	79%	21%
	Overall	32	88%	13%	31	84%	16%

The results of question 3 indicate experience with CAD remained static from pre-test to post-test. Data suggest a perception that CAD is AutoCad as opposed to Computer Aided Design. BIM is three-dimensional Computer Aided Design but not AutoCad, two dimensional Computer Aided Design. One student didn't complete the post class survey in 2014.

	Year	n	<u>Pre-Test</u>		n	<u>Post-Test</u>	
			Yes	No		Yes	No
4) Have you used CAD to complete assignments in previous coursework?	2014	9	67%	33%	8	88%	13%
	2015	9	44%	56%	9	56%	44%
	2016	14	86%	14%	14	71%	29%
	Overall	32	69%	31%	31	71%	29%

The results of question 4 indicate the use of CAD remained static from pre-test to post-test. CAD – Computer Aided Design is not being associated with BIM – Building Information Modeling. Students

reported no increased experience with CAD pre-test to post-test while experience with BIM increased pre-test to post-test.

	Year	n	<u>Pre-Test</u>		n	<u>Post-Test</u>	
			Yes	No		Yes	No
5) Are you generally able to easily learn technical software and integrate technology	2014	9	100%	0%	8	88%	13%
	2015	9	33%	67%	9	100%	0%
	2016	14	86%	14%	14	86%	14%
	Overall	32	75%	25%	31	90%	10%

The results of question 5 indicate an increase in the integration of technology to complete assignments from pre-test to post-test. The percentage of students pre-test with ability to learn and integrate technology was lower in 2015 when compared to 2014 and 2016.

	Year	n	<u>Pre-Test</u>		n	<u>Post-Test</u>	
			Yes	No		Yes	No
9) Do you have any experience with building code analysis	2014	9	44%	56%	8	88%	13%
	2015	9	22%	78%	9	89%	11%
	2016	14	36%	64%	14	50%	50%
	Overall	32	34%	66%	31	71%	32%

The results of question 9 indicate an increase in experience with building code analysis from pre-test to post-test. BIM was used as a teaching tool for this material.

	Year	n	<u>Pre-Test</u>		n	<u>Post-Test</u>	
			Yes	No		Yes	No
10) Any Experience with Scheduling and sequencing construction projects?	2014	9	67%	33%	8	100%	0%
	2015	9	67%	33%	9	78%	22%
	2016	14	36%	64%	13	62%	38%
	Overall	32	53%	47%	30	77%	23%

The results of question 10 indicate an increase in experience with scheduling and sequencing construction projects pre-test to post-test. BIM was used as a teaching tool for this material.

	Year	n	<u>Pre-Test</u>		n	<u>Post-Test</u>	
			Yes	No		Yes	No
11) Any Experience with total development cost estimating of construction projects?	2014	9	44%	56%	8	100%	0%
	2015	9	44%	56%	9	78%	22%
	2016	14	50%	50%	14	50%	50%
	Overall	32	47%	53%	31	71%	29%

The results of question 11 indicate an increase in experience with total development cost estimating of construction projects pre-test to post-test. BIM was used as a teaching tool for this material.

	Year	n	<u>Pre-Test</u>		n	<u>Post-Test</u>	
			Yes	No		Yes	No
12) Any experience coordinating component systems in building design or construction?	2014	9	22%	78%	8	75%	25%
	2015	9	44%	56%	9	67%	33%
	2016	14	43%	57%	14	64%	36%
	Overall	32	38%	63%	31	68%	32%

The results of question 12 indicate an increase in experience with coordination component systems in building design pre-test to post-test. BIM was used as a teaching tool for this material.

	Year	n	<u>Pre-Test</u>		n	<u>Post-Test</u>	
			Yes	No		Yes	No
13) Do you think BIM can be used as a teaching tool to deliver instruction in the previously mentioned assignments?	2014	9	100%	0%	8	100%	0%
	2015	9	100%	0%	9	100%	0%
	2016	14	71%	29%	14	100%	0%
	Overall	32	88%	13%	31	100%	0%

The results of question 13 indicate that in 2016 students perceived an increase in the perception that BIM can be used as a teaching tool pre-test to post-test. In 2014 and 2015 all students felt BIM could be used as a teaching tool both pre and post-test.

	Year	n	<u>Pre-Test</u>		n	<u>Post-Test</u>	
			Yes	No		Yes	No
14)Do you think BIM will lend itself to hands on experiential learning?	2014	9	100%	0%	8	100%	0%
	2015	9	89%	11%	9	100%	0%
	2016	14	93%	7%	14	100%	0%
	Overall	32	94%	6%	31	100%	0%

The results of question 14 indicate a slight increase in the perception that BIM will lend itself to experiential learning pre-test to post-test. Students consistently responded in the affirmative both pre and post-test.

	Year	n	<u>Pre-Test</u>		n	<u>Post-Test</u>	
			Yes	No		Yes	No
15)Do you think BIM can be used to market projects and secure work?	2014	9	100%	0%	8	100%	0%
	2015	9	89%	11%	9	100%	0%
	2016	14	93%	7%	14	100%	0%
	Overall	32	94%	6%	31	100%	0%

The results of question 15 indicate a slight increase in the perception that BIM will can be used to market projects and secure work pre-test to post-test. Students consistently responded in the affirmative both pre and post-test.

Summary of Dichotomous Items

The results of the dichotomous survey items revealed the students reported a much higher frequency of using BIM to complete assignments in previous courses in 2016 (71%) than they did in 2014 or 2015 (11%). The participants also reported that BIM could be used both as a teaching tool through experiential learning and to market and secure work both pre and post-test. The results indicate that the students experience with the course content is increasing pre-test to post-test while learning the technology at the same time. Data indicates the use of CAD remained static from pre-test to post-test. This may be interpreted as follows: Computer Aided Design is not being associated with BIM – Building Information Modeling. Students reported no increased experience with CAD pre-test to post-test while

experience with BIM increased pre-test to post-test. We may indicate a perception that CAD is AutoCad as opposed to Computer Aided Design. BIM is three-dimensional Computer Aided Design but not AutoCad, traditionally thought of as two-dimensional Computer Aided Design.

Analysis of Likert Scale Items

Students responded to three items (survey items 1, 7 and 8) that addressed their perceived level of experience in three areas on a 6-point Likert scale (1 = No experience, 2 = No Experience but I know about the topic, 3 = little experience but I have explored the topic, 4 = Some Experience, but have not used knowledge in this area to complete work, 5 = More experienced and have use knowledge in this area to complete work on more than 3 assignments/projects, and 6 = very experienced and have used knowledge in this area to successfully complete project in academia or private practice). As noted previously, the Likert scale responses were then modified to combine no experience “1” and no experience “2” into one response and the analysis changed to a 5-point scale to accommodate a paired samples t-test Table 4.3, 4.4 and 4.5 provide the Number of Respondents (*n*), Mean (*M*) and Standard Deviation (*SD*) by year of enrollment in the CON 571 course. The wording of each item was as follows:

Item 1: Do you have any experience with BIM?

Item 7: Do you have any experience with master planning or construction site logistics planning?

Item 8: Do you have any experience with building programming and conceptual building design?

Table 4.3: Sample Size, Mean, Standard Deviation for Item 1 Level of Perceived Experience with BIM by Year

Year	<i>n</i>	<u>Pre-Test</u>		<i>n</i>	<u>Post-Test</u>	
		M	SD		M	SD
2014	9	2.00	1.12	8	4.67	0.71
2015	9	2.22	1.64	9	3.67	1.23
2016	14	2.71	1.54	14	4.07	1.14
Overall	32	2.38	1.45	31	4.13	1.10

From 2014 to 2016 the mean of the student responses showed increased experience with BIM at the time at which they entered the class. Data also indicates an increase in experience with BIM between pre and post-tests.

Table 4.4: Sample Size, Mean, Standard Deviation for Item 7 Level of Perceived Experience with Master Planning/Site Logistics by Year

Year	<i>n</i>	<u>Pre-Test</u>		<i>n</i>	<u>Post-Test</u>	
		M	SD		M	SD
2014	9	2.75	1.05	8	4.63	0.55
2015	9	2.56	1.33	9	4.00	1.23
2016	14	2.36	1.01	14	2.86	1.17
Overall	32	2.47	1.11	31	3.65	1.31

From 2014 to 2016 the mean of the student experience with master planning and site logistics was static, while experience increased over the study period pre to post test.

Table 4.5: Sample Size, Mean, Standard Deviation for Item 8 Level of Perceived Experience with Building Programming/Conceptual Building Design by Year

Year	<i>n</i>	<u>Pre-Test</u>		<i>n</i>	<u>Post-Test</u>	
		M	SD		M	SD
2014	9	2.63	1.06	8	4.63	0.91
2015	9	2.33	1.66	9	4.11	1.36
2016	14	2.43	0.97	14	3.21	0.98
Overall	32	2.41	1.46	31	3.84	1.21

From 2014 to 2016 the mean of the student experience with Building Programming/ Conceptual Building Design entering the class was static, while experience increased over the study period pre to post test.

Paired Samples T-Tests

After compiling the data for the Likert scale items (questions 1, 7 and 8) the researcher conducted a paired samples t-test for each item. These tests compared the same people on each variable, at the pre-test and post-test intervention for students taking the CON 571 class. The objective of running the paired t-test was to determine if student perceptions of their experience with BIM and associated development planning assignments were significantly different before and after taking CON 571. We tested a Null Hypothesis with the t-test and then determined to either retain or reject the null hypothesis. The null hypothesis states that there is not a significant difference in the mean at pre-test and post-test. The associated results would show the statistic of p-value ($p > 0.05$). The alternative hypothesis was then identified as there is a significant difference in the mean at pre-test and post-test. The associated results would show the statistic of $p < 0.05$. Table 4.5 includes the number of participants

(N), the Mean (M), the Standard Deviation (SD) , the t-statistic (t), the degree of freedom (df) , and the p-value (p).

Table 4.6 Paired Samples Test

Variable	M	SD	t	df	p
Pair 1 - Q1post - Q1 pre	1.406	1.241	6.412	31	0.000
Pair 2 - Q7 post - Q7 pre	1.032	1.224	4.694	30	0.000
Pair 3 - Q8 post - Q8 pre	1.065	1.548	3.829	30	0.001

Summary of Likert Scale Items and Paired Samples t-Test

In comparing the pre-test to post-test results, the Likert scale survey items revealed the students reported a higher level of perceived experience with BIM and development planning after the class intervention. This analysis was further supported by the t-stat results where the probability (p) = .000 (Q1 post/pre), .000 (Q7 post/pre) and .001 (Q8 post/pre). For all items the p value was significantly less than .05 and thus rejected the null hypothesis and supported the alternative hypothesis. There is a significant difference in the mean at pre-test and post-test which provide evidence that the student perceived that they were able to learn the course materials and the BIM technology at the same time.

Analysis of Qualitative – Post-Test Survey Questions

The open-ended survey questions are presented with discussions summarized below. All qualitative survey questions are included in Appendix III.

16. Please describe opportunities to further integrate BIM in other classes you are or have previously been enrolled in:

Student responses to item 16 indicated a consistent desire to leverage the tool in cost estimating, communications, scheduling, logistics and regulatory review as well as project marketing.

Students felt building the project virtually had a great impact on understanding 3D model components and system integration. Students noted the unanticipated capacity of the BIM tool to market projects were excited about presentation and communication methodologies that combine BIM with a PDF interface such as BlueBeam or Adobe.

17. Please note any challenges with course materials and or methods as well as the amount of time allocated for each assignment:

Student responses to item 17 indicate that there was a lot of material to cover but the progression of the class modules and instruction made sense. At the beginning of the course, students consistently wanted to use more efficient software (CAD or Sketch-Up) to complete the initial assignments but understood by the end of the class the need to start and end in BIM (AutoDesk Revit) if we were to learn the material and software at the same time. Feedback revealed that the class was emulating professional practice and required careful consideration of the assigned work and associated planning within the teams and individually to keep up with the work, (it was perceived to be very difficult to catch up if weekly work was delayed). We see a variety of requests for more focused study of different sections of the class with some consistency around wanting more detail on the procurement and contracting strategies especially around the front-end development of Design-Build Requests for Proposals.

18. Please describe your experience working in teams using the most current technology as it relates to your perception of professional practice:

Student responses to item 18 indicated that group and teamwork is essential in the construction industry, that learning how to build relationships and rely on the team helped assimilate learning the technology. Completing the volume of work required of the class while learning the technology was only possible through leveraging the team. Favorable discussion around having more experiential coursework

that emulates professional practice and gaining a pragmatic skill and product at the end of class that can aid in professional pursuits was well articulated as favorable.

19. Do you feel some aptitude or initial experience with BIM will provide you with a competitive edge in seeking employment?

Consistent feedback that BIM is being used in the construction industry and having capacity for the technology would prove to be an advantage. Many expressed an interest in continuing to develop BIM skills integrating VICO and Navisworks software more robustly with the REVIT platforms

20. Do you anticipate using BIM in the future to solve problems related to your academic or professional pursuits?

Discussions revealed that this would be dependent on the student's future employment role but where the work involved building and component design, cost estimating, scheduling, sequencing, drawing coordination and conflict resolution, the technology could be leveraged widely if applicable and appropriate.

Summary of Qualitative – Post-Test Survey Questions

When considered in aggregate the qualitative results revealed that the experiential learning model was successful, and teamwork was critical in keeping up with the expectations of the course. Due to time limitations, the study revealed the need for additional prioritization of course materials or expanding the course over a longer period of time. The end of the semester consistently revealed a momentum of learning that would inform additional discovery if the use of BIM could be leveraged over a longer period of time or in new, follow up or parallel courses. Building Information Modeling can serve as a tool in solving the problems inherent to the AEC industry and can also be used as a tool for teaching. Students acclimated with BIM reveal that they will continue to pursue the technology outside of class and as such may see an advantage not only in initial professional employment pursuits but also in professional practice.

Answering the Case Study Research Question

As previously stated, this case study sought to address the following overarching research question and explored the use BIM/VDC technology as a teaching tool:

- 1) Can VDC applications be used as a tool to effectively teach BIM technologies and CM course content simultaneously?

The results of this study provided evidence that BIM can be successfully integrated into existing construction management curriculum and supports the critical thinking, planning and problem-solving skills required of successful construction management graduates. The case study provided a method used to integrate BIM as a teaching tool to teach the existing curriculum. The students learned the existing material and the technology at the same time. This study suggests that BIM can be integrated into existing curriculum and that separate classes focusing on the technology itself may not be needed. The study also illustrates teaching methodologies developed in the subject course that can be utilized in other courses to support the integration of BIM across curricula.

Chapter 5: Discussion and Conclusions

This study supports industry demand for construction management graduates with some aptitude for BIM; utilized the researchers industry and professional experience with BIM; deployed BIM in a classroom setting; used BIM as a teaching tool; developed and documented methods to integrate BIM in existing construction management curricula; collected data through case study development and survey tool research and examined the findings to determine that BIM can be successfully integrated into an existing construction management course without the need for standalone BIM classes.

First, the researcher established the need for BIM instruction in Construction Management programs and developed strategies for integration of the technology within existing curricula. Through existing literature review and professional observation, the researcher developed an understanding of current conditions in the AEC industry and in education to support the need for BIM instruction in the Construction Management discipline.

Second, the researcher explored if BIM could be used as a teaching tool as opposed to simply teaching the technology. Through experiential learning, we solved relevant problems and completed existing assignments using the BIM tool. Using experiential learning theory, the existing syllabus for CON 571 Facilities Planning and Design was successfully redesigned to integrate BIM. BIM was successfully used as a teaching tool in instruction without the need to recreate existing assignments or evaluation criteria. As a result of the study, the CON 571 course was reorganized to provide a more robust integration of BIM earlier in the semester.

Third, at the onset and conclusion of the class, student surveys were administered to determine initial experience and aptitude for the tool and at the conclusion, effectiveness of instruction. The student surveys indicated that using BIM as a teaching tool in experiential learning was highly successful and seemed to emulate professional practice.

Research Aims Met by the Study

Through the course and resulting study, the researcher was able to leverage industry and professional experience with BIM. Having professional experience with BIM proved to aid in instruction and students seemed to participate more robustly in discussions around real projects they could see on campus. The routine use of BIM in developing building projects directly on campus also informs instruction with real world examples of projects that were under development. The study revealed that BIM could be successfully integrated into an existing curriculum and in a computer laboratory classroom setting. The course syllabus was modified in three phases with opportunities for continued refinements. As a result of the study, the researcher determined to fully deploy the “row champion” concept in future classes. BIM was used as a teaching tool through experiential learning to study building planning, design, code analysis, scheduling, sequencing and construction document coordination. The researcher was also able to study and implement experiential learning theory, learning with technology, and connectivism learning theory as developed by Siemens (2014).

Contribution to Existing Knowledge

First, the study indicated a robust proliferation of BIM in the construction industry over the last seven years and demonstrated an industry need for construction management graduates with some aptitude for BIM.

Second, continuing construction management education and associated graduation requirements need to adopt BIM into their curriculum. Survey respondents were consistent in their response around the need for integration in preparation for professional practice.

Third, T-test analysis revealed that student perception that BIM could be used as a teaching tool and successfully integrated into an existing graduate level construction management course increased at post-test. These results provide evidence that BIM was successfully deployed in an existing course over three semesters.

Fourth, the completed case study promotes the benefits of experiential learning, using the campus itself as a teaching and learning laboratory, and the use of BIM technology to explore concepts and complete assignments that parallel and prepare students for professional practice. The results of the case study continues to inform course refinements today.

Application in the Construction Industry

Buildings are becoming more complex and delivery schedules more accelerated. Today the construction industry is leveraging technology to improve project delivery and needs construction management graduates with some propensity for Building Information Modeling (BIM). An experiential aptitude for technology, most specifically BIM, is important for CM graduates who wish to successfully navigate the growing complexities of project delivery and meet industry demand. Of equal importance is the ability to collaborate and work in teams. This collaboration is promoted and supported by BIM. BIM is used today in the construction industry as the platform on which design-build and integrated project delivery is practiced; to complete construction, lift and shop drawings; for cost estimating and cost management, to generate and analyze project schedules and communicate this information. It is reasonable to conclude that the use of BIM will continue to grow, and the ways in which BIM is leveraged will continue to evolve. Preparing construction management students to think critically and innovate using BIM will provide a solid foundation for the next generation of construction industry leaders.

Opportunities for Further Research

Continuing efforts to integrate BIM into Construction Management education is needed. Further research is directed toward teaching methodologies and interdisciplinary team-based adaptation of this parametric, data driven tool to encourage discovery and innovation. BIM is rapidly changing the way we deliver buildings and preparing students to leverage this tool in preparation for future work engagements is important. This case study could be repeated given the ever-advancing

nature of technology in the AEC industry. While the current course is updated on an annual basis, new VDC tools and their impact on CM education is a pertinent topic for continued exploration. Further study would allow for additional data collection to help validate the results and provide additional insight and recommendations around using BIM as a teaching tool. The study could also be applied to an undergraduate level course. This work can provide the basis for ongoing study of educational theory and how it is impacted or informed by technology. Opportunities exist to more closely align and leverage CM education and AEC collaboration with professional practice through experiential learning.

Study Limitations and Generalization of the Findings

The study was limited to three semesters and focused primarily on graduate students. Due to the limited duration of the study and limited sample size, the findings are general but do offer verification that AEC students are becoming increasingly aware of the BIM tool while new technology and course materials can be learned at the same time. The course was developed in a dynamic way; that is, adaptations were implemented in subsequent semesters given changes in the technology itself and/or the processes used to procure projects at CSU. Small course changes between semesters to enhance the course may have had an impact on the survey results. The exploratory descriptive case study approach, the generalization of the study and the associated survey questions were intended to mitigate the impact of the small course modifications between semesters. BIM can be used as a teaching tool, and that the need for separate courses focused on the technology itself may not be needed. Students reported a preference for experiential learning, working in teams, and using the campus, including the ongoing planning, design and construction projects, as a learning lab for the course.

The case study survey data is from 2014, 2015 and 2016 and the study was compiled in 2021. The data and results, while several years old, remain relevant since the BIM application implements and

building development process remain static since the case study was performed. That said, continuation and refinement of the study would promote that new data be assembled and analyzed and reported to confirm and expand the finding herein.

Survey questions were developed through collaborative discussion with a number of inputs from a number of individuals interested in the study. While the feedback was embraced, this may have led to a complexity in the questions that impacted interpretation, the response data and associated analysis. Future similar studies would benefit from a simplification of the Likert scale survey questions towards less options for the response. In order to complete the t-test analysis responses to Likert scale questions needed to be combined. Responses in the No Experience, and No Experience but aware of the technology, were combined into a no experience category of response to allow for clarity of the analysis within the Statistical Program for the Social Sciences (SPSS) software.

In 2014, when the study started, literature around the need for BIM education in the construction management discipline was somewhat limited. As a result, the researcher leveraged professional experience and correspondence with industry to help validate the need for the study. Professional experience revealed that BIM was being used in the construction industry, and that the AEC professionals reinforced a need for new employees with some aptitude for BIM. The current proliferation of BIM in the construction industry and the associated response in construction management education presents another compelling opportunity for further study and more in-depth analysis of the survey tool across a wider sample. Additional study might focus on current technology and the use of BIM in the construction industry to determine how best to prepare CM students. With emerging trends it was also important to study the incorporation of BIM in both architectural and engineering education as well as in construction management education to determine potential strategies for the integration in CON 571. This portion of the literature review was also valuable in formulating the case study. Additional literature review was then required around educational theory

that could help support a more interdisciplinary, experiential learning model that aligned with professional practice. As a follow on to this case study, a future study should deploy a more focused literature review which could be focused on educational theory and methods. The majority of the references continue to be included in new subject studies but in light of the rapid proliferation of technology and desired incorporation into CM education, many of the research sources are aging.

Reflections on course evolution and using BIM as a Teaching Tool since 2016

Terms associated with the construction industry and the associated technology are perhaps uncommon to other types of research and have been defined by reference and through a listing of terms at the beginning of the documentation. Of Importance in the teaching of construction industry students is to clearly define the language associated with the industry. This practice better informs an understanding of the material being presented. Understanding of the terms and bracketing the ongoing evolution of technology in the construction industry is critical in professional practice. Clearly defining qualifications, methods, metrics and practice is critical to the study of construction management and associated education pedagogies. The listing and presentation of critical terms helped inform the initial literature review and establish elements of the study. Using the definitions and concepts determined as the case study emerged helped to define the parameters of the study and explain the materials through reporting the results of this study. We had a great diversity of graduate students and associated experience with construction. It was important to determine that the class was familiar with the terms, concepts and language early to help promote understanding as the course progressed.

As informed by implementing the overarching results of the study, In the fall of 2017, we saw the work completed on the master planning/ logistics planning assignment exceed expectations with the entire cohort well engaged within their teams. The teams produced work that informed a change in the second project (program planning and conceptual building design). Traditionally, the programming and conceptual design work of the class had continued, and the teams completed a 25-40 page written

document. In 2017 we determined to combine the two teams into one development team that would in theory develop individual buildings to inform development needed to accommodate campus growth for the next 10 years. The team would develop the work in a three dimensional graphic and drawing form as opposed to the more narrative based analysis used to complete the work in previous semesters. Each team member would work in REVIT to develop individual buildings to a schematic design level of detail with the associated spatial analysis, schedule, code analysis, cost estimates and logistics planning. This individual work was used to inform a larger effort where the entire class would present their work as a team indicating that these buildings are required to accommodate campus growth for the next ten years. The work included a running schedule for development and associated costs with appropriate compounding escalation built in over time. The individual models were linked to the campus map and instruction around how the individual files would update automatically in the master file was administered. The syllabus was updated live after discussions around delivery of remaining work immediately after class in 2017.

One of the more significant changes derived from the study and associated discussions was the implementation of a “row champion” for each student group. A row champion is defined as an individual on each team that would sit in the middle of each seating row to help the other team members with instruction around the use of BIM. These individuals were identified via informal discussions during the first class and in studying the responses to the pre-class survey. The row champions volunteered to participate in this role, having identified that they had some experience with BIM coming into the class. The intent of this strategy was to have an active team member that could help others with less experience keep up with the pace of instruction. This also proved valuable in team building, promoting leadership and seemed to encourage discussion well beyond the technological interface.

Coordinating Instruction

Coupled with the work in CON 571, we were coordinating BIM instruction efforts with CON 511 Project Procurement and Preconstruction. CON 511 planned to leverage BIM to document existing conditions of the Industrial sciences building from cloud point data provided by industry. In 2017, four students in the CON 571 class were also enrolled in the CON 511 class and were able to leverage BIM instruction from both classes to make significant progress and help instruct other members of the team with less experience using the technology.

Throughout the duration of the study we witnessed a very favorable, positive exchange of information, ideas, personal experience and expression. The products were perceived to be of higher quality as a result of the collaborative, creative, real world endeavor. The class, as always, was labor intensive and required hard work in learning the development process while at the same time learning the cutting-edge technology and associated applications required to add efficiencies to the process.

The CON 571 students emulated what should be expected of graduate students. The instructor was able to point the group a certain direction, have a robust discussion, work with very intentional positive feedback and have the resulting solution exceed the requirements and expectations. Instruction was based on a mentor in the middle coaching model. The instructor leveraged ongoing professional practice on campus and actual campus projects to solicit and maintain interest. Continuous positive reinforcement was also paramount especially when the material and technology seemed overwhelming. It was important to carefully monitor the work required of other university and sometimes professional commitments to ensure the engagement and associated work was properly scheduled. The intent was to promote a positive, low stress learning environment where all students could benefit from the team dynamic and leverage experiential, live learning which was essential to the success of the class. It was also important to reinforce the required contributions of each individual team member if the team was to be successful. (Kolb, 2005)

The researcher and instructor experienced an unanticipated interest in the technology and class materials. Students often stayed engaged after the three-hour class to discuss the material and gain a better individual understanding. Students routinely visited my office to further develop their solutions. Project teams were often found in adjacent hallways strategizing before and after class. To emulate professional work, the tenants we practice in class include researching, collaborating in a team and then delivering a quality product with innovation while maintaining efficiencies through the use of technology and lean construction methodologies.

The accumulation of the class resulted in a compelling three-dimensional virtual campus map illustrating the coordinated buildings the students had developed over the course of the term.

Further Developments and Lessons Learned

In 2017, with only seven students, we saw more progress in BIM, earlier in the course. We found the project planning assignment was well in excess of expectations especially in comparison to previous semesters. We saw a robust exploration of BIM and the highly challenging project planning and design deliberation. The work readily demonstrated the if – then; cause-effect deliberation so closely associated with critical thinking, project development and logistics planning. We saw BIM deployed robustly to illustrate process and solutions for the three major assignments. In presenting their work, the students promoted the path and process they used in developing the design documents using BIM. As a result of this, we reassessed the remaining syllabus, and as a class, determined that the more narrative based portions of the building program plan assignment could be reduced in favor of each student having more time to work to develop the same information graphically through their individual building investigation in BIM. We established the goal of reincorporating the resulting conceptual design work back into a consensus master plan and logistics frame work at the end of the course and then presented the resulting graphics as a cohesive team.

Conclusion of Study

As professionals, we often think of development planning as a skill that is practiced over time and eventually mastered over a career. Fundamentals can be taught, but experience and practice is required. The use of BIM in planning, design and construction should not only be taught to evoke critical thinking, but also to leverage opportunities for more in depth and perhaps more efficient development study. The tool allows for more trials, with the trials investigated in more depth in the same amount of time when compared to the same study attempted without the use of the BIM technology.

Subjective and qualitative discussion from students reinforced that the instructor packs a lot into a short amount of time, that each of the study areas or assignments could be a semester course. While working in teams is required and promoted, the amount of work product required of the course is ambitious. Each year the researcher observes apparent anxiety and worry as the syllabus is presented in the initial class compared to the comfort and sense of accomplishment displayed when the students complete their final assignment and reflect on the hard work required of the course.

Team based methodologies are essential to successful project delivery, especially as building complexity increases and the allowable time to deliver the projects seems to decrease. The class is structured to emulate professional practice where students of various disciplines are selectively diversified and allowed to work in teams. The teams have the opportunity to strategically plan the workload among the team members to ensure successful assignment delivery. This case study indicated, and continues to reinforce, that a highly successful integration of technology in an existing course while maintaining and promoting the team-based, interdisciplinary project delivery methods that are critical to success in professional practice. The work of the students who participated in this study continues to

inform ongoing research, discussion and influence professional practice. The students should be proud of the process, the products, and their contributions to future coursework at Colorado State University and the profession.

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Appendices

Colorado State University

Institutional Review Board

**REQUEST FOR EXEMPTION
for the Use of Human Subjects in Research**

Research involving surveys, interviews, the use of existing data, taste and food quality evaluation and standard educational research generally fall within the exempt category. Projects that are considered exempt must be less than minimal risk to the participants.

An IRB Administrator or IRB member must review the application and determine that the project is exempt from expedite or full review. Once a protocol has been determined to be exempt, the protocol will not be monitored by the IRB on an ongoing basis. If the research qualifies for exemption, a notification will be forwarded to the PI. Please keep the notification for documentation that the project is considered exempt and does not need continuing review by the IRB. The PI must notify the IRB Administrator if any proposed changes to the research will be made. At that time, an IRB Administrator or IRB member will determine whether the status of the research has changed. Any complaints that may have been received during the course of the research must also be reported.

A determination that research is exempt does not absolve the investigators from ensuring that the welfare of human subjects participating in research activities is protected, and that methods used and information provided to gain subject consent are appropriate to the activity.

Data collection may not begin until the PI has been notified that the project has been determined to be exempt.

The six exempt categories can be found at: <http://web.research.colostate.edu/ricro/hrc/forms.aspx>
Below are exceptions that are NOT considered exempt.

Exceptions:

Exemptions will not be granted for the following circumstances:

- Research involving prisoners. All prisoner research is reviewed by the full IRB.
- Research that includes both exempt and non-exempt activities cannot be determined to be exempt and should be submitted for expedite or full review.
- Research involving coercion, undue influence, deception, risks or discomforts greater than encountered in daily life.

NOTE: If the project is determined not to be Exempt, the protocol will need to be entered into eProtocol and sent out for Expedite or Full review electronically.

Colorado State University
Institutional Review Board (IRB)

REQUEST FOR EXEMPTION

(Administrative Review) for the Use of Human Subjects in Research

APPLICATION INSTRUCTIONS: Complete the 2 parts below, submit to address at the end of this form. NOTE: The form is protected for your convenience to tab through the form. If you need to unprotect the document, please contact Janell.Barker@Research.colostate.edu.

PART I: GENERAL INFORMATION

Title of Project: An initial case study describing the integration of Building Information Modeling (BIM) in an existing graduate level construction management course to support construction industry demand for candidates with some aptitude for BIM.

Principal Investigator (PI): Jonathan M. (Mike) Rush **email:** mike.rush@colostate.edu
Department: Construction Management
Campus mail code: 6030 **phone:** 970-491-0080, 970-567-1011
(for student projects; PI must be advising faculty member)

Co- Principal Investigator (Co-PI): n/a **email:** n/a
Department: n/a
Campus mail code: n/a **phone:** n/a

Source of funding: n/a
If externally funded, include PASS number if known: enter pass number here
Please provide a copy of the grant proposal, if applicable.

Indicate the anticipated start and ending date for this project.
Start: August 20, 2014 **End:** December 20, 2014

Rank of PI: ☐ Faculty Special Appointment, Assistant Professor
X ☒ Other: Working Professional, Adjunct Faculty

Rank of Co-PI: ☐ Faculty ☐ PhD student ☐ Masters Student ☐ Undergraduate
☐ Other: describe 'other' here

PART II: PROJECT DESCRIPTION

1. Provide a lay summary for all study activities. Please provide a copy of the thesis/dissertation methods section if applicable.

The research project will include a literature review based need for the research, a case study of CON 571 and associated qualitative analysis and reporting. Qualitative analysis is readily applicable to case study research especially where the proposed surveys will result in limited samples. (Creswell (2010);Gay,L.,(2011) The CON 571 case study will include a pre course survey and post course survey of enrolled students. Due to the limited sample size of the proposed surveys, qualitative research and analysis techniques as defined by Creswell (2010) will be deployed. Case study planning and methods as defined by L. Gay (2011) with associated class surveys will be the focus of the research. The most compelling tenant of using CON 571 as a case study is that data can be secured over time in subsequent courses and become the basis for ongoing research toward possible doctoral studies in education. For the author, learning by teaching fits into a readily defined learning ecology on a university campus. A case study is appropriate when a researcher needs to answer the “ How did they do that” question. Educational theory shall form the basis of a case study proposal and first time researchers should limit their sample to one case study. (L. Gay 2011). Experiential learning theory as defined initially by John Dewey in 1938 is learning informed by transformative experience (Kolb, A. Y., Kolb, D. A., and others .2005). Also of interest is recent work by CSU’s Institute for Teaching and Learning around “leaning ecologies” and possible grant opportunities for innovative course redevelopment which may directly align with this proposal.

The research project will develop a structured case study in CON 571. The aim of the study will be to utilize the findings of the literature review, informal student employee case studies and recent instructional experience to redevelop a graduate level construction management course to fully integrate BIM as a teaching tool. The process for implementation will be described in detail with the intent of retaining existing course materials and assignments while utilizing BIM and Virtual Design and Construction (VDC) technology as a tool to complete the work. I believe by definition and if formally documented, this integration process can be identified as an ongoing case study to inform proposed current and future research.

Research Questions

- 1) What methods can be utilized to integrate BIM into existing Construction Management curriculum.
- 2) What is the experience level of an initial random sample of CM graduate students in the use of BIM.
- 3) At the end of the course, will the student sample be prepared to use the BIM tool for completing future assignments?
- 4) At the end of the course, will the student sample feel they are better prepared (via the experience gained in using BIM) to seek employment opportunities in the construction industry.
- 5) Identify the challenges and benefits of BIM integration to inform ongoing course modifications and subsequent research over time.

The non-experimental, qualitative case study plan of research includes administering a student class survey at both the beginning and at the conclusion of the class. It is anticipated that qualitative methods and associated graphics will be used to simply report the results of these very pragmatic surveys. The majority of the anticipated questions will be closed for ease of interpretation with two open ended questions at the end of the surveys to promote discovery and not limit the content, quality or length of response. After IRB approval, pilot surveys will be administered. I plan to leverage students who have completed the course in previous years and feedback will be used to refine the questions. Initial survey questions are attached and most of which will utilize a Likert scale to add consistency of response format.

2. Describe the participant population, including age range and inclusion/exclusion criteria. State how many will be recruited.

Construction Management Graduate students enrolled in CON 571, Fall 2014. Anticipate between 11 and 20 students

3. Describe how potential participants will be approached about the research and how informed consent will be obtained. Alternatively, provide an explanation of why informed consent or documented informed consent will not be obtained. Please attach a copy of the consent document, if applicable.

The survey will begin with the following language:

You have been selected to participate in this research because of your interest in the course, Facilities Planning and Management and BIM. Participation is voluntary but Your perspective as a student completing coursework using BIM as a tool is essential to inform ongoing integration strategies in the department of Construction Management, Colorado State University. A copy of the consent form is attached.

4. Describe how identifying information will be recorded and associated with the data, i.e., codes. Alternatively, provide details on how study data will be collected and stored anonymously (i.e., without a code or identifiers linking the data to the participants' identity.)

Due to the limited sample size of the survey, non-personal, non-identification based questions, coding of the data will not be completed. The data (survey results) will be secured such that only the principal investigator has access to the data. The analysis and reporting of the data will be anonymous.

5. Describe all study procedures, including topics that will be discussed in interviews and/or surveys. Please attach the interview questions or survey questions, if applicable.

A copy of the survey instrument is attached. Also attached is a copy of the email/consent to participate. Both documents will be administered in the first two classes, fall semester 2014.

6. Which exemption category does your study fall in? (list of categories are at: <http://web.research.colostate.edu/ricro/hrc/forms.aspx>)

Category 1: Research conducted in established or commonly accepted education settings, involving normal education practices, such as (a) research on regular and special education strategies, or (b) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

45CFR46.101(b)(1)

As the principal investigator, I assure the IRB that all procedures performed under this project will be conducted exactly as outlined in this form and that any modification to this protocol will be submitted to the IRB in the form of an amendment for its approval prior to implementation.

Principal Investigator:

Jonathan M. Mike Rush

(typed/printed name)

(signature, if paper copy)

June 30, 2014

(date)

WHEN COMPLETE:

Email electronic version from PI's email address to:

Janell.Barker@Research.Colostate.edu

Sent email will serve as electronic signature from PI.

OR

Deliver signed original copy to:

IRB Administrator, RICRO, 321 General Services Building, campus delivery 2011

APPENDIX II: Institutional Review Board Approval



Research Integrity &
Compliance Review
Office Office of Vice
President for Research
Fort Collins, CO
80523-2011
(970) 491-1553
FAX (970) 491-2293

Date: July 11, 2014

To: Mike Rush, Construction Management

From: IRB Coordinator, Research Integrity & Compliance
Review Office (RICRO_IRB@mail.colostate.edu)

Re: An initial case study describing the integration of Building Information Modeling (BIM)
in an existing graduate level construction management course to support construction
industry demand for candidates with some aptitude for BIM

IRB ID: 103-15H
2014

Review Date: July 11,

This project is valid from three years from the review date.

The Institutional Review Board (IRB) Coordinator has reviewed this project and has declared the study exempt from the requirements of the human subject protections regulations with conditions as described above and as described in U45 CFR 46.101(b):

Category (1) Commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

The IRB determination of exemption means that:

- **This project is valid for three years from the initial review.** After the three years, the file will be closed and no further research should be conducted. If the research needs to continue, please let the IRB Coordinator know before the end of the three years. You do not need to submit an application for annual continuing review.
- You must carry out the research as proposed in the Exempt application, including obtaining and documenting (signed) informed consent if stated in your application or if required by the IRB.
- Any modification of this research should be submitted to the IRB through an email to the IRB Coordinator, prior to implementing any changes, to determine if the project still meets the Federal criteria for exemption.
- Please notify the IRB Coordinator (RICRO_IRB@mail.colostate.edu) if any problems or

complaints of the research occur.

Please note that you must submit all research involving human participants for review by the IRB. **Only the IRB or designee may make the determination of exemption**, even if you conduct a similar study in the future.

APPENDIX III: Student Surveys

PRE CLASS SURVEY QUESTIONS

Con 571 – Case Study – Implementing BIM in an existing Construction Management Graduate Level Course.

Pre Class Survey

Mike Rush

mike.rush@colostate.edu

970-491-0080, 970-567-1011

- **Do you have any experience with or an aptitude for Building Information Modeling (BIM)?**
 - No Experience – I know nothing about BIM
 - No Experience - But I know what BIM is and how it can be used.
 - Little Experience – I have only explored the software (REVIT).
 - Some Experience - I have used BIM on assignments or projects.
 - More Experienced – I have used BIM on more than three assignments and/or projects.
 - Very Experienced- I routinely used BIM to complete projects either in academia or in private practice.
- **Have you used BIM to complete assignments in any of your previous coursework?**
 - Yes
 - No
- **Do you have any Computer Aided Design (CAD) experience?**
 - Yes
 - No
- **Have you used CAD to complete assignments in previous coursework?**
 - Yes
 - No
- **Are you generally able to easily learn technical software and integrate technology?**

- Yes
- No
- **What is your age?**
 - 18-24
 - 24-30
 - 30-36
 - 42-48
 - Over 48
- **Do you have any experience with master planning or construction site logistics planning?**
 - No Experience – I know nothing about planning
 - No Experience - But I know what planning is and how it can be used.
 - Little Experience – But I have explored planning projects
 - Some Experience - I have used planning to complete one assignment or project.
 - More Experienced – I have used planning to complete work on more than three assignments and/or projects.
 - Very Experienced- I have successfully used planning to complete projects either in academia or in private practice.
- **Do you have any experience with building programming and conceptual building design?**
 - No Experience – I know nothing about programming and building design.
 - No Experience - But I know what programming and building design is and how it can be used.
 - Little Experience – But I have explored programming and building design.
 - Some Experience - I have used programming and building design to complete assignments or projects.
 - More Experienced – I have used programming and building design to complete work on more than three assignments and/or projects.

- Very Experienced- I have successfully used programming and building design to complete projects either in academia or in private practice.
- **Do you have any experience with building code analysis?**
 - Yes
 - No
- **Any experience with scheduling and sequencing construction projects?**
 - Yes
 - No
- **Any experience with total development cost estimating of construction projects?** Total Development Cost estimating for the purpose of this question, combines all hard (construction) costs, soft (fee based costs) with land costs and any and all furniture and equipment necessary to eventually operate the building. It does not include the cost of project financing.
 - Yes
 - No
- **Any experience coordinating component systems in building design or construction?**
 - Yes
 - No
- **Do you think BIM can be used as a teaching tool to deliver instruction in the previously mentioned assignments? (Master Planning, Programming, Conceptual Building Design, Building Code Analysis, Cost Estimating, Component System Coordination)**
 - Yes
 - No

- **Do you think BIM will lend itself to hands on, experiential learning?** (experiential learning most simply defined by learning by doing)

- Yes

- No

- **Do you think BIM can be used to market projects and secure work?**

- Yes

- No

POST CLASS SURVEY QUESTIONS

Con 571 – Case Study – Implementing BIM in an existing Construction Management Graduate Level Course.

Post Class Survey

Mike Rush

mike.rush@colostate.edu

970-491-0080, 970-567-1011

- 1. Do you have any experience with or an aptitude for Building Information Modeling (BIM)?**
 - a. No Experience – I know nothing about BIM
 - b. No Experience - But I know what BIM is and how it can be used.
 - c. Little Experience – I have only explored the software (REVIT).
 - d. Some Experience - I have used BIM on assignments or projects.
 - e. More Experienced – I have used BIM on more than three assignments and/or projects.
 - f. Very Experienced- I routinely used BIM to complete projects either in academia or in private practice.
- 2. Have you used BIM to complete assignments in any of your previous coursework?**
 - a. Yes
 - b. No
- 3. Do you have any Computer Aided Design (CAD) experience?**
 - a. Yes
 - b. No
- 4. Have you used CAD to complete assignments in previous coursework?**
 - a. Yes
 - b. No
- 5. Are you generally able to easily learn technical software and integrate technology?**
 - a. Yes
 - b. No

6. What is your age?

- a. 18-24
- b. 24-30
- c. 30-36
- d. 42-48
- e. Over 48

7. Do you have any experience with master planning or construction site logistics planning?

- a. No Experience – I know nothing about planning
- b. No Experience - But I know what planning is and how it can be used.
- c. Little Experience – But I have explored planning projects
- d. Some Experience - I have used planning to complete one assignment or project.
- e. More Experienced – I have used planning to complete work on more than three assignments and/or projects.
- f. Very Experienced- I have successfully used planning to complete projects either in academia or in private practice.

8. Do you have any experience with building programming and conceptual building design?

- a. No Experience – I know nothing about programming and building design.
- b. No Experience - But I know what programming and building design is and how it can be used.
- c. Little Experience – But I have explored programming and building design.
- d. Some Experience - I have used programming and building design to complete assignments or projects.
- e. More Experienced – I have used programming and building design to complete work on more than three assignments and/or projects.
- f. Very Experienced- I have successfully used programming and building design to complete projects either in academia or in private practice.

9. Do you have any experience with building code analysis?

- a. Yes
- b. No

10. Any experience with scheduling and sequencing construction projects?

- a. Yes
- b. No

11. Any experience with total development cost estimating of construction projects?

Total Development Cost estimating for the purpose of this question, combines all hard (construction) costs, soft (fee based costs) with land costs and any and all furniture and equipment necessary to eventually operate the building. It does not include the cost of project financing.

- a. Yes
- b. No

12. Any experience coordinating component systems in building design or construction?

- a. Yes
- b. No

13. Do you think BIM can be used as a teaching tool to deliver instruction in the previously mentioned assignments? (Master Planning, Programming, Conceptual Building Design, Building Code Analysis, Cost Estimating, Component System Coordination)

- a. Yes
- b. No

14. Do you think BIM will lend itself to hands on, experiential learning? (experiential learning most simply defined by learning by doing)

- a. Yes
- b. No

15. Do you think BIM can be used to market projects and secure work?

- a. Yes
- b. No

16. Please describe opportunities to further integrate BIM in other classes you are or have previously been enrolled in:

17. Please note any challenges with course materials and or methods as well as the amount of time allocated for each assignment:

18. Please describe your experience working in teams using the most current technology as it relates to your perception of professional practice:

19. Do you feel some aptitude or initial experience with BIM will provide you with a competitive edge in seeking employment?

- a. Yes
- b. No

If Yes, Please describe how you might present these qualifications when seeking employment:

20. Will you continue to study BIM outside of this course? Do you anticipate using BIM in the future to solve problems related to your academic or professional pursuits?

- a. Yes
- b. No

2010 CON 571 SYLLABUS

CON 571 Facility Planning and Management Course Syllabus

Class time: Monday - 4:00- 6:45 PM Location: 226 Guggenheim Bldg. Credits: 3

Lead Instructor: Bill Franzen
Office:
Office Hours: 6:45-7:30 PM Monday. or
by appt. Telephone: (970) 556-9668
E-mail: SAGE2LLC@gmail.com

Advisory Instructor: Brian H.
Dunbar Office: 114
Spruce Hall
Office Hours: 3-4 Monday, or by appt.
Telephone: (970)
491-0244
E-mail: brian.dunbar@colostate.edu

Course Description:

Planning, organizing and managing large educational and/or community facilities

Course Objectives:

To assist graduate students in understanding the issues involved in, and the facets of, facility planning and management through hands-on projects working with actual clients

Each student will;

1. Be exposed to the components of facility management such as: space planning, life safety and security management, and building systems planning and management.
2. Understand the major components required to develop a facility management plan, perform existing facility analysis and integrate sustainable practices into facility planning and management.
3. Be required to work on a project team to develop a comprehensive facility plan. The project will include space utilization plans, building layout, equipment and furniture plans, and building energy systems and materials schematics.
4. Develop an understanding of the tools and techniques of planning and managing facilities, including knowledge of a facilities management software program.

Grading Criteria:

Class, Project, and Small Project/Charrette Participation	30%
Project Assignment	30%
Group Facility Planning/Management project	40%

Projects:

Individual Research Assignment

Use a facility as a case study from the list provided or self-selected with the instructor approval. Interview the owners, facility management administrators and/or staff. Identify the selected facility issue(s) and describe how the owner, facility management administrators and/or staff respond to them on a day-to-day and long-term basis. A professional presentation, presented as if you were making it to your colleagues and employer, will be required.

- 10 minute concise Power Point presentation – **limit of seven slides**.
- 3-4 cited resources/references
- Electronic and 4-6 page hard copy report due with presentation
- Incorporate graphs and photos as appropriate

Group Facility Planning/Management Project – “LEED EB/OM ”

From the selected Group Facility Planning/Management Project, identify unresolved issues, or alternative approaches to resolved issues, that are important to the owner for the completion of the project. Working in small project groups describe the issue, develop alternatives, research resolutions to similar issues, and fully develop a plan that addresses the issue. Coordinate with the other project groups to develop a comprehensive presentation that addresses the work of all the project groups. A professional presentation by the class will be made to the owner's group at the end of the semester.

Small Project/Charrette – “*Integrating Energy Management into the Organization Culture*”

In addition to the Group and Individual project, a Small Project/Charrette, will be held. This is an actual Charrette to assist a client. A summary of the Charrette findings will be presented by the class to the client several weeks following the Charrette. It will be essential to be present for the Charrette.

CON 571 Facility Planning and Management – Fall
2010 Course Outline
Monday 4:00 – 6:45 PM

August 23

- Instructor, Student, Course Introduction
- Facility Management Discussion
- Class Assignments
 - Individual Research
 - Small Group Project (SGP)
 - Large Group Project (LGP)

August 30*

- Tour – Class meets for LGP Site Tour
 - Discuss LGP Assignments
- Select Individual Research Project

September 6

- **Labor Day – No Class**

September 13

- Sustainability & Integrated Building
- Review of LEED EB O&M
- Select LGP Project Teams
- LGP Team work session
- Individual Research – Review and Support

September 20

- Sustainable Management Systems
- LGP Team work session
- Individual Research – Review and Support

September 27*

- Tour - Class Meets at PSD Operations Center – 2445 La Porte Avenue
 - Facility Management within Poudre School District
 - Dinner Served
- LGP Team Work Session

October 4

- Facility Management – Cultural Change
- Individual Research Assignment Presentations Due and Presentations

*** Class will meet at another location**

October 11

- Individual Research Assignment Presentations
- LGP Team Work Session

October 18

- Facility Management at CSU
- Small Group Project Review
- LGP Project – Review and Status Report

October 25*

- Small Group Project Charrette
- Class meets at Kinard Middle School
- “Integrating Energy Management into the Organization Culture”

November 1*

- Tentative Tour
- LGP Team work session

November 8

- Facility Management - Energy Management
- LGP Team Work Session

November 15

- Facility Management – Retro Commissioning
- LGP Project Wrap-up and Begin Preparation for Final Presentation

November 22

- **Thanksgiving Break – No Class**

November 29

- Small Group Charrette Outcome Presentation to Representatives
- LGP Project – Work Session

December 6

- LGP Project Presentation – Internal Review

December 13*

- LGP Project Presentation to Representatives

2011-2013 CON 571 SYLLABUS

Course Syllabus – Fall 2011 – CON 571 – FACILITIES PLANNING AND MANAGEMENT

Class Time: Thursday – 4:00-6:45PM

Location: 101 Preconstruction

Credits: 3

Instructor: Mike Rush

Office: 145 Facilities Management North

Office Hours: By Appointment –

Contact: o. 491-0080, m. 567- 1011 or Linda White 491-0312

e. mike.rush@colostate.edu

Course Description:

Campus planning and management. Expertise will be applicable in large academic and institutional environments as well as in building specific planning and management.

Course Objective:

To assist graduate students in securing a skill set that will be directly applicable in the practice of integrated project delivery and securing work in an increasingly competitive construction industry. The class will be taught through hands-on project based study in master planning, programming, and operations. We will develop a campus master plan, program plans and associated bridge documents. The documents will include integral building code and spatial analysis to inform conceptual design and cost estimating. The RFP/RFQ development and solicitation process as well as contract preparation and amendment process will be also covered to better prepare students for Owner expectations in securing work.

All projects will be developed with an underlying thread for sustainable initiatives in the built environment. We will use the latest technology and presentation media. The instructor will share formulas for budget and schedule management to begin to eliminate project uncertainties and shortfalls. A number of guest speakers are scheduled to provide additional industry expertise in the subject materials. Aligned with this, students will develop the ability to organize and present the assignments and project solutions to the class and instructor.

Each student will:

- Be exposed to the components of facility management such as: space planning, life safety and security management, and building systems planning and management.
- Understand the major components required to develop a facility management plan, perform existing facility analysis and integrate sustainable practices into facility planning and management.
- Be required to work on a project team to develop a comprehensive facility plan. The project will include space utilization plans, building layout, equipment and furniture plans, and building energy systems and materials schematics.
- Develop an understanding of the tools and techniques of planning and managing facilities, including knowledge of a facilities management software program.

These skills can be utilized to:

- Secure work with public and private sector clients.

- Lead the team in projects developed through integrated project delivery methods including CM/GC and Design-Build.
- Develop charrette based projects, utilizing group study and team based methodologies.
- Manage owner and/or client expectations and deliver successful projects.
- Manage and operate complex sustainable facilities and/or overall complexes or campuses.

Grading Criteria:

Class and team participation: 25 pts

Presentation of course projects: 25pts

Assignments: 50pts

Late Work and Attendance Policy:

Attendance will be monitored. As a three credit hour class that meets once a week through the semester, attendance at each class is essential and with the extent of interrelated, hands-on, in class team work, missing the material presented in any class will make it extremely difficult to keep up with the subsequent coursework. While missing any class is certainly not recommended, it is understood that occasionally, circumstances come up that are beyond our direct control. As a result, the following absentee policy has been developed:

One Absence: 5 pts will be deducted from the class and team participation grading criteria.

Two Absences: Final Grade will be adjusted downward one letter grade.

Three Absences: Final Grade will be adjusted downward two letter grades.

Late Work:

Assignments are to be posted to RAM CT as delineated in this syllabus. For each day late, 1 pt will be deducted from the assigned score. Three days late and the assignment will not be graded.

Materials:

- **Have in hand by September 1, 2011**

18" wide roll of trace paper, aka Bum Wad, aka Onion Skin (white or yellow)

Sharpe markers - thick and thin (Blue, Black and Red)

Architect and Engineering Scales

Facilities:

A great deal of work will be completed in the Preconstruction Center Room 101. Later in the semester; the computer lab, Preconstruction Center room 200, will also be utilized in the course.

Using the campus itself for the master planning/ programming exercises as well as monitoring the current construction projects for the field reports and discussion topics will be essential in completing the assignments.

- Downloading the most current trial versions of Google sketch-up and AutoDesk Revit to personal computers may be of benefit but is not required.

Assignments, 50pts:

- Discussion Papers – 10pts (your 10 best scoring papers will be averaged)
- Field Reports - 10pts (your 10 best scoring reports will be averaged)
- Master Plan solution - 5pts
- Abbreviated Program Plan – 5pts
- Abbreviated Project Schedule– 5pts
- RFQ/RFP development and response – 5pts
- Conceptual Revit Model and Navigation – 5pts
- Conceptual Revit Model PDF Print – 5pts

Presentations, 25pts:

- Master Plan Presentation - 10pts
- Program Plan Presentation – 10 pts
- BIM Presentation (On Screen) – 5pts

Course Outline, Presentation and Assignment Schedule

August 25:

- Welcome, Introductions and past student experience – use data in assigning teams
- Instructors Research Interests – BIM as a teaching tool.
- Review Course Syllabus
- Determine Field Report Assignments – Hand Out Suggested Format
- CSU Master Planning to accommodate 35,000 students
 - Next 4 class sessions – section accumulates in final team presentation.
 - Distribute preliminary analysis of additional facilities required to accommodate an additional 10,000 students
- Assign Teams
- Tour of the recently completed campus buildings and buildings currently under construction
 - Discuss sustainable initiatives in the completed projects on site.

Assignments – (Lets all use Calibri 11pt for the papers).

Discussion Papers: Draft a one page report with your thoughts on the subject matter being presented in preparation for the subsequent class discussion.

- **Discussion Paper 1 – One page summary of the Building Tour, note sustainable features, material qualities, building placement in overall campus context, etc as it relates to planning, design and construction.**

Field Reports: Throughout the course, complete weekly field reports on the buildings in progress on CSU main campus. Limited in format to chart progress and ask questions to be addressed/discussed in selected classes. The design work and electronic scheduling and sequencing documentation will be made available via RAM CT for students to track actual progress/derivation in weekly field reports.

A Building Information Modeling (BIM) construction schedule animation file will be available for the Parmelee Revitalization project. I may also have the same for the Engineering II project later in the semester.

The following on-campus building projects are currently available for study: the Parmelee Resident Hall Revitalization, the Engineering II Building, The Alder Hall Addition, The Morgan Library Revitalization – Study Cube Addition, The Lory Student Center Theater Revitalization – North Prefunction Space Addition and North Wall modifications. Instructor will hand-out suggested format in the first class.

- **Develop Field Report 1 for a current construction project as determined in class.**

IMPORTANT: *Observations will be limited to those that can be made from beyond the construction fence. Do not attempt to gain access to the construction sites. Students can certainly monitor more than one project at their discretion but access will be limited to already established public ways for obvious safety reasons.*

Weekly Assignments Due: Post to RAM CT no later than Wednesday at noon prior to each class.

Reference also the attached Assignment Schedule.

September 1:

- Discuss recently completed projects
- Review Field Reports –Address Questions and Discuss
- Master Planning – Part 1: Facilities Planning in a University or Large Institutional Environment
 - Slides from BOG presentation
 - Reference 2004 Campus Master plan
 - Present Campus Sketch-Up File
 - Review Overlay and Design/Planning Process
- In Class Team Work – Master Planning 1: CSU Master Planning to accommodate 35,000 students
 - Use +10,000 students preliminary analysis to begin to identify sites for development.
- Cameron Gloss, Former City Planner with the CFC and Senior Planner EDAW/ADCOM
 - <http://www.aecom.com/>
 - Presentation – Planning in the Public and Private sectors

Assignments:

- **Discussion Paper 2: A one page report describing progress and challenges in developing master plan solutions –or – a summary/discussion of industry expert presentation.**
- **Document individual ideas and concepts in master planning to inform team work in next class**
- **Field Report 2**

September 8:

- Discuss the Field Reports and Discussion Papers to date
- Discuss master planning progress
- Mr. Gino Campana, Developer and Owner Bellisimo Inc.:
 - <http://www.bellisimo-inc.com/>
 - A Developers Perspective on Planning, Finding Opportunities and Building Relationships
- Master Planning - Part 2
 - Slides and video from LSC – to show direction site or building specific Master Planning is headed – parallel using BIM and current technologies.
 - Discuss the importance of developing skills associated with master planning programming and design as a CM graduate student – parallel with Integrated Project Delivery and Design Build.
- In Class Team Work – Master Planning 2

Assignments:

- **Discussion Paper 3: A one page report describing progress and challenges in developing master plan solutions –or – a summary/discussion of the industry expert presentation.**
- **Continue with individual concepts in master planning to inform team work in next class**
- **Field Report 3**

September 15:

- Discuss the Field Reports and Discussion Papers to date
- The charrette based process
 - <http://www.fm.colostate.edu/character/>
 - The CSU Design Review Committee
- Sustainable site and building planning
 - Building orientation, parking maximums, pedestrian and bike circulation
 - Use USGBC LEED Checklist in developing master planning strategies
- Carol J. Dollard, P.E., LEED AP, Energy Engineer, Facilities Management, CSU
 - <http://www.green.colostate.edu/>
 - www.fm.colostate.edu/sustain
 - Sustainable initiatives in Planning and Practice @CSU
- In Class Team Work – Master Planning 3

Assignments:

- **Discussion Paper 4: A one page report describing progress and challenges in developing master plan solutions relate to sustainable initiatives –or – a summary/discussion of the industry expert presentation.**
- **Continue with individual concepts in master planning to inform team work in next class**
- **Field Report 4**

September 22

- Discuss the Field Reports and Discussion Papers to date
- Integrated Project Delivery – As the Project Delivery Leader
 - Gaining experience with the process to be able to actively participate.
- Chris Banter, Kiewit Construction
 - <http://www.kiewit.com/>
 - Integrated Project Delivery in Practice
- In Class Team Work – Master Planning 4

Assignments:

- **Discussion Paper 5: A one page report describing progress and challenges in developing master plan solutions –or – a summary/discussion of the industry expert presentation.**
- **Continue with individual concepts in master planning to inform team work in next class**
- **Field Report 5**

September 29

- Steve Hultin, P.E., Director of Facilities Management, CSU
 - Facilities Operational and Infrastructure Considerations in Master Planning
 - <http://www.facilities.colostate.edu/>
- In Class Team Work – Master Planning 5
 - Prepare team presentations

Assignments:

- **Discussion Paper 6: A one page report describing progress and challenges in developing master plan solutions –or – a summary/discussion of the industry expert presentation.**
- **Prepare Master Plan Presentations and post to Ram CT – Power Point or PDF**

October 6

- Present Master Plans
 - 10 - 15 minutes each team including interactive Q&A
- Developing an abbreviated project / construction schedule for executive level review
 - Use detailed construction and sequencing schedule to derive important milestones for presentation.

Assignments:

- **Field Report 6**
- **Prepare and Post Abbreviated Project Schedule**

October 13

- Programming 1 – Introduce Program Plans, Concept Papers and Bridging Documents
 - Bridging documents in integrated project delivery
- Steve Brooks – Principal, Oz Architecture
 - <http://ozarch.com/>
 - International Master Planning and Design- City of Kigali Master Plan - City of Kigali Master Plan - Kigali, Rwanda, Africa; Patan Hospital: Kathmandu, Nepal
 - Steps in Developing a Program Plan – Bridging Documents – Conceptual Design
- In Class Team Programming Work Session - 1

- Identify building from your Master Plan to use in developing the programming documents
- Review with Instructor

Assignments:

- **Discussion Paper 7: A one page summary of the industry expert presentation. Compare and contrast global planning initiatives with your campus specific master planning and programming to date.**
- **Field Report 7**

October 20

- Owner Formulas for Schedule and Budget Management
 - Through the design process
 - Through the bid process
 - Strategically working through the CMGC Contract and Amendments/Allowances
- Programming 2 - Components
 - Abbreviated Program Planning Guidelines
 - Code Analysis – planning level
 - CSU Building Code Compliance Program
 - Cost Estimating – planning level
 - Spatial Analysis – Planning level
- In Class Programming Team Work Session – 2
 - Complete Programming 2 session components using instructors templates
 - Discuss forms and suggest enhancements

Assignments:

- **Discussion Paper 8: A one page discussion of building programming progress to date with issues/ questions.**
- **Field Report 8**

October 27

- Programming 3 – Components
 - LEED Checklist
 - Aesthetic Guidelines
 - Planning Level Schedules
 - Life Cycle Costing
 - Introduce define and discuss Bridging Documents in the Design Build Procurement process
 - Review Conceptual Design Report – E2
- In Class Team Programming Work Session – 3
 - Discuss forms and suggest enhancements
 - Complete Programming 2 and 3 session components using instructors templates
 - Prepare Presentations
 - Discuss the required evolution of the program plan to bridge documents

Assignments:

- **Prepare Program Plan Presentations and post to Ram CT – Power Point or PDF**
- **Field Report 9**

November 3

- Steve Hultin, P.E., Director Facilities Management
Facilities Operations and Maintenance Overview:
 - Considerations in Building Programming
 - The engineers design review process
 - Establishing long term infrastructure and ongoing maintenance and operation considerations and costs associated with new facilities
- Abbreviated Program Plan– Team Presentations
 - Slides: 10 – 15 minute duration

Assignments:

- **Discussion Paper 10: A one page summary of the industry expert presentation.**
- **Field Report 10**

November 10

- CSU Standards Manual - Overview
 - Reference to the Office of the State Architects – High Performance Building Standards
 - Reference to USGBC LEED Gold Facilities
 - <http://www.facilities.colostate.edu/index.asp?url=construction/home>
 - http://www.facilities.colostate.edu/index.asp?url=construction/constr_standards
 - Review AE Contract for Reference to HPBS
- Poudre School District - Sustainable Design Guidelines
 - Mike Spearnak, Director of Planning, Design and Construction, PSD
 - Using the Guidelines to Develop Energy Efficient Schools
 - <http://psd.k12.co.us/departments/planning-design-construction>
 - http://eweb.psdschools.org/documentlibrary/downloads/Plan_Design_and_Construction/Sustainable_Design_Guidelines_2005.pdf

Assignments:

- **Discussion Paper 11: A one page summary of the industry expert presentation. Compare and Contrast the CSU Standards and PSD Tech Spec.**
- **Field Report 11**

November 17

- Review Technical Standards Analysis: Discussion Paper 11
- State Procurement Process Overview
- Project specific advertisement RFP/RFQ Overview
 - Importance of asking for what you want
 - Importance in responding: following the directions
- BIM Overview – Working in Revit
- Assignment – work through tutorials in REVIT

Assignment:

- **Develop and Post an Advertisement RFP/RFQ from instructors template**
- **Work through tutorials in REVIT**

November 24

- No Class – Thanksgiving

December 1

- Review Advertisements and Discuss Revit
- Conceptual Building Design - BIM 1
 - BIM Technical Lecture – In Lab
 - Use completed program plan/ bridging documents to develop massing studies for a simple building in Revit
 - Use BIM to develop conceptual massing models for the program planned building
 - Through Integration and shade and daylighting studies directly integrate USGBC LEED initiatives through the use of REVIT
 - Outcome is to be able to navigate and provide an introduction to BIM specifically addressing it as the current industry standard for developing buildings through the use of Autodesk REVIT
 - 3 class sessions

Assignment:

- **Discussion Paper 12: A one page summary of questions and concerns in using REVIT based on the initial class.**
- **Work on Massing Studies in Revit**
- **Field Report 12 – The Last One!**

December 8

- Conceptual Building Design - BIM 2
 - Continue work on conceptual model
 - Hands On – On Screen w/ Instructor

Assignment:

- **Discussion Paper 13: A one page summary of questions and concerns in using REVIT based on the two classes.**
- **Work on Massing Studies in Revit**

December 15

- Conceptual Building Design - BIM 3
- Present Concepts on Screen and Demonstrate capacity to navigate in REVIT
- Distribute BIM Survey and Class Evaluations

Assignment:

- **Discussion Paper 14: A one page summary of questions and concerns in using REVIT based on the three classes.**
- **Complete and post BIM Survey and Class Evaluations**
- **Have a Great Break!**

Course materials – Will be Posted or Links provided @ RAM CT prior to subject instruction

- Facilities Master Plan Analysis for 10,000 additional students
- Braiden and Parmelee sequencing and scheduling BIM animation file
- CSU Master Plan and BOG slides
- Housing and Dining Services Master Plan
- CSU Standards Manual
- PSD Technical Specifications – Sustainable Design Guidelines
- Program Plans / Bridge Documents
- Abbreviated Schedule examples

- Excerpts from 2009 IBC
- Planning Level Code Analysis Form
- State Buildings Exhibit K – CSU Building Code Compliance Program
- Conceptual Design Report – Engineering II
- Academic Village North – Program Plan and Conceptual Design
- Lory Student Center Master Plan
- State of Colorado - Contracts
- State of Colorado – Office of the State Architect Policies and Procedures – Example RFQ/RFP's

CON 571 Fall 2011 Assignment List

Date Assigned	Assignment	Date Due by Noon
25-Aug	Discussion Paper 1	31-Aug
1-Sep	Discussion Paper 2	7-Sep
1-Sep	Master Plan - Individual Ideas and Concepts	7-Sep
1-Sep	Field Report 2	7-Sep
8-Sep	Discussion Paper 3	14-Sep
8-Sep	Master Plan - Individual Ideas and Concepts	14-Sep
8-Sep	Field Report 3	14-Sep
15-Sep	Discussion Paper 4	21-Sep
15-Sep	Master Plan - Individual Ideas and Concepts	21-Sep
15-Sep	Field Report 4	21-Sep
22-Sep	Discussion Paper 5	28-Sep
22-Sep	Master Plan - Individual Ideas and Concepts	28-Sep
22-Sep	Field Report 5	28-Sep
29-Sep	Discussion Paper 6	5-Oct
29-Sep	Prepare Master Plan Presentations	5-Oct
6-Oct	Field Report 6	12-Oct
6-Oct	Abbreviated Project Schedule	12-Oct
13-Oct	Discussion Paper 7	19-Oct
13-Oct	Field Report 7	19-Oct
20-Oct	Discussion Paper 8	26-Oct
20-Oct	Field Report 8	26-Oct
27-Oct	Prepare Program Plan Presentations	2-Nov
27-Oct	Field Report 9	2-Nov
3-Nov	Discussion Paper 10	9-Nov
3-Nov	Field Report 10	9-Nov
10-Nov	Discussion Paper 11	16-Nov
10-Nov	Field Report 11	16-Nov
17-Nov	Advertisement RFP/RFQ	Nov-31
17-Nov	Work Through Tutorials in REVIT	Nov-31
	NO CLASS NOVEMBER 24-THANKSGIVING	
1-Dec	Discussion Paper 12	7-Dec
1-Dec	Work on Massing Studies in REVIT	7-Dec
1-Dec	Field Report 12- The Last One!	7-Dec
8-Dec	Discussion Paper 13	14-Dec
8-Dec	Work on Massing Studies in REVIT	14-Dec
15-Dec	Complete Class Evaluations	15-Dec – Need before you leave.
15-Dec	Discussion Paper 14	18-Dec

2014-2016 CON 571 SYLLABUS

Course Syllabus – CON 571 – FACILITIES PLANNING AND MANAGEMENT

8/7/2014

Updated 11/20/2014

Class Time: Wednesday – 4:00-6:45PM Location: 101 Preconstruction Credits: 3

Instructor: Mike Rush, AIA, ICC

Office: 145 Facilities Management North

Office Hours: By Appointment –

Contact: o. 491-0080, m. 567- 1011 or Lindsay Brown 970.491.0020

e. mike.rush@colostate.edu

Course Description:

Campus planning and management. Expertise will be applicable in large academic and institutional environments as well as in building specific planning and management.

Course Objective:

To assist graduate students in securing a skill set that will be directly applicable in the practice of integrated project delivery and securing work in an increasingly competitive construction industry. The class will be taught through hands-on project based study in master planning, programming, and operations. We will develop a campus master plan, program plans and associated RFP/RFQ documents. We will integrate building code and spatial analysis to inform conceptual design and cost estimating. The RFP/RFQ development and solicitation process as well as contract preparation and amendment process will be also covered to better prepare students for Owner expectations in securing work.

All projects will be developed with an underlying thread for sustainable initiatives in the built environment. We will use the latest technology and presentation media. The instructor will share formulas for budget and schedule management to begin to eliminate project uncertainties and shortfalls. A number of guest speakers are scheduled to provide additional industry expertise in the subject materials. Aligned with this, students will develop the ability to organize and present the assignments and project solutions to the class and instructor.

Each student will:

- Be exposed to the development components of facility management such as: procurement procedures, space planning, life safety and regulatory management. Building system infrastructure planning and operations management will also be discussed.
- Understand the major components required to develop a facility planning documents, perform existing facility analysis and integrate sustainable practices into facility planning and management.
- Be required to work on a project team to develop a comprehensive facility plan. The project will include space utilization plans, building layout, equipment and furniture plans, and building energy systems and materials schematics.
- Develop an understanding of the tools and techniques of planning and developing facilities, including the use of BIM through out the course

These skills can be utilized to:

- Secure work with public and private sector clients.
- Lead the team in projects developed through integrated project delivery methods including CM/GC and Design-Build.
- Develop charrette based projects, utilizing group study and team based methodologies.
- Manage owner and/or client expectations and deliver successful projects.
- Manage and operate complex sustainable facilities and/or overall complexes or campuses.

Grading Criteria:

Class and team participation: 20 pts

Presentation of course projects: 30pts

Assignments: 50pts

Late Work and Attendance Policy:

This is experiential learning, a hands on class. Attendance has never been an issue but attendance will be monitored. As a three credit hour class that meets once a week through the semester, attendance at each class is essential and with the extent of interrelated, hands-on, in class team work, missing the material presented in any class will make it extremely difficult to keep up with the subsequent coursework. While missing any class is certainly not recommended, it is understood that occasionally, circumstances come up that are beyond our direct control. As a result, the following absentee policy has been developed:

One Absence: Depending on circumstance, No more than 5 pts will be deducted from the class and team participation grading criteria.

Two Absences: Additional deductive adjustment in grading

Three Absences: Final Grade may be adjusted downward one letter grade.

Late Work:

Assignments are to be posted to RAM CT as delineated in this syllabus. For each day late, 1 pt will be deducted from the assigned score. Three days late and the assignment will not be graded.

Materials:

****Have in hand by September 3, 2013**

18" wide roll of trace paper, aka Bum Wad, aka Onion Skin (white or yellow)

Sharpe markers - thick and thin (Blue, Black and Red)

Architect and Engineering Scales

Text: A Pattern Language, By Christopher Alexander. ISBN: 978-0-19-501919-3

Download the most current trail versions of AutoDesk Revit to personal computers will be of benefit.

Facilities:

A great deal of work will be completed in the Preconstruction Center Room 101. The computer lab, Preconstruction Center room 200, will also be utilized in the course.

Using the campus itself for the master planning, programming research and exercises as well as monitoring the current construction projects for the field reports and discussion topics will be essential in completing the assignments.

Class and Team Participation, 20pts:

- Prepared to inform productive discussion and work sessions.
- Develops material between classes to help inform teamwork during class.
- Asset and obvious contributor to the team and class.
- Engaged during presentations w/ compelling inquiry (questions).
- Offers ideas for continued course improvement aligned with industry expectations.
- Participation Points will also be defined by:
 - Unplanned between class assignments that materialize as a result of progress discussion. These tasks will include:
 - Definitions, Master Plan Research, Program Plan Research, and BIM Research to help inform solutions and process.

Assignments, 50pts:

- Discussion Papers – 5pts (your 5 best scoring papers will be averaged)
- Field Reports - 5pts (your 5 best scoring reports will be averaged)
- Master Plan Solution - 10pts
- Abbreviated Program Plan – 10pts
- Conceptual Building Design -10pts
- BIM Implementation in Assignments– 10pts
- **** All assignments posted to Blackboard by noon Tuesday prior to class.**

Presentations, 30pts:

- Master Plan Presentation - 10pts
- Program Plan Presentation – 10 pts
- BIM Implementation Presentation (Final Exam) – 10pts

Course Outline, Presentation and Assignment Schedule

August 27 (Session 1):

- **Welcome**, Introductions and past student experience/ research interests –

Exciting, Breaking News!

This year we will be fully deploying BIM in our assignments. Some of the presentations have been abbreviated and discussion time reallocated to accommodate in class work directly in REVIT through the master planning, programming and conceptual building design process

-No worries here. We have introduced BIM at the end of the CON 571 class for the last 4 years and haven't left anyone behind. Reviews have been good.

Why? – Technology is.....Competitive edge.... Critical thinking.....Added Efficiencies.....A Teaching Tool

- Instructors Research Interests –
 - Building Information Modeling (BIM) as a teaching tool.
 - Tracking atypical construction projects and illustrating challenges/ solutions
 - Study of facilities developed in the mid century modern aesthetic 1950's – 1960's
 - Study of building code compliance procedures for same period.

- Background and current position
- Review student experience and goals for the class
- The ability to actively participate in design and planning activities to better prepare for integrated project delivery – Who leads the team? What do you do as building industry professionals?
- Review Course Syllabus – Weekly assignments:
 - Clearly record objectives of the course
 - **Discussion Papers:** Draft a one page report with your thoughts on the class materials assignments, readings all weaved together into an executive summary. The discussion papers have successfully promoted class discussion week to week and help me gain an understanding of potential challenges and opportunities associated with the material. The intent is to practice developing short, concise, “executive summary” type writing skills with an introduction sentence and concluding sentence. “Tell them what you are going to tell them, tell them and tell them what you told them”. The intent is to help you developing the ability to have your work surface and gain attention in an age of information overload (AKA bullet point writing).
 - **Field Reports:** Throughout the course, complete weekly construction observation “field reports” on the buildings in progress on CSU main campus. Limited in format, to simply observe, chart progress and ask questions to be addressed/discussed in selected classes. The design work and scheduling and sequencing documentation will be made available upon on black board for students to track actual progress/derivation in weekly field reports.
- The following on-campus building projects are currently under construction on main campus:
 - The Lory Student Center Revitalization (remaining site work and some interior finish remain), Scheduled completion October 2014.
 - Health and Exercise Sciences Addition on the north side of Moby “B” Wing
 - Eddy Hall Revitalization
 - **IMPORTANT:** *Observations will be limited to those that can be made from beyond the construction fence. Do not attempt to gain access to the construction sites. Students can certainly monitor more than one project at their discretion but access will be limited to already established public ways for obvious safety reasons.*
- Determine Field Report Assignments – Hand Out Suggested Format
- CSU Master Planning to accommodate 35,000 students
 - Next 5 class sessions – section accumulates in final team presentation.
 - Distribute preliminary analysis of additional facilities required to accommodate an additional 10,000 students
- Assign Teams – Discuss continuity through the semester... Teaming and collaboration, this is the way we work today.
- Discuss course reference text –

Author Alexander, Christopher.

Title	A Pattern Language : Towns, Buildings, Construction / Christopher Alexander, Sara Ishikawa, Murray Silverstein, with Max Jacobson, Ingrid Fiksdahl-King, Shlomo Angel.
Publisher	New York : Oxford University Press, 1977.
ISBN:	978-0-19-501919-3

- Master Planning Part 1: Tour of main campus to inform master planning activities.
 - WEAR COMFORTABLE WALKING SHOES. Bring rain gear if it appears necessary
 - We'll review and discuss the recently completed campus buildings and buildings currently under construction
 - Discuss sustainable initiatives in the completed projects on site.
 - Discuss current campus planning
 - Carefully define buildable, non-buildable areas
 - Hand out Main Campus Existing Conditions and Master Plan Maps

Weekly Assignments Due: Post to Black Board no later than Tuesday at noon prior to each class.

Reference also the attached Assignment Schedule.

August 27 Assignments (Due September 2) –

- Research and find examples of master plans from other universities and try to determine process in developing – updating. Site Sources and be prepared to share findings next class.
- Read APL Introduction and Pages 1-91
- Discussion Paper 1: One to two page summary of the Main Campus Tour, may note sustainable features, material qualities, building placement in overall campus context, etc as it relates to planning, design and construction. Weave into the discussion your thoughts on the APL reading, master plan research findings, anticipated class challenges, opportunities..... perhaps, how you might utilize the text in your master planning.
- Field Report 1 for a current construction project as determined in class.

September 3 (Session 2):

Fully deploy BIM in our assignments. work directly in REVIT through the master planning, programming and conceptual design process

The Sorting Hard Hat Will Determine Teams

Why? – Update from previous discussion – What is experiential learning?

Administer Pre Course Surveys – Talk about Research

Presentation – Colorado State University Master Plan – History and Evolution.

- Students Present and Discuss Master Planning Research Findings
- Review the discussion papers
- Review Field Reports –Address Questions and Discuss
- Master Planning – Part 2: Facilities Planning in a University or Large Institutional Environment

- Slides from BOG presentation
- Reference 2004 Campus Master plan-
- Look at South Campus Master Plan
- Present Campus Sketch-Up File – Talk about the use of BIM, Revit.
 - Can REVIT be used in initial planning, logistics and site sequencing?
 - Review Building Information Modeling (BIM) virtual construction schedule (animation files) for Parmelee and the Laurel Village projects.
- Review Overlay and Design/Planning Process – RidgeGate Process
 - Discuss the use of scale and floor plate extrusion to generate actual building areas for site plan representation. How do we do this in REVIT.
- The secret is to work back and forth between hand sketching and the computer.
- Discuss APL 1-92
- What is the South Campus? Should we call it Main Campus South?
- In Class Team Work – Master Planning 2: CSU Master Planning to accommodate 35,000 students
 - Use +10,000 students preliminary analysis to begin to identify sites for development.
 - Work w/ instructor review progress in class.
 - Start initial investigation of REVIT in Planning – On Screen.

Assignments (September 9):

- **Continue to research other campus master planning. Do other Universities have BIM standards?**
 - **Prepare a brief overview to present next class w/ findings.**
- **Read APL: Pages 92-220**
- **Explore Revit =Review Initial Investigation –**
- **Discussion Paper 2:**
 - **A one page report describing perceived strategies in developing master plan solutions with a summary/discussion of class one and initial plans for developing you solution.**
 - **Weave in applicable thoughts from your study of APA, Initial exposure to REVIT other campus master plans.**
- **Document individual ideas and concepts in master planning to inform team work in next class**
 - **Out of class initial sketching and planning work to prepare for productive team work (Does not need to be turned in on Blackboard, please just bring to class Wednesday)**
- **Field Report 2**

September 10 (Session 3):

- Discuss the Field Reports and Discussion Papers to date
- Brief presentation of research findings – Master Plans at other Universities, et al. Discuss master planning progress
- Discuss APL reading to date w/ applicable concept review.

Presentation - The College of Business Master Plan

- Developed a roadmap to help inform development efforts long term.
- Master Planning - Part 3

- Slides and video from LSC – to show direction on where building specific Master Planning is headed – parallel using BIM and current technologies.
- Laurel Village, Parmelee and Braden sequencing and scheduling BIM animation file.
 - How are these developed? Research and tell me next class

Discussion – The Illusive Parti and The Importance of Developing PPD skills for IPD and DB

In Class Team Work with Instructor– Master Planning 3

Assignments (Due 9/18):

- **Read APL Pages 221-334**
- **Discussion Paper 3: A one page report describing progress and challenges in developing master plan solutions –or – a summary/discussion of the industry expert presentation.**
- **Continue with individual concepts in master planning to inform team work in next class**
- **Field Report 3**

September 17 (Session 4):

- Discuss the Field Reports and Discussion Papers to date
- Teams to present progress on master plans w/ comments and questions from class.

Presentation: The Charrette Based Process

- <http://www.fm.colostate.edu/character/>
- The CSU Internal and External Design Review Committees

Presentation: State Buildings Delegation- State Procurement

- In Class Team Work – Master Planning 4

Assignments (Due 9/23):

- **Read APL Pages 335-539**
- **Discussion Paper 4: A one or two page report describing progress and challenges in developing master plan solutions relate to sustainable initiatives –and/or – a summary/discussion of the presentations with insightful notes from your study of APL.**
- **Continue with individual concepts in master planning to inform team work in next class**
- **Field Report 4**
- **Definition of Deconstruction (Compose a short paragraph definition and submit on Blackboard)**

September 24 (Session 5):

- Field Reports and Discussion Papers to date – Have you turned any in?
-
- Sustainable site and building planning
 - Deconstruction in redevelopment initiatives
 - Building orientation, parking maximums, pedestrian and bike circulation
 - Use USGBC LEED Checklist in developing master planning strategies?

Presentation – Master Planning, Programming and Designing a remote campus in Todos Santos, Mexico

- Catch up on previous class sessions plans where materials exceeded time constraints
- In Class Team Work – Master Planning 5
 - Draft Master Plan Presentations
 - Prepare team presentations – review format, content w/ instructor

Assignments (Due September 30):

- Continue with individual concepts in master planning to inform team work in next class
- Field Report 5
- Read APL pages 539-646
- Definition of Promenade from APL

October 1 (Session 6)

Presentation: Steve Hultin, P.E., Executive Director of Facilities Management, CSU

- Facilities Management Operational Overview and Infrastructure Considerations in Master Planning
- <http://www.facilities.colostate.edu/>
- In Class Team Work – Master Planning 6 – Prepare Presentations
- Develop Schedule for Presentations

Assignments (Due 10/7):

- **Prepare Master Plan Presentations and post to Ram CT – Power Point or PDF**

October 8 (Session 7)

- Present Master Plans
 - 15-20 minutes each team including interactive Q&A
- Project teaming and joint ventures – Integrated Project Delivery – CMGC and Design Build
PRESENTATION: -Using BIM to develop a DB procurement for an AG ED facility.
- Discuss Programming – Why are these documents necessary.... Are they? and How do we deploy BIM here? What better way to learn how to respond to bridge documents in an RFP than to prepare some?
- How To? - Developing an abbreviated project / construction schedule for executive level review
 - Use detailed construction and sequencing schedule to derive important milestones for presentation.
 - Executive, upper level review – hit the high points try to stay out of the weeds.

Assignments (Due 10/14):

- **Read APL Pages 647-788**
- **Field Report 6**
- **Discussion Paper 6: A one page review of Master Plan Presentations.**
- **Prepare and Post Abbreviated Project Schedule**

October 15 (Session 8):

- Begin Program Planning. – Your Guide to Developing a Project.
 - Where do you want to take this?
- Programming 1 – Introduce Program Plans, Concept Papers and Bridging Documents
 - Bridging documents in integrated project delivery
- Presentation: Lou Bieker, Principal, 4240 architecture
 - Programming, conceptual building design, integrated project delivery, a “Good Architect” perspective.
- Distribute component templates for more in depth presentation October 22 Class. – Review in preparation for.
- In Class Team Programming Work Session - 1
 - Identify building from your Master Plan to use in developing the programming documents
 - Review with Instructor – Lets get going on screen and ?????

Assignments (Due 10/21):

- **Research and find examples of program plans and annual approval documents from other universities and try to determine process in developing – updating. Site Sources and be prepared to share findings next class.**
- **Discussion Paper 7: A one page summary of the industry expert presentation. Compare and contrast global planning initiatives with your campus specific master planning and programming to date.**
- **Field Report 7**
- **Read APL pages 789-906**

October 22 (Session 9):

- Class discussion of research findings
- Presentation: Alan Plummer, Cummings Corporation – Cost Estimating
- Review Program Plan Templates – Use these!
- Talk about Building Code Analysis – Shall we study all the CODES? What are the chapters of greatest interest in the 2012 IBC for early development?
- Work Session – Programming in BIM, Schedule and Total Development Cost Estimating

Assignments (Due 10/30):

- **Discussion Paper 8: A one page discussion of building programming progress to date with issues/ questions, include APL reading analysis and thoughts.**
- **Field Report 8**
- **Read APL pages 907-1005**

October 29 (Session 10):

- Work session – Using Conceptual Building Design to inform Programming?. How quickly can we get there?
- Campus Walk: Review master plan solutions, programming work to date on site and buildings as lanterns in way finding. – How might this inform building placement orientation?
 - WEAR COMFORTABLE WALKING SHOES AND WARM/WEATHER APPROPRIATE CLOTHING

Assignments (Due 11/4):

- Continue work on program plans.
- Field Report 9
- Discussion Paper 9: CSU after dark – walking tour and way finding.
- Read APL 1005-1086

Review syllabus for remaining class sessions:

November 5 (Session 11)

- Review Program Plan Draft in preparation for presentations
- Address questions and evaluate overall progress
- State Procurement Process Overview
- Project specific advertisement RFP/RFQ Overview
 - Importance of asking for what you want
 - Importance in responding: following the directions

Assignments (Due 11/11):

- **Prepare MS Power Point Presentations Post to Ram CT by Wednesday November 11 @ noon**

November 12 (Session 12)

- Individual Program Plan Presentations: MS Power Point Slides: 30 min each group
- BIM Conceptual Building Design to inform an RFP process
- State Buildings Policies and Procedures Review
- Conceptual Building Design – Work Session

Assignments (Due 11/18):

- **Take a look at REVIT loaded on computers in the 2nd floor computer lab precon building.**
- **Discussion Paper 10: A one page summary of the program plan presentations**
- **Develop and Post an Advertisement RFP/RFQ from instructors template**
- **Field Report 10**
- **Finish Reading APL - Write report on the text for DP #11**

November 19 (Session 13)

- Discuss the program plan presentations
- Weaving it all together into a Final Document. – Should we start again by hand?
- Conceptual Building Design Work Session
- Conceptual Building Design - CBD1
 - BIM Technical Discussion – In Lab
 - Use completed program plan/ bridging documents to develop massing studies for your building in Revit
 - Add site planning
 - Review your plans against your code analysis add stair and check egress routes
 -
 - Use BIM to develop conceptual massing models for the program planned building
 - Through Integration and shade and daylighting studies directly integrate USGBC LEED initiatives through the use of REVIT

- Outcome is to be able to navigate and provide an introduction to BIM specifically addressing it as the current industry standard for developing buildings through the use of AutoDesk REVIT
- 3 class sessions
- Prepare a brief presentation on how you used BIM to complete the assignments so far.
- Ensure you have turned in adequate DP's and FR's

November 26 – No Class – Thanks Giving Break – Woo Hoo!

Assignment (Due 12/2):

- **Discussion Paper 11 –an overall analysis of APL**
- **Field Report 11**
- **Be prepared to put the throttle down as we wrap up and develop your buildings in BIM**

December 3 (Session 14):

- Conceptual Building Design (CPD2) – Work Session – How far Can we Get? What do you want to focus on? –
 - Target Rich Environment
 - Discuss the Final Exam – Work LIVE

Assignment (Due 12/9):

- **Discussion Paper 12: A one page summary of questions and concerns in using REVIT based on the initial class.**
- **Work on Massing Studies in Revit**
- **Field Report 12 –**

December 10 (Session 15)

- Conceptual Building Design - CPD3
 - Continue work on conceptual model
 - Hands On – On Screen w/ Instructor
 - Administer Post Class Survey
 - Resume Review – My opinion on how to make it to the top of the pile.
 - Class Evaluations

Assignment (Due 12/17):

- **Prepare Presentation – How you implemented BIM through out the course**

December 18 (Session 16)- Final Exam Session- 4:10-6:10pm

- Conceptual Building Design - BIM 3
- Presentation – Each Student 15MIN – How you Implemented BIM - FINAL ASSESSMENT
- Present Concepts on Screen and Demonstrate capacity to navigate in REVIT – FINAL INDIVIDUAL ASSESSMENT
- Distribute and Complete Exit BIM Survey

Assignment (Due 12/20 by Midnight):

- **Have a Great Break and I wish you the very best as you make your way out into the construction industry or where ever your path leads you!**

Course materials – Will be Posted or Links provided @ RAM CT prior to subject instruction

- Facilities Master Plan Analysis for 10,000 additional students
- CSU Master Plan and BOG slides
- Housing and Dining Services Master Plan
- CSU Standards Manual
- PSD Technical Specifications – Sustainable Design Guidelines
- Program Plans / Bridge Documents
- Abbreviated Schedule examples
- Excerpts from 2009 IBC
- Planning Level Code Analysis Form
- State Buildings Exhibit K – CSU Building Code Compliance Program
- Conceptual Design Report – Engineering II
- Aggie Village North – Program Plan and Conceptual Design
- Lory Student Center Master Plan
- State of Colorado - Contracts
- State of Colorado – Office of the State Architect Policies and Procedures – Example RFQ/RFP's
- Presentations and Other Materials

The Syllabus for CON 571 represents the planning for the first year of full implementation of BIM into existing coursework. The instructor cannot predict the timing of associated instruction and thus the syllabus shall be considered a fluid document that will evolve to accommodate acceleration or deceleration as we make our way through the material and develop a understanding of the current technology and how long it takes to become acclimated with it.

2017 CON 571 SYLLABUS

Course Syllabus

July 24, 2017

Updated October 22, 2017

Class Time: Thursday – 4:00-6:50PM Location: Precon 200 – Computer Lab Credits: 3

Instructor: Mike Rush, AIA, ICC, CBO

Office: 145 Facilities Management North

Office Hours: By Appointment –

Contact: o. 491-0080, m. 567- 1011 or Lindsay Brown (My Assistant) 970.491.0020

e. mike.rush@colostate.edu

Course Description:

Campus and Development Planning and Management. Expertise will be applicable in large academic and institutional environments as well as in building specific planning and management.

Course Objective:

To assist graduate students in securing a skill set that will be directly applicable in the practice of integrated project delivery and securing work in an increasingly competitive construction industry. The class is taught through hands-on project based study in master planning, programming, building design and operations. We will develop a campus master plan, program plans and associated RFP/RFQ documents. We will integrate building code and spatial analysis to inform conceptual design and cost estimating. The RFP/RFQ development and solicitation process as well as contract preparation and the amendment process is covered to better prepare students for Owner expectations in securing work.

All projects are developed with an underlying thread for lean, integrated, interdisciplinary and sustainable initiatives in the built environment. We will use the latest technology and presentation media. The instructor will share formulas for budget and schedule management to begin to eliminate project uncertainties and shortfalls. Aligned with these objectives, students will develop the ability to organize and present the assignments and project solutions to the class and instructor. **Over the last few semesters, the course has woven in a focus on the Design Build Lump Sum delivery method and associated procurement process. This is directly aligned with current project acquisition, delivery and development planning at Colorado State University.**

Each student will:

- Be exposed to the development components of facility management such as: procurement procedures, space planning, life safety and regulatory management. Building system infrastructure planning and operations management is discussed.
- Understand the major components required to develop facility planning documents, perform existing facility analysis and integrate sustainable practices into facility planning and management.
- Be required to work on a project team to develop a comprehensive facility plan. The project will include space utilization plans, building layout, equipment and furniture plans, and building energy systems and materials schematics.
- Develop an understanding of the tools and techniques of planning and developing facilities, including the use of BIM through the duration of the course

These skills are utilized to:

- Secure work with public and private sector clients.
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- Manage owner and/or client expectations and deliver successful projects.
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One Absence: Depending on circumstance, no more than 10 pts will be deducted from the class and team participation grading criteria.

Two Absences: Additional deductive adjustment in grading

Three Absences: Final Grade may be adjusted downward one letter grade.

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Materials:****Have in hand by September 7, 2017**

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Sharpe markers - thick and thin (Blue, Black and Red)

Architect and Engineering Scales

Text: A Pattern Language, By Christopher Alexander. ISBN: 978-0-19-501919-3

Sketch Book – 5"x8" +/- or of equal proportions

Downloading the most current trial versions of Autodesk Revit to personal computers will be of benefit.

Facilities:

The computer lab room 200 in the preconstruction center **and** we will leverage the entire main campus in the course. Using the campus itself for the master planning, programming, and building design and construction research, as well as monitoring the current construction projects for the field reports and discussion topics will be essential in completing the assignments.

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- Conceptual Building Design -10pts
- BIM Implementation in Assignments– 10pts
- **** All assignments posted to Canvas by noon Tuesday prior to the Thursday class.**

Presentations, 30pts:

- Master Plan Presentation - 10pts
- Program Plan Presentation – 10 pts
- BIM Implementation Presentation (Final Exam) – 10pts

2017 Course Outline, Presentation and Assignment Schedule

August 24 (Session 1): Welcome to CSU – Welcome to CON 571 – Course Overview and Campus TOUR

- **Welcome**, Introductions and past student experience/ research interests – **TEAM BUILDING – COLLABORATION AND COMPETITION**

Why use BIM? – Technology is a tool, a competitive edge, can foster critical thinking, lead to added efficiencies, and serve as a teaching tool.

- Instructors Research and Development Interests –
 - Design Build – Lump Sum procurement and the associated bridging document preparation.
 - Building Information Modeling (BIM), especially as a development and use in teaching associated materials.
 - Tracking atypical construction projects and illustrating challenges/ solutions
 - Study of facilities developed in the midcentury modern aesthetic 1950's – 1960's
 - Study of structural innovations and building code compliance procedures for same period.
- Mike's background and current position
- Review student experience and goals for the class
- The ability to actively participate in design and planning activities to better prepare for integrated project delivery – Who leads the team? What do you do as building industry professionals?
- Review Course Syllabus – Weekly assignments:
 - Clearly record objectives of the course
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 - **Field Reports:** Throughout the course, complete weekly construction observation "field reports" on the buildings in progress on CSU main campus. Limited in format, to simply observe, chart progress and ask questions to be addressed/discussed in selected classes. The design work and scheduling and sequencing documentation will be made available upon on black board for students to track actual progress/derivation in weekly field reports.
 - The following on-campus building projects will be under construction on main campus:
 - Michael Smith - Addition to the Warner College of Natural Resources
 - Immediately south of the WCNR building

- Richardson Design Center
 - East of the Stadium – South of Visual Arts
- JBS Global Food Innovation Center
 - Immediately south of the Animal Sciences Building
- Health Education Outreach Center –
 - East of Anatomy and Zoology

▪ **IMPORTANT:** *Observations will be limited to those that can be made from beyond the construction fence. Do not attempt to gain access to the construction sites. Students can certainly monitor more than one project at their discretion but access will be limited to already established public ways for obvious safety reasons.*

- Determine Field Report Assignments – Hand Out Suggested Format
- **EACH ROW – IDENTIFY A TEAM RESOURCE TO HELP WITH BIM ?’S – SIT IN THE MIDDLE OF THE ROW**
- CSU Master Planning to accommodate 35,000 students
 - Next 5 class sessions – section accumulates in final team presentation.
 - Distribute preliminary analysis of additional facilities required to accommodate an additional 10,000 students.
- Assign Teams – Discuss continuity through the semester... Teaming and collaboration, this is the way we work today.
- Discuss course reference text –

Author	<u>Alexander, Christopher.</u>
Title	A Pattern Language : Towns, Buildings, Construction / Christopher Alexander, Sara Ishikawa, Murray Silverstein, with Max Jacobson, Ingrid Fiksdahl-King, Shlomo Angel.
Publisher	New York : Oxford University Press, 1977.
ISBN:	978-0-19-501919-3

- Master Planning Part 1: Tour of main campus to inform master planning activities.
 - Line drawing exercise.
 - WEAR COMFORTABLE WALKING SHOES. Bring rain gear if it appears necessary
 - We’ll review and discuss the recently completed campus buildings and buildings currently under construction
 - Discuss sustainable initiatives in the completed projects on site.
 - Discuss current campus planning
 - Carefully define buildable, non-buildable areas
 - Hand out Main Campus Existing Conditions and Master Plan Maps
- Return to PreCon 200, attempt log in and open REVIT 2017 - import main campus base map. Preview of next class

Weekly Assignments Due: Post to Canvas prior to the next class session – NTL 4:00 pm on Thursdays.

August 24 Assignments:–

- *Research and find examples of master plans from other universities and try to determine process in developing – updating.*
- -OR-
- *Explain the City of Fort Collins - CFC planning process*
- -OR-
- *Develop a brief summary that supports the notion of drawings as a means to discovery and more robust building design solutions. Hint: Start research around right brain/left brain function. Look at the work of Dr. Iain McGilchrist.*
- -OR-
- *AEC Cross Pollination – The Concept of the Master Builder- Interdisciplinary study as informed by BIM, Design Build, Integrated Project Delivery.*

IN REGARDS TO THE ABOVE..... Turn nothing in but coordinate with your classmates to ensure we can have a brief but meaningful discussion about each of the above topics -- COORDINATE WITH YOUR CLASSMATES TO ENSURE WE CAN HAVE A BRIEF BUT MEANINGFUL DISCUSSION ABOUT EACH OF THE TOPICS. -----AS IN INDUSTRY – ALWAYS BE PREPARED ----

- *Read APL Introduction and Pages 1-91*
- *Discussion Paper 1: One to two-page summary of the Main Campus Tour, may note sustainable features, material qualities, building placement in overall campus context, etc as it relates to planning, design and construction. Weave into the discussion your thoughts on the APL reading, master plan research findings, anticipated class challenges, opportunities.... perhaps, how you might utilize the text in your master planning.*

August 31 (Session 2): - MASTER PLANNING, DEVELOPMENT PLANNING, LOGISTICS PLANNING

Fully deploy BIM in our assignments. Work directly in REVIT through the master planning, programming, conceptual design and construction document processes.

Why? – Update from previous discussion – What is experiential learning?

Administer Pre Course Surveys – Talk about Research

Presentation – Colorado State University Master Plan – History and Evolution.

- Students Discuss Master Planning Research Findings
- Review the discussion papers
- Review Field Reports –Address Questions and Discuss
- Master Planning – Part 2: Facilities Planning in a University or Large Institutional Environment
 - Slides from BOG presentation
 - Reference 2004 Campus Master plan-
 - Look at South Campus Master Plan
 - Present Campus Sketch-Up File – Talk about the use of BIM, Revit.
 - Can REVIT be used in initial planning, logistics and site sequencing?
 - Review Building Information Modeling (BIM) virtual construction schedule (animation files) for Parmelee and the Laurel Village projects.

- Review Overlay and Design/Planning Process – Ridge Gate Process
 - Discuss the use of scale and floor plate extrusion to generate actual building areas for site plan representation. How do we do this in REVIT.
- The secret is to work back and forth between hand sketching and the computer.
- Discuss APL 1-92
- What is the South Campus? Should we call it Main Campus South?
- In Class Team Work – Master Planning 2: CSU Master Planning to accommodate 35,000 students
 - Use +8,000 student's preliminary analysis to begin to identify sites for development.
 - Work w/ instructor review progress in class.
 - Start initial investigation of REVIT in Planning – On Screen.
- Review Field Reports and Hand Out Form

Assignments:

- *Continue to research other campus master planning. Do other Universities have BIM standards?*
 - *Prepare a brief overview to present next class w/ findings.*
- *Define Parti*
- *Read APL: Pages 92-220*
- *Explore Revit =Review Initial Investigation –*
- *Discussion Paper 2:*
 - *A one-page report describing perceived strategies in developing master plan solutions with a summary/discussion of class one and initial plans for developing you solution.*
 - *Weave in applicable thoughts from your study of APA, Initial exposure to REVIT other campus master plans.*
- *Document individual ideas and concepts in master planning to inform team work in next class*
 - *Out of class initial sketching and planning work to prepare for productive team work (Does not need to be turned in on Canvas, please just bring to next class*
- *Field Report 1*

September 7 (Session 3): - MASTER PLANNING AND PROCUREMENT PROCESS

- Discuss the Field Reports and Discussion Papers to date
- Brief presentation of research findings – Master Plans at other Universities, et al. Discuss master planning progress
- Discuss APL reading to date w/ applicable concept review.

Presentation - The College of Business Master Plan

- Developed a roadmap to help inform development efforts long term.
- Master Planning - Part 3
 - Slides and video from LSC – to show direction on where building specific Master Planning is headed – parallel using BIM and current technologies.
 - Laurel Village, Parmelee and Braden sequencing and scheduling BIM animation file.
 - How are these developed? Research and tell me next class.

Discussion – The Illusive Parti and The Importance of Developing PPD skills for IPD and DB

In Class Team Work with Instructor– Master Planning 3

Assignments:

- Read APL Pages 221-334
- Discussion Paper 3: A one-page report describing progress and challenges in developing master plan solutions –or – a summary/discussion of the industry expert presentation.
- Continue with individual concepts in master planning to inform team work in next class
- Field Report 2

September 14 (Session 4): The Collaborative Process and State Procurement

- Discuss the Field Reports and Discussion Papers to date
- Teams to present progress on master plans with comments and questions from class.

Presentation: The Charrette Based Process

- <http://www.fm.colostate.edu/character/>
- The CSU Internal and External Design Review Committees

Presentation: State Buildings Delegation- State Procurement

- In Class Team Work – Master Planning 4

Assignments:

- Read APL Pages 335-539
- Discussion Paper 4: A one or two-page report describing progress and challenges in developing master plan solutions relate to sustainable initiatives –and/or – a summary/discussion of the presentations with insightful notes from your study of APL.
- Continue with individual concepts in master planning to inform team work in next class
- Field Report 3
- Definition of Deconstruction (Compose a short paragraph definition and submit on Blackboard)

September 21 (Session 5): - MASTER PLANNING AND DEVELOPMENT PROCESS

- **Power Point or PDF format for presentations**
- Field Reports and Discussion Papers to date – Have you turned any in?
- Sustainable site and building planning
 - Deconstruction in redevelopment initiatives
 - Building orientation, parking maximums, pedestrian and bike circulation
 - Use USGBC LEED Checklist in developing master planning strategies?

Presentation – Master Planning, Programming and Designing a remote campus in Todos Santos, Mexico AND/OR Eastern and Western Colorado Research Centers.

- Catch up on previous class sessions plans where materials exceeded time constraints
- In Class Team Work – Master Planning 5
 - Draft Master Plan Presentations
 - Prepare team presentations – review format, content w/ instructor

Assignments:

- Continue with individual concepts in master planning to inform team work in next class

- *Field Report 4*
- *Read APL pages 539-646*
- *Definition of Promenade from APL*
- *Discussion paper – what does it take to operate a city or university. Condense to 11 bullet points with introduction sentence and conclusion sentence.*

September 28 (Session 6) - MASTER PLANNING AND OPERATIONAL / INFRASTRUCTURE CONSIDERATIONS

Presentation - discussion

- Facilities Management Operational Overview and Infrastructure Considerations - What Does it Take to Run a University?
- Existing buildings –Revitalization Lessons Learned
 - What is the most sustainable building project anyway?
- In Class Team Work – Master Planning 6 – Prepare Presentations
- Develop Schedule for Presentations

Assignments:

- *Prepare Master Plan Presentations and post to Canvas – **Power Point or PDF***

October 5 (Session 7) – MASTER PLANNING PRESENTATIONS AND NOTES TO INFORM NEXT PROJECT

- Present Master Plans
 - 15-20 minutes each team including interactive Q&A
- Project teaming and joint ventures – Lean Construction - Integrated Project Delivery and Design Build

INSTRUCTOR PRESENTATION: -Using BIM to develop a DB procurement for the last round of significant projects.

- Discuss Programming – Why are these documents necessary.... Are they? and How do we deploy BIM here? Learn how to respond to bridging documents in an RFP by preparing a portion of the RFP. Review the design-build lump sum RFP for several projects.
- How To? - Developing an abbreviated project / construction schedule for executive level review
 - Use detailed construction and sequencing schedule to derive important milestones for presentation.
 - Executive, upper level review – hit the high points -- try to stay out of the weeds.

Assignments:

- *Read APL Pages 647-788*
- *Field Report 5*
- *Discussion Paper 6: A one-page review of Master Plan Presentations.*
- *Prepare and Post Abbreviated Project Schedule*
- *Identify a building from your master plan for programming and be prepared to discuss why you want to develop it further*

October 12 (Session 8): Building Programming and Conceptual Design

- Begin Program Planning. – Your Guide to Developing a Project.
 - Where do you want to take this?
- Programming 1 – Introduce Program Plans, Concept Papers and Bridging Documents
 - Bridging documents in integrated project delivery
- Industry Partner
 - Programming, conceptual building design, integrated project delivery, a “Good Architect” perspective.
- Distribute component templates for more in depth presentation October 22 Class. – Review in preparation for.
- In Class Team Programming Work Session - 1
 - Identify building from your Master Plan to use in developing the programming documents
 - Review with Instructor – Let’s get going on screen

Assignments:

- *Research and find examples of program plans and annual approval documents from other universities and try to determine process in developing – updating. Site Sources? and be prepared to share findings next class.*
- *Discussion Paper 7: A one-page summary of the presentation. Compare and contrast global planning initiatives with your campus specific master planning and programming to date.*
- *Field Report 6*
- *Read APL pages 789-906*

October 19 (Session 9): Conceptual Cost Estimating, Abbreviated Scheduling – TAKE 2, Code Analysis

- Class discussion of research findings
- Potential Industry Partner Presentation: Cost Estimating
- Review Program Plan Templates – Use these!
- Talk about Building Code Analysis – Shall we study all the CODES? What are the chapters of greatest interest in the 2012 IBC for early development?
- Work Session – Programming in BIM, Schedule and Total Development Cost Estimating
- **Update syllabus for remaining class sessions from October 12 discussion**

Assignments:

- *Discussion Paper 8: A one-page discussion of building programming progress to date with issues/questions, include APL reading analysis and thoughts. **Tell me how you are doing with BIM***
- *Field Report 7*
- *Read APL pages 907-1005*

October 26 (Session 10): Program Plans and Conceptual Building Design – Catch Up

- Work session – Using Conceptual Building Design to inform Programming? How quickly can we get there?
- Is this working backwards or strategically?

Assignments:

- *Continue work on program plans.*

- *Field Report 8*
- *Discussion Paper 9: Reflect on BIM and associated discoveries and challenges*
- *Read APL 1005-1086*

Review syllabus for remaining class sessions:

November 2 (Session 11): Campus Walk and Continue Conceptual Design and Programming work

- Campus Walk: Review master plan solutions, programming work to date on site and “buildings as lanterns”. – How might this inform building placement, orientation, and building entry articulation?
 - WEAR COMFORTABLE WALKING SHOES AND WARM/WEATHER APPROPRIATE CLOTHING
- Review Program Plan Conceptual Design Work
- Address questions and evaluate overall progress
- State DBLS Procurement Process Overview
- Project specific advertisement RFP/RFQ Overview
 - Importance of asking for what you want
 - Importance in responding: following the directions

Assignments:

- *Discussion Paper 10: A one-page summary of the program plan presentations*
- *Develop and Post an Advertisement RFP/RFQ from instructor’s template*
- *Field Report 9*
- *Finish Reading APL - Write report on the text for DP #11*

November 9 (Session 12): BIM Work Session in Preparation for Program Plan Presentations

- Conceptual Building towards RFP towards Construction Document – Work Session

Assignments:

- *Prepare MS Power Point Presentations. Bring to next class – Hard copy of presentation, usb thumb drive of all electronic files*

November 16 (Session 13) – Program Plan – Conceptual Building Design Presentations, BIM and Conceptual Building Design and Parametric(s)

- Program plan – conceptual Building design Presentations
- Weaving it all together into a Final Document. – Should we start again by hand?
- Building Design - RFP – Construction Document Work Session
- Building Design - BD1
 - BIM Technical Discussion – In Lab
 - Use completed program plan/ bridging documents to develop more detailed studies for your building in Revit
 - Add site planning
 - Review your plans against your code analysis add stair and check egress routes
 - Use BIM to develop conceptual massing models for the program planned building

- Through Integration and shade and daylighting studies directly integrate USGBC LEED initiatives through the use of REVIT
- Outcome is to be able to use BIM to solve problems in future assignments
- 3 class sessions
- Prepare a brief presentation on how you used BIM to complete the assignments so far.
- Ensure you have turned in adequate DP's and FR's

Assignment:

- *Discussion Paper 11 –an overall analysis of APL*
- *Field Report 10*
- *Be prepared to “put the throttle down” as we wrap up and develop your buildings in BIM*

November 23 – No Class – Thanks Giving Break – Woo Hoo!

November 30 (Session 14): - BIM and Building Design– Understanding this Powerful Tool

- Building Design (BD2) – Work Session – How far Can We Get? What do you want to focus on? –
 - Target Rich Environment
 - Discuss the Final Exam – Work LIVE

Assignment:

- *Prepare Presentation – Individual On Screen with Instructor - How you implemented BIM throughout the course*
- *Discussion Paper 12: A one-page summary of questions and concerns in using REVIT based on the initial class.*
- *Work on Massing Studies in Revit*
- *Field Report 11 –*

December 7 (Session 15): - BIM and Building Design– Using this Powerful Tool

- Building Design - BD3
 - Continue work on your models
 - Hands On – On Screen w/ Instructor
 - Administer Post Class Survey
 - Resume Review – My opinion on how to make it to the top of the pile.
 - Class Evaluations

December 13: 8:30 TO 10:30PM –Final EXAM

- Building Design – BD4 – PRESENT YOUR WORK ON SCREEN.
- Presentation – Each Student 15MIN – How you Implemented BIM - FINAL ASSESSMENT
- Present Concepts on Screen and Demonstrate capacity to use REVIT for problem solving– FINAL INDIVIDUAL ASSESSMENT
- Distribute and Complete Exit BIM Survey

Assignment:

- *Have a Great Break and I wish you the very best as you make your way out into the construction industry or where ever your path leads you!*

The Syllabus for CON 571 (2017) represents the planning for the fourth year of full implementation of BIM into existing coursework and the reflective analysis of teaching the course for seven years. The instructor cannot predict the timing of associated instruction and thus the syllabus shall be considered a fluid document that will evolve to accommodate acceleration or deceleration as we make our way through the material and develop an understanding of the current technology and how long it takes you all to become acclimated with it.

APPENDIX IV: Instructor Examples to Inform Student Work

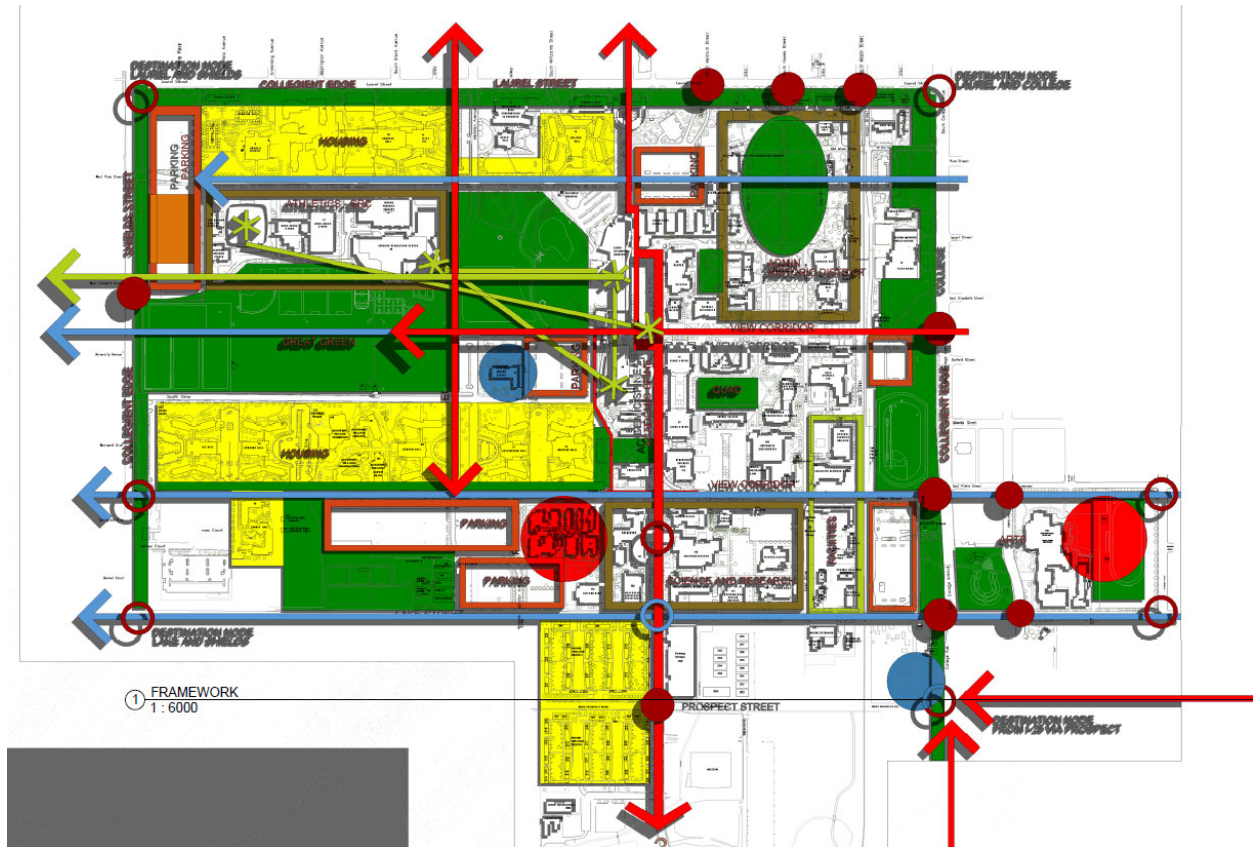


Figure 4.1 Instructor Example -Framework Diagram



Figure 4.3 Instructor Example -Conceptual Rendering

APPENDIX V: Student Work Exhibits

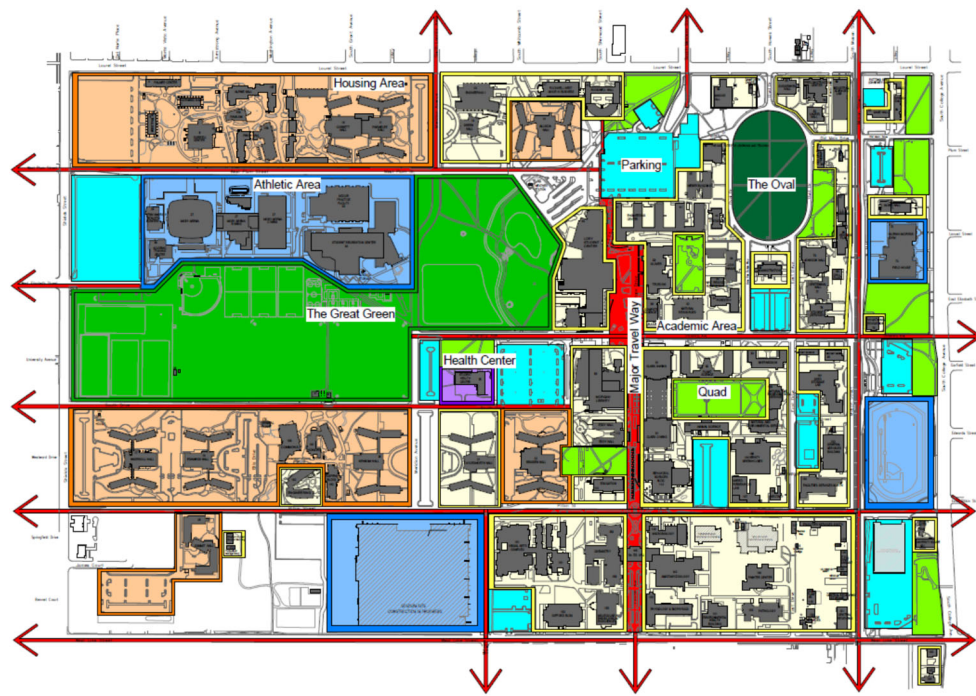


Figure 5.1 Student Work Exhibit -Framework Diagram

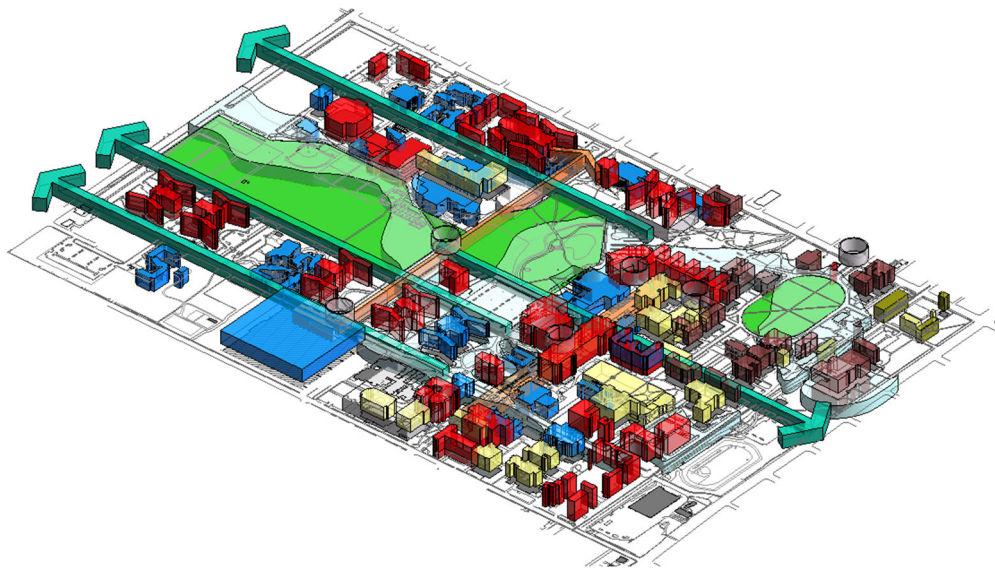


Figure 5.2 Student Work Exhibit - Three-Dimensional Framework Diagram

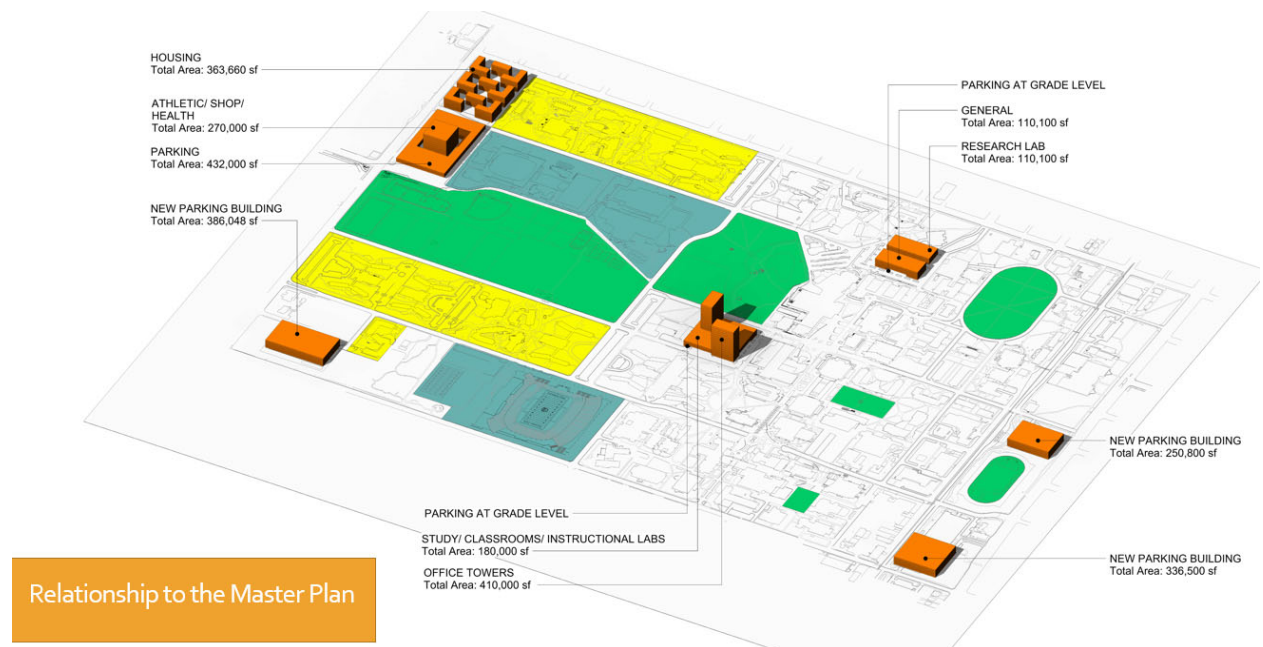


Figure 5.3 Student Work Exhibit - Three-Dimensional Development Plan



Figure 5.4 Student Work Exhibit – Big Moves Diagram

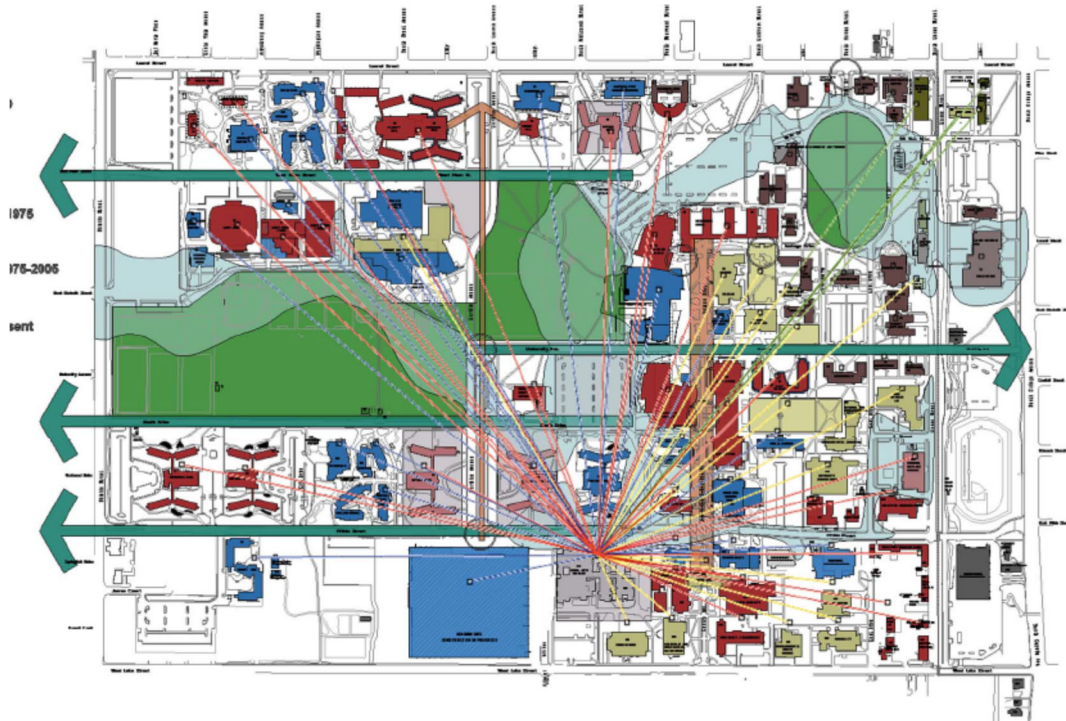


Figure 5.5 Student Work Exhibit – Framework Diagram

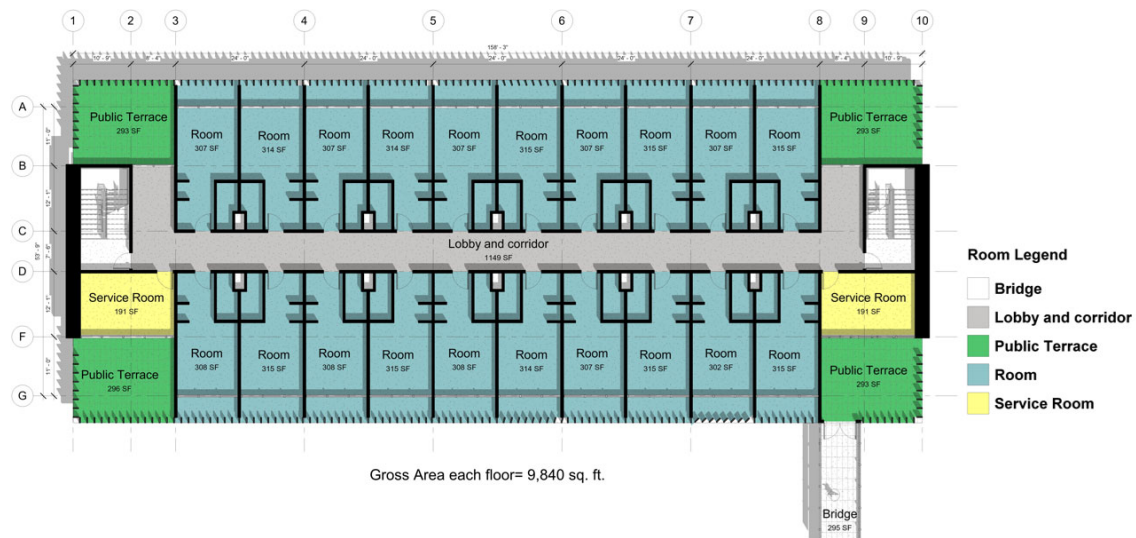


Figure 5.6 Student Work Exhibit – Spatial Analysis

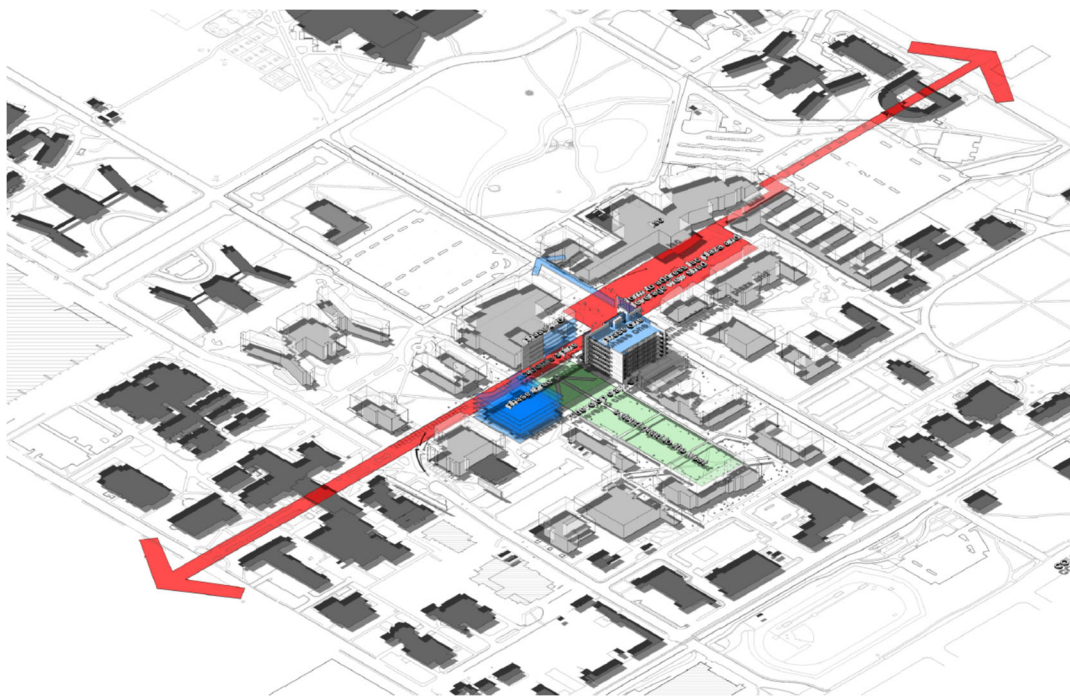


Figure 5.7 Student Work Exhibit – Three-Dimensional Site Area Analysis

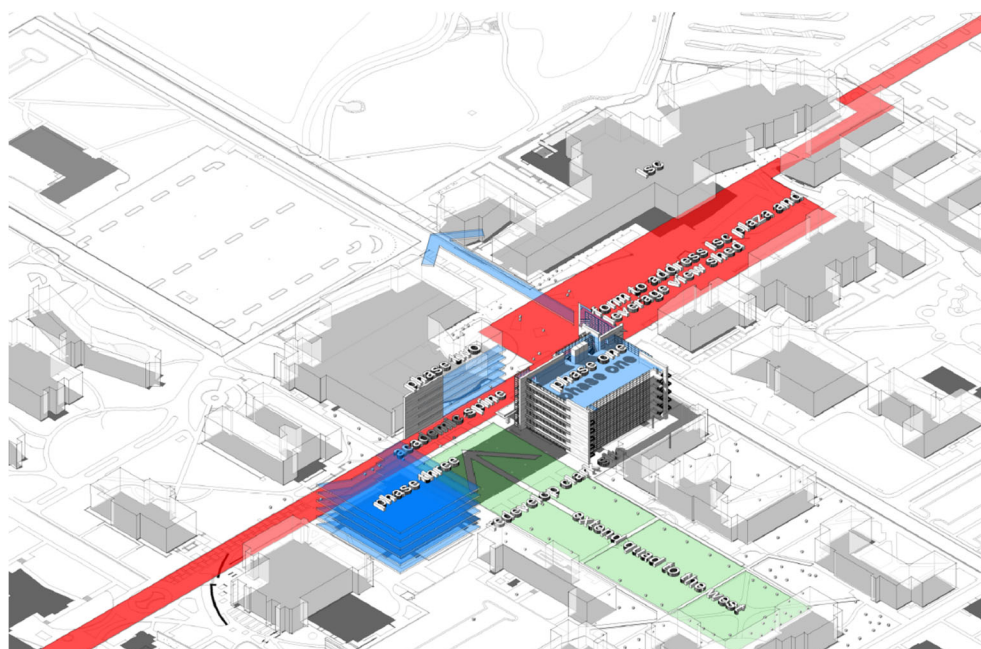


Figure 5.8 Student Work Exhibit – Enlarged Three-Dimensional Site Area Analysis

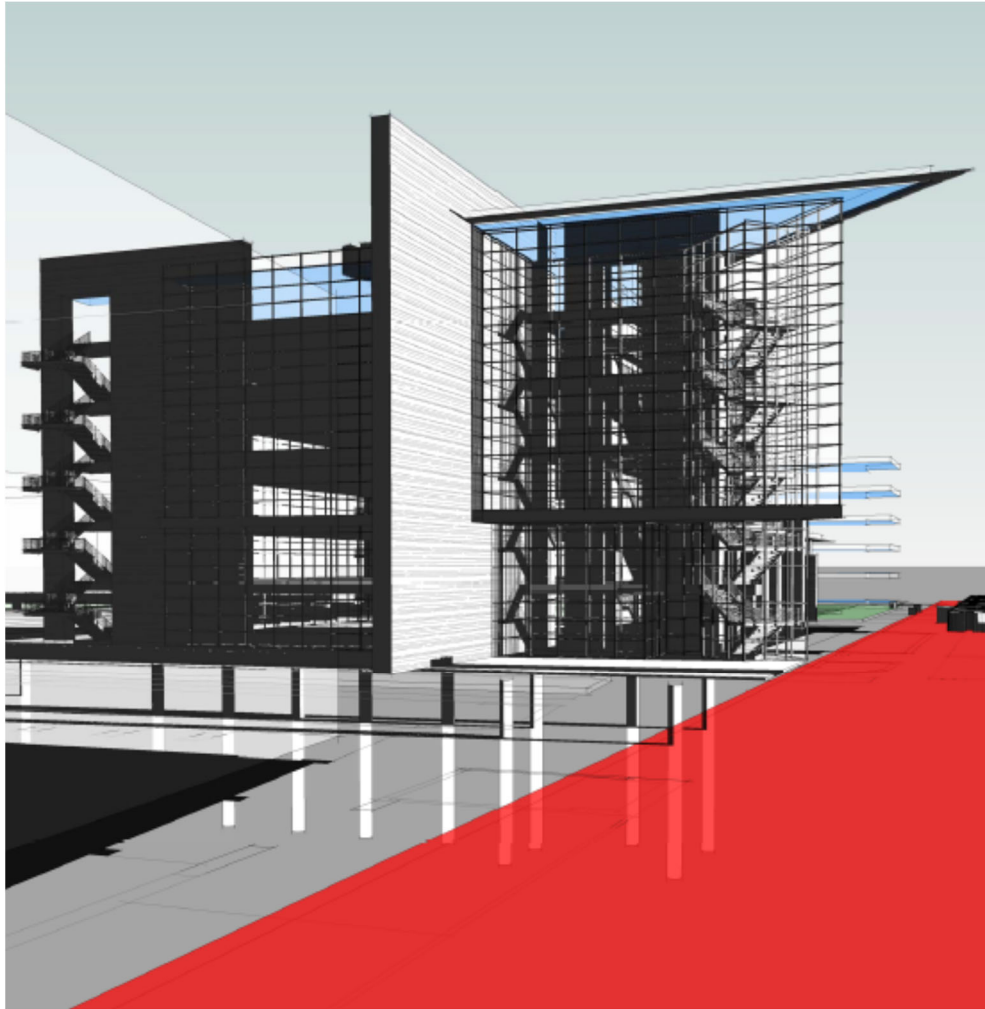


Figure 5.9 Student Work Exhibit – Conceptual Rendering

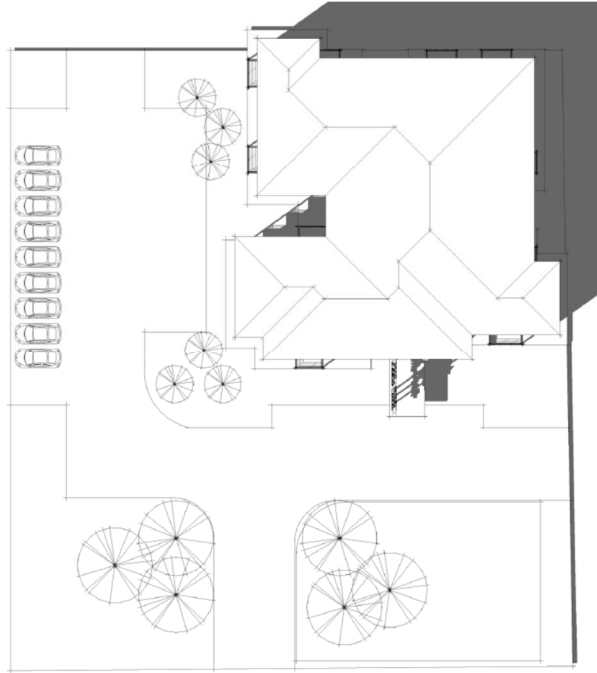


Figure 5.10 Student Work Exhibit – Conceptual Site Plan



Figure 5.11 Student Work Exhibit – Conceptual Building Section



Figure 5.12 Student Work Exhibit – Schematic Perspective

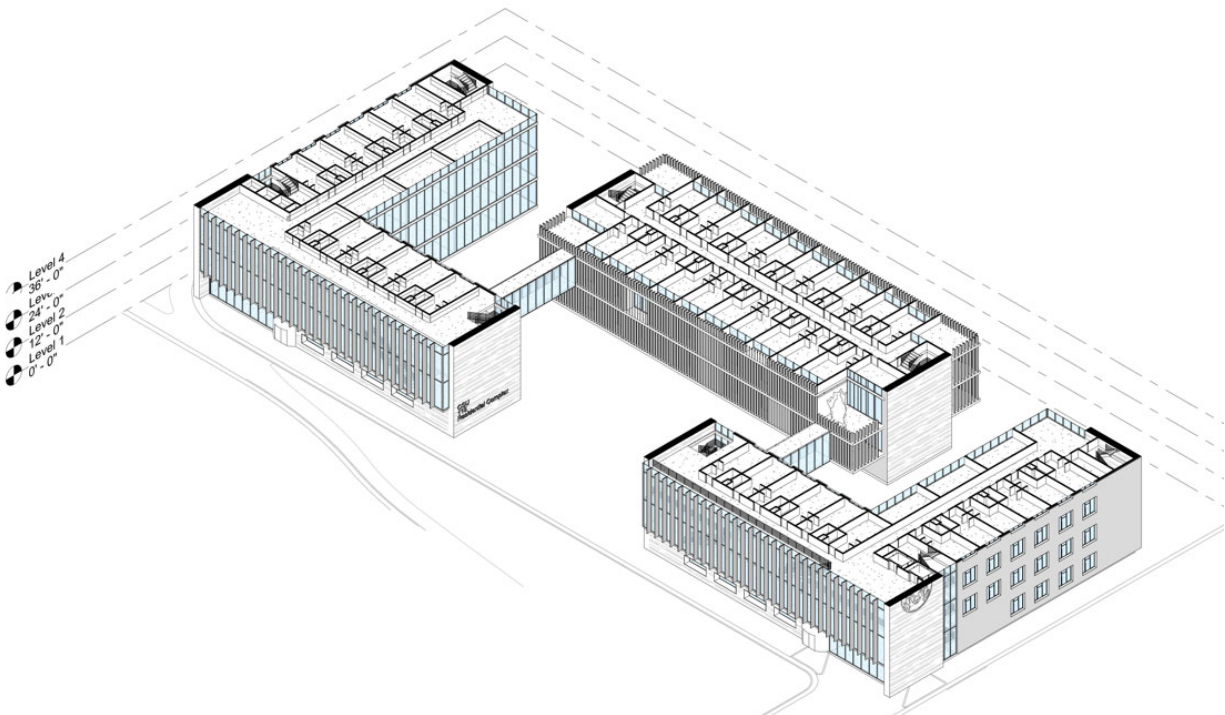


Figure 5.13 Student Work Exhibit – Schematic Axonometric



Figure 5.14 Student Work Exhibit – Schematic Perspective