Assessing the Impact of

BIM Process Mapping Activities

in Construction Education

by

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ABSTRACT

This research focuses on assessing the impact of various process mapping activities aimed at improving students' abilities to plan for Building Information Modeling (BIM). During the various educational activities, students were tasked with generating process maps to illustrate plans for hypothetical construction projects. Several different educational approaches for developing process maps were used, beginning in the Fall 2015 semester. In all iterations of the learning activity, students were asked to create level 1 (project-specific) and level 2 (BIM use-specific) process maps based on a previously published BIM Project Execution Planning Guide. In Fall 2015, a peer review activity was conducted. In Spring 2016, a collaborative activity was conducted. Beginning in the Fall 2016 and Spring 2017 semesters, an additional process mapping activity was conducted aimed at separating process mapping and BIM planning into separate activities. In Fall 2016, the BIM activity was conducted in groups of three whereas in Spring 2017, the students were asked to create individual process maps for the given BIM use. To understand the impact of the activity on students' perception of their own knowledge, a pre-and post-activity questionnaire was developed. It covered questions related to: (i) students' ability to create a process map, (ii) students' perception about the importance of a process map and (iii) students' perception about their own knowledge of the BIM execution process. The process maps were analyzed using a grading rubric developed by the author. The grading rubric is the major contribution of the work as there is no existing rubric to assess a BIM process map. The grading rubric divides each process map into five sections, including: core activity; activities preceding the core activity; activities following the core activity; loop/iteration; and communication across the swim lanes. The rubric consist of two parts that evaluate (i) the ability of students to demonstrate each section and (ii) the quality of demonstration of each section. The author conducted an inter-rater reliability index to validate the rubric. This inter-rater reliability index compares the scores students' process maps were when assessed by graduate students, faculty, and industry practitioners. The reviewers graded the same set of twelve process maps. The inter-rater reliability index was found to be 0.21, which indicates a fair agreement between the graders. The non-BIM activity approach was perceived as the most impactful approach by the students. The assessment of the process maps with the rubric indicated that the non-BIM approach was the most impactful approach for enabling students to demonstrate their ability to create a process map.

Key Words: BIM, BIM Process Mapping, Grading Rubric, BIM Education

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INTRODUCTION

Building Information Modeling (BIM) can be defined as the development and use of digital representations of buildings that include both physical and functional characteristics (Building SMART alliance 2007). BIM as a technology has found its value in cost estimating, construction sequencing, conflict, interference and collision detection, forensic analysis and facilities management (Azhar 2011).

BIM can be also viewed as a virtual process that encompasses all aspects, disciplines, and systems of a facility within a single, virtual model, allowing all team members (owners, architects, engineers, contractors, subcontractors and suppliers) to collaborate more accurately and efficiently than traditional processes (Azhar 2011). A well-documented BIM Project Execution Plan will ensure that all parties are clearly aware of the opportunities and responsibilities associated with the incorporation of BIM into the project workflow. A completed BIM Project Execution Plan (PxP) should define the appropriate Uses for BIM on a project (e.g., design authoring, design review, and 3D coordination), along with a detailed design and documentation of the process for executing BIM throughout a facility's lifecycle. The four steps to create and implement PxP plan are (CIC, 2010) :

1) Identify high value BIM uses during project planning, design, construction and operational phases

2) Design the BIM execution process by creating process maps

3) Define the BIM deliverables in the form of information exchanges

4) Develop the infrastructure in the form of contracts, communication procedures, technology and quality control to support the implementation

BIM process maps provide a method for communicating a PxP and helping an entire project team to understand the overall BIM process. They also help to define the information exchanges that will be shared between multiple parties (CIC 2010). BIM process maps are developed using Business Process Mapping Notations (BPMN). BIM process maps are defined at two levels: level 1; and level 2. A level 1 BIM process map is a BIM overview map and it shows the relationship between various BIM uses that will be implemented for a given project. A level 2 BIM process map is a detailed BIM use map, which demonstrates the plan for executing a given BIM use. A project will normally have one level 1 map and a level 2 process map for every BIM use that will be implemented on a project.

The author explored the use of process maps to facilitate students' understanding of BIM as a technology and a process. Specifically, the author assessed the maps developed by students in a fourth-year course (CON 453- Project Management 1) offered at Arizona State University. The course curriculum for CON 453 includes BIM planning and execution integrated with multiple construction delivery methods. In 2015, BIM Project Execution Planning (PxP) was added to the course curriculum to enhance knowledge specific to the processes supporting a successful BIM implementation. As a part of this research, a BIM process mapping activity was introduced into the course curriculum in Fall 2015. Since the fall 2015 semester, the author implemented different approaches to present the process mapping activity to students.

In Fall 2015 a peer review activity was conducted, where students created a level 1 and level 2 process maps, exchanged their maps with a peer, reviewed the maps and gave feedback. In Spring 2016, the author led a collaborative activity. In this activity students were given three different colored pens (red, blue and black). Students initially created individual process maps and then formed groups of three to create a collaborative process map. In the Fall 2016 and Spring 2017 semesters, the author first introduced process maps with a non-BIM activity prior to assigning the BIM process mapping activity. The non-BIM activity was a familiar process, creating process map for ordering and serving food at a sit-down restaurant. In Fall 2016, the BIM activity was conducted in groups of three whereas in Spring 2017, the students were asked to create individual process maps for the given BIM use. In all cases, the author gave students pre-and post-activity questionnaires to analyze the impact of the activity on students' perception about (i) their ability to create a process map, (ii) the importance of a process map, and (iii) their own knowledge of the BIM execution process.

In addition to assessing the impact of these activities on students' perception, the author also aimed to assess the actual performance of the students during the activity. To assess the process maps developed by the students, the author developed a grading rubric. While other researchers have developed methods to analyze demonstration of a process and to assess the quality of content, a previously developed grading rubric for assessing BIM process maps could not be identified. Therefore, part of the contribution of this work is in developing a rubric to assess BIM process maps. This rubric was developed for students completing the in-class process mapping activities over several semesters.

The author developed this rubric by combining the findings of previous research done by Riddle on the types of rubric (Riddle et. al 2016) and Elo and Kyngas on developing a rubric (Elo and Kyngas 2007).

In the grading rubric developed by the author, a process map is divided into 5 sections that are commonly found on effective BIM process maps. The rubric allows each of these sections to be evaluated based on: (i) the ability of the students to demonstrate that they can include each section; and (ii) the quality of their development of each section. The author conducted an inter-rater reliability index to validate the rubric. This inter-rater reliability index compares the scores obtained when assessed by graduate students, faculty, and industry practitioners. The reviewers graded the same set of twelve process maps.

Therefore, this research addresses the following questions related to both student performance in the different semesters and related to the development of a BIM process map assessment rubric:

(i) Are there any observable differences in the students' performance when participating in different process mapping learning activities?

(ii) How do students perceive the value of each pedagogical strategy for their own BIM process mapping education?

(iii) Can a finite and specific list of critical issues related to BIM process maps be developed that is agreed upon by experts in BIM PxP?

(iv) Can a rubric be developed that yields an acceptable inter-rater reliability index when used by a graduate student, a faculty member, and an industry practitioner?

CHAPTER 2

BACKGROUND LITERATURE

As the importance of BIM is widely recognized in the Architecture, Engineering and Construction (AEC) industry, it is essential for the new generation of construction management professionals to learn BIM during their time at universities. BIM education can help students understand the complexity of construction projects from both the product and process perspective (Sacks and Pikas 2013). A BIM course may enable students to: (1) define BIM, (2) describe workflow in using BIM in the building life cycle, (3) describe the process of model-based cost estimating, (4) perform 4D simulations, (5) apply BIM to reduce error and change orders in capital projects, (6) evaluate the use of 3D point clouds to support construction and asset management, (7) perform building energy performance simulations, and (8) evaluate and communicate ideas related to the use of BIM in the building life cycle (Wang and Leite 2014). Even though BIM education is common, one of the major issues observed among students is the lack of understanding of strategic BIM implementation (Wu and Issa 2013). In academic settings, BIM is often recognized by students as simply a digital design, which does not directly incorporate learning tasks related to developing a BIM process for implementation on a project (Wang and Leite 2014). Thus, enhancing students' understanding of the BIM process has the potential of adding real and measurable value to the students' professional career potential. This work focuses on enhancing the learning process of BIM Project Execution Planning (PxP) through the process of activity mapping.

Process maps are excellent for evaluating continuous as well as non-linear improvement potentials for all departments and operations including facilities management (CIC 2010). Process maps will also serve as the basis for identifying other important implementation topics including contract structure, BIM deliverable requirements, information technology infrastructure, and selection criteria for future team members (CIC 2010). A process map is created using Business Process Modeling Notations (BPMN). A standard BPMN helps in understanding the business procedures in a graphical notation and will give organizations the ability to communicate these procedures in a standard manner. Furthermore, the graphical notation will facilitate the understanding of the performance collaborations and communication across different sections of the organization or between different organizations. This will ensure that the participants are aware of their roles and responsibilities (OMG 2008). BPMN is used to communicate a wide variety of information to a wide variety of audiences by creating process maps (OMG 2008). BPMN creates a simple mechanism for creating a process model, while at the same time being able to handle the complexity of the process. The approach taken to handle these two conflicting requirements was to organize the graphical aspects of the notation into specific categories (OMG 2008). This provides a small set of notation categories so that the reader of a BPMN diagram can easily recognize the basic types of elements and understand the diagram. The four-basic category of elements are (OMG 2008)

1. Flow Objects
2. Connecting Objects
3. Swim lanes
4. Artifacts Flow

Flow objects can be events/activities/gateways. They are otherwise called as tasks. The flow objects are connected to each other or other information using ‘connecting objects. There are three Connecting Objects: 1. Sequence Flow 2. Message Flow 3. Association Swim lanes separates different sections of a process map. The flow of the process can occur across swim lanes. Artifacts are used to provide additional information about the Process (OMG 2008).

The main challenge faced during this research is that there is no hard and fast rule for creating or evaluating a process map. Many researchers have created rubrics to analyze various aspects of students’ performances such as creative thinking, critical thinking, reasoning, demonstration, inquiry and analysis, problem solving, and written communication (Elo and Kyngas 2007). Despite the contributions of prior work related to assessment, there is no tool developed to assess a BIM process map.

Rubrics are tools for evaluating and providing guidance for students’ writing process. A widespread definition of the educational rubric states that it is a scoring tool for qualitative rating of authentic or complex student work (Jonsson and Svingby 2007). Rubrics facilitate timely and meaningful feedback to students (Stevens and Levi 2005). Rubrics have explicitly defined criteria, and can lead to increased objectivity in the assessment of writing (Riddle et. al 2016). Thus, a rubric can be used as an effective tool to ensure consistent measurement of students’ performance. Rubrics used in many subject areas in higher education generally include two elements: (a) a statement of criteria to be evaluated, and (b) an appropriate and relevant scoring system (Riddle et. al 2016). In other words, it includes criteria for rating important dimensions of performance, as well as standards of attainment for those criteria (Jonsson and Svingby 2007).

The rubric tells both instructor and student what is considered important and what to look for when assessing (Arter and McTighe 2001, Busching 1998, Perlman 2003).

Rubrics can be classified as either holistic or analytic (Riddle et. al 2016). Holistic rubrics award a single score based on the student's overall performance, whereas analytic rubrics give multiple scores along several dimensions. In analytic rubrics, the scores for each dimension can be summed for the final grade. Although an advantage of the holistic rubric is that papers can be scored quickly, the analytic rubric provides more detailed feedback for the student and increases consistency (Riddle et. al 2016). For this research, a combination of analytic and holistic rubric was developed to analyze the process maps.

For the analysis process, the method of content analysis was adopted. Content analysis is a method of analyzing written, verbal or visual communication messages (Elo and H. Kyngas 2007). Content analysis is a method that may be used with either qualitative or quantitative data and in an inductive or deductive way. It was first used as a method for analyzing hymns, newspaper and magazine articles, advertisements and political speeches in the 19th century (Elo and Kyngas 2007). Content analysis allows the researcher to test theoretical issues to enhance understanding of the data. Through content analysis, it is possible to distil words into fewer content-related categories. It is assumed that when classified into the same categories, words, phrases and the like share the same meaning (Elo and Kyngas 2007). Usually the purpose of those concepts or categories is to build up a model, conceptual system, conceptual map or categories.

The method found its critics in the quantitative field, who considered it to be a simplistic technique that did not lend itself to detailed statistical analysis, while others considered that content analysis was not sufficiently qualitative in nature (Elo and Kyngas 2007). Here, a grading rubric is developed for qualitative analysis, and it was done in a deductive method.

When it comes to the usability of screening tools, both validity and reliability of the instrument are important quality indicators. Reliability estimates describe the precision of an instrument. They refer to its capacity to produce constant, similar results. Validation is the process of accumulating evidence that supports the appropriateness of the inferences that are made of student responses for specified assessment uses (American Educational Research Association, American Psychological Association & National Council on Measurement in Education 1999). Validity refers to the degree to which the evidence supports that these interpretations are correct and that the way the interpretations are used is appropriate (American Educational Research Association, American Psychological Association & National Council on Measurement in Education 1999).

Every assessment has to be credible and trustworthy, and as such be made with disinterested judgment and grounded on some kind of evidence (Wiggins 1998). An assessment should be independent of who does the scoring and when and where the assessment is carried out. There are different ways in which variability in the assessment score can come up. It might be due to variations in the raters' judgments or with time (Shavelson et. al 1996). There are different ways to measure reliability, e.g., across raters that evaluate the same participant (inter-rater reliability) or across different points in time (test-retest reliability) (Stolarova et. al 2014).

For this activity, validation of the rubric was done by evaluating the inter-rater reliability index. This inter-rater reliability index compares the scores students' process maps earn when assessed by graduate students, faculty, and industry practitioners. The reviewers graded the same set of twelve process maps. The graders were given only the rubric and they had the freedom to interpret the rubric and the grading instructions in their own way. To measure the inter-rater reliability, Cohen's Kappa was calculated. Reliability between two graders can be calculated by using Cohen's Kappa, which approaches one as perfectly reliable and goes to a value equal to or less than zero when there is no agreement (Haney et al., 1998). The kappa value can be interpreted as the proportion of agreement between raters after accounting for chance (Cohen 1960).

CHAPTER 3

METHODOLOGY

PROCESS MAPPING ACTIVITY

To enhance students' awareness of BIM process, BIM Execution Planning was added to the curriculum of CON 453- Project Management 1. The course schedule included two 75-minute lectures and a single 2-hour lab session every week. The lecture focused on the importance of BIM in the construction industry and the lab session provided students with a hands-on experience with the modeling software programs. To enhance students' ability to use BIM in every aspect of the project, a semester long project was introduced into the course curriculum.

Various teaching methods were introduced to enhance students' understanding of BIM PxP over several years. As a part of the research, a process mapping activity was added to the curriculum in Fall 2015. Along with the process mapping activity, students completed a pre-and post-activity questionnaire. This questionnaire was developed to understand the impact of the process mapping activity on students' perceptions about their own abilities. Even though this is a class activity, the responses from students were used only for this study and only the research team had the access to the data. All the responses were anonymous and prior to the activity students were given an informed consent sheet in accordance with the Institutional Review Board (IRB) requirements

Pre-Activity Questionnaire

The pre-activity questionnaire consisted of two sections. The first section was the general information section, which asked students' general information such as their major, academic year and a unique identification number to anonymously track their responses.

The second section contained questions pertaining to BIM process mapping. The questionnaire included 6 Likert-scale questions that were intentionally asked before and after the activity. This enabled the responses to be compared to identify shifts in perceptions. The questions included are shown in Table 1.

Table 1: Paired questions for BIM Process Mapping Activity

Pre- and Post-Activity Paired Questions	Possible Responses
Indicate your level of agreement with the following statement: I am fully prepared to create a level 1 process map	7-Point Likert-scale (Strongly Disagree to Strongly Agree)
Indicate your level of agreement with the following statement: I am fully prepared to create a level 2 process map	7-Point Likert-scale
Rate your ability to create Process Mapping Dialogue Box	7-Point Likert-scale
Indicate your level of agreement with the following statement: this process mapping activity improved my ability to organize parallel and overlapping activities.	7-Point Likert-scale
Rate your ability to organize activities in sequence	7-Point Likert-scale
Rate your ability to identify responsible parties in each BIM use	7-Point Likert-scale

Post-Activity Questionnaire

After the activity, a post questionnaire was given to the students. It consisted of 15 questions, including the 6 paired questions from Table 1. It also contained 4 open ended questions. The post activity questionnaire helped in assessing the students' perception about their ability to create process map after the activity and in getting a feedback and further suggestions for the activity.

BIM Process Mapping Activity

For the process mapping activity, a hypothetical building project was given to the students. The building chosen for the activity was College Avenue Commons, as this is a familiar building for the students. Students were tasked with developing BIM process maps for this building project. Prior to beginning the task of BIM process mapping, students were provided with a list of high priority BIM uses that were selected to offer value to this building project (APPENDIX C). Students were challenged in all iterations of the process mapping activity to create: a level 1 process map that included all high priority BIM uses; and a level 2 BIM process map for the given BIM use. Students were asked to include the given high priority BIM uses in their level 1 process map. The given BIM use for the level 2 process map was based on the completed lab sessions to ensure that students' have a hands-on experience in the given BIM use. The given BIM use for creating a level 2 process map in Fall 2015 was 4D modeling. For all other semesters, the given BIM use was 3D coordination. In all cases, students were tasked with completing this process mapping activity during a 75-minute lecture session. While this general approach remained consistent in all iterations, the specific methodology used to enable students to generate these deliverables varied in different semesters.

The following sections illustrate the different approaches used in different semesters.

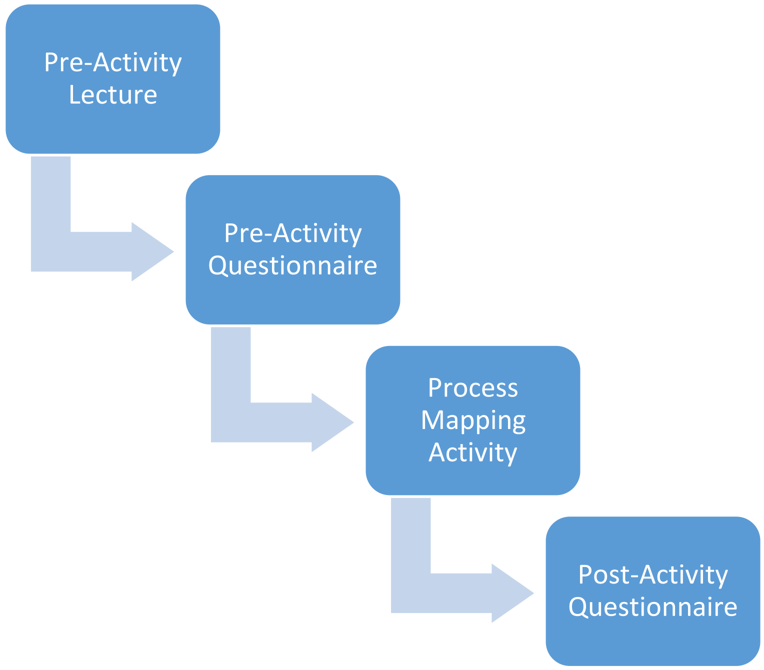

Figure 1: Methodology for Process Mapping Activity

Fall 2015:

In Fall 2015, a peer review activity was conducted. Students were asked to create their own level 1 and level 2 process maps for a hypothetical building project. After generating these process maps, two students would form a group to peer-review each other's maps. During this peer-review, students were asked to consider how effective and clear the map of their peer was. While assessing a peer's work, students had the freedom to add comments or diagrams to illustrate their feedback to the original authors. After reviewing the process maps, students exchanged back with their peer to review their original maps.

At that point, the original map author had the freedom to incorporate the suggestions into the process map or ignore them if they felt that the feedback was not appropriate or necessary.

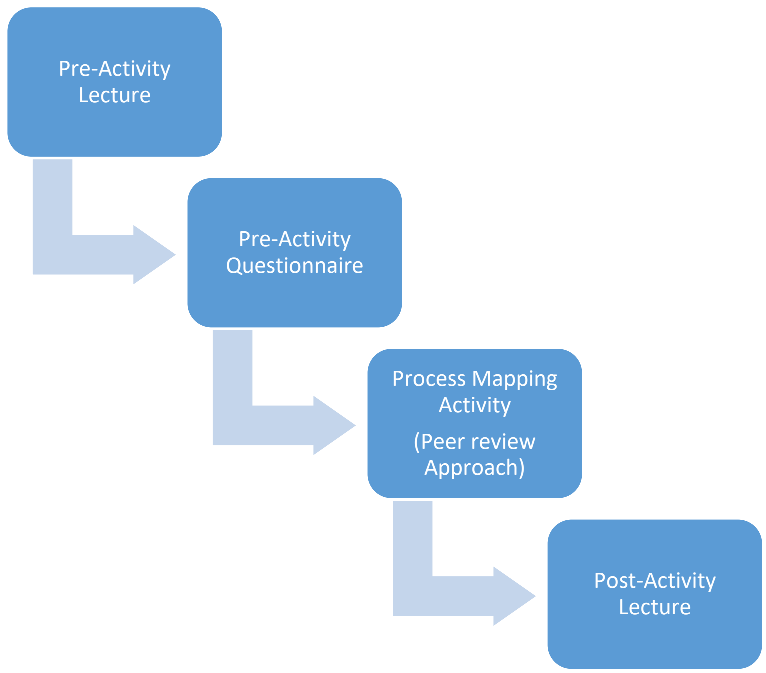

Figure 2: Methodology for Process Mapping Activity (Fall 2015)

Spring 2016:

In Spring 2016, a collaborative process mapping activity was conducted for the same hypothetical building project. Here students were given three different colored pens (red, blue and black) and students developed level 1 and level 2 process maps individually. They then formed groups of three ensuring each student had a different colored pen. When the student teams were formed, they were provided with new blank process map templates for both level 1 and level 2 process maps.

Students were then asked to create a new level 1 process map for all the high priority BIM uses and a level 2 map for 4D modeling. During this process, each student still had access to their originally developed process map that they created individually. When students created the new process maps, they were asked to use the same pen that they used for their individual process maps. This enabled the researcher to determine which student(s) provided which contributions to the process maps during analysis and how those contributions compared to their individually developed maps.

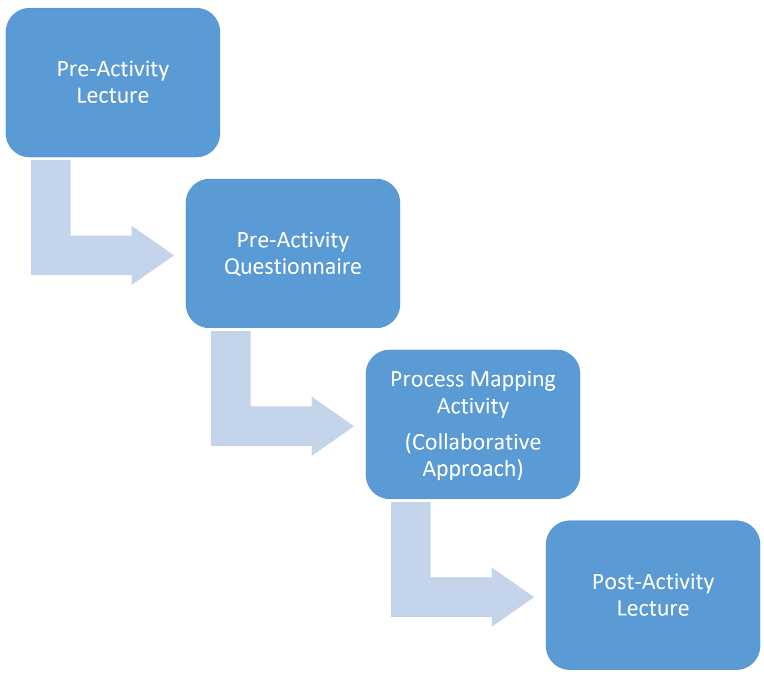

Figure 3: Methodology for Process Mapping Activity (Spring 2016)

Fall 2016:

In Fall 2016, the in-class process mapping activity was re-configured to try to simplify the introduction of BIM planning. Before creating the in-depth BIM process maps, students were provided with a simplified process mapping activity that did not include BIM.

Since the course explored is one of the first in-depth BIM courses for most students, this learning activity was hypothesized to make this learning content easier to understand for the students. Therefore, this semester included 2 separate, but related process mapping learning activities. These separated process mapping activities allowed the author to assess students' understanding of the BIM process separately from students' understanding of process mapping as a technique for documenting communication and information flows within a given process. The activities presented are presented in the following sub-sections.

Activity 1: Simplified process mapping activity without the incorporation of BIM.

This first learning activity tasked students with creating a process map for a simplified and familiar process. Students were tasked with creating a process map for ordering a meal at a sit-down restaurant. This activity was chosen because it is familiar to nearly all students and still requires communication and collaboration between stakeholders (i.e. Customer, Waiter, and Chef), which would mimic the communication challenges necessary for BIM implementation. Students were given a handout explaining the process for which they are expected to create a process map.

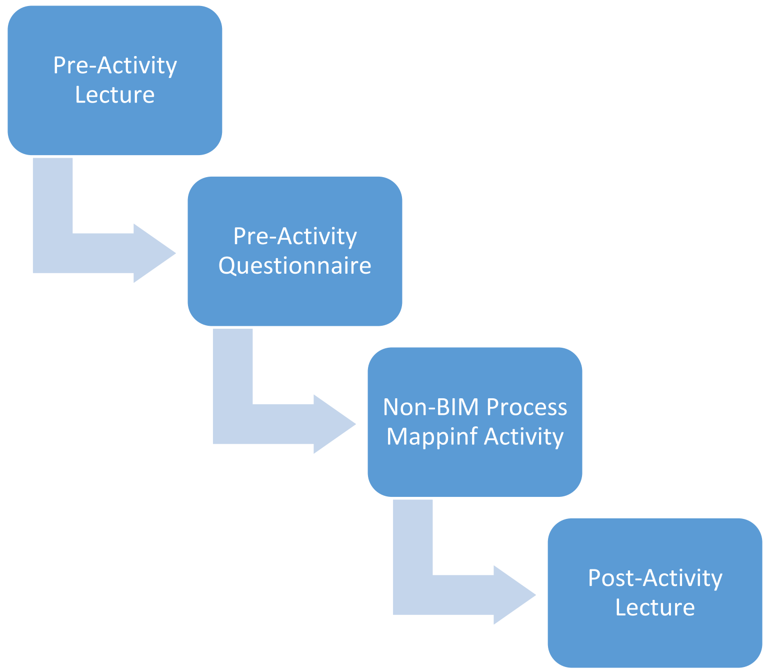

Figure 4: Methodology for non-BIM Process Mapping Activity (Fall 2016)

The same data collection activities that preceded and followed the prior process mapping activity implementations were conducted with this simplified process mapping activity. Students were still provided with a pre-activity lecture to introduce content related to the activity. In this case, this included presenting a simplified process map to the whole class for ordering an item from an online store. Additionally, students completed a similar pre- and post-activity questionnaire to assess their perceptions about the activity.

Activity 2: BIM based Process Mapping Activity

One week after students completed the simplified process mapping activity for ordering food at a restaurant, students were provided with the BIM planning activity that included the same scenario from prior semesters. Students completed the same activities before beginning the BIM planning activity (i.e. introductory lecture and pre-activity questionnaires).

Then the activity was conducted in a similar manner as the prior semesters using three different colored pens (red, blue and black). After receiving a colored pen, students formed groups of three so that each team member had a different pen color. Then the students were asked to create a level 1 and level 2 process map in groups. The level 2 process map was created for 3D coordination process. Upon completion of the BIM process mapping activity, students completed the same post-activity questionnaire that was implemented in prior semesters.

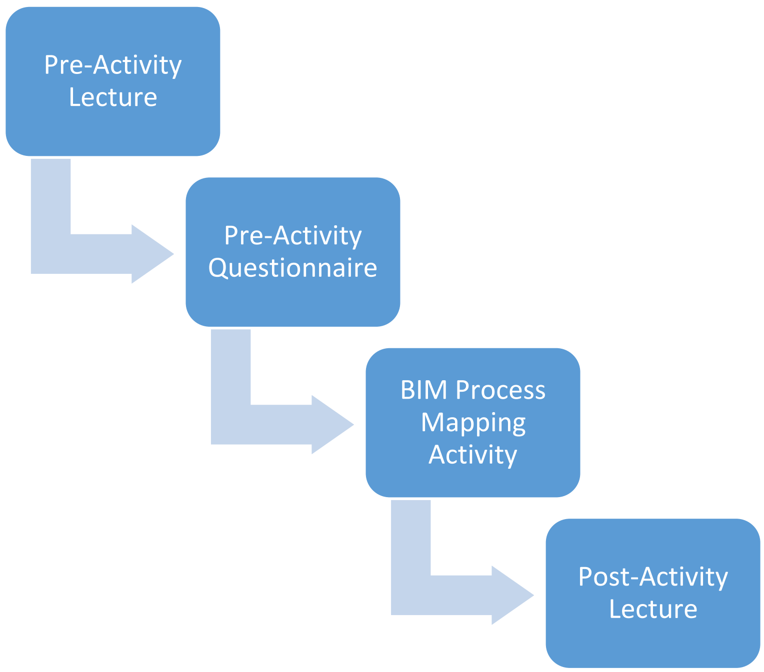

Figure 5: Methodology for BIM based Process Mapping Activity (Fall 2016)

Spring 2017:

This activity followed nearly the same procedure as that in the Fall 2016. The only difference to this semester's implementation is that students developed their BIM process maps individually rather than in teams. This helped to illustrate whether there was any positive or negative impact of working in teams to create BIM process maps.

DATA ANALYSIS

The collected data was analyzed in two different ways: perception based analysis and observation based analysis. The pre- and post-activity questionnaires were analyzed to determine the impact of the various BIM process mapping activities on the students' perceptions about their own knowledge. A two-tailed probability test was used to analyze the paired questions. This helped to indicate whether there were significant differences in the responses from students before and after completing the BIM planning activities. There were 6 paired questions in the BIM activity (Table 1). Only the responses from students who consented to allow their data to be used for research were analyzed. A detailed analysis of the perception was conducted to determine the exact percent of positive, negative and impartial impact on students for those paired questions that indicated an impact upon conduction two tailed probability test (APPENDIX H).

In addition to exploring the shifts in students' perception, the author also aimed to explore the quality of the process maps that were developed during the activity. To do this, the author developed a grading rubric to assess the level 2 BIM process maps. This rubric provided a tool that would allow process mapping scores to be consistently assigned and tracked through the different semesters. This allowed the author to determine the impact of the different process mapping activities on the students' performance.

The process maps created by students who consent to participate in this study were graded. The author graded process maps from all semesters using the grading rubric. To compare students' perception to their performance, the perception results were compared to the results obtained from assessing the process maps using the grading rubric. The perception results were also compared to the grades scored by students' during their class PxP project. This was to compare students' perception and their performance during the class project. The process maps created by students for the PxP was compared to the process maps crated during the class activity. The process maps created by students in the class project was also assessed using the grading rubric for this comparison. The following section outlines the methodological steps used to generate the required grading rubric.

RUBRIC DEVELOPMENT AND VALIDATION

A grading rubric was developed to analyze the process maps developed by the students. This rubric consisted of two main parts that assessed: the students' ability to demonstrate a process; and the quality of the process by considering the contextual factors.

Rubric Development: Prior to the development of the rubric, the process maps were assessed by observation. Specifically, the author reviewed the maps and checked that the map used BPMN symbols, mentioned the relevant and required stakeholders, and illustrated communication across the swim lanes. While this provided some insight into the map, the author recognized that the presence or absence of these items did not necessarily indicate whether or not students could effectively translate their concepts into a coherent process map that could actually be used in practice. In other words, a student could theoretically develop a map that using correct notation, with the appropriate stakeholders, and illustrating communication across swim lanes, but if that process map has a fundamental flaw, it may not effectively illustrate a BIM process.

To guide the process map reviewer, the rubric strategically broke down the student process maps into five distinct sections.

These sections were created to guide a reviewer's feedback without prescribing exactly how they should be assessing the process map. A deductive content analysis approach was adopted for defining the five sections of the rubric (Satu Elo & Helvi Kynga, 2008). The five sections were selected based on the shared features of the task. In content analysis of the process maps, the tasks that share the same purpose are categorized as a category. Each category will be a standalone section, but each section will be related to each other to form the whole data. In this rubric, the categories are named as 'sections'.

There is not one single 'right' way to develop a process map. Instead, there are infinite 'right' ways to develop a process map. Despite the plethora of "right ways" to develop a process map, there is arguably one task that must occur in any implementation of a given BIM use. This task is often the technical task that is at the 'core' of the given BIM use. Therefore, the first section of the rubric aims to have a reviewer identify what they believe to be the "core" task shown on the students' process maps.

There are some activities that occur before the core task. These activities prepare for successful implementation of the core task. In the similar way, there are few activities that occur after the core task. These activities lead to completion of the process.

After identifying the core BIM task and preceding and following activities, reviewers were asked to determine whether the students' process maps included some type of iterative loop to experiment with design and construction options in BIM. Arguably, one of the consistent attributes of all BIM initiatives is that it allows project teams to build a virtual version of the physical facility and therefore, iteratively experiment with design and construction decisions to enable the best outcome for the project.

Therefore, a section was added to the rubric to task reviewers with identifying the presence of some type of loop/iteration illustrates that the process map enable this type of experimentation.

The final section that was incorporated into the BIM process map rubric relates to documentation of communication between project stakeholders. BIM often acts as a bridge between design and construction teams. Therefore, there is typically a need for coordination and communication among the stakeholders of the project. In a BIM process map, this would typically be illustrated through interactions of activities across the swim lanes. Therefore, this was added as the final section for the process map grading rubric.

The five sections of the rubric are defined as below:

- Core activity: This is the technical task that needs to occur in all implementations of this BIM use, regardless of how different companies may approach BIM. For example, when developing a process map for BIM-based “3D Coordination”, a core task might be “run BIM clash report”. While different companies may use different procedures for including or excluding certain project stakeholders in 3D coordination sessions, the author of this work argues that all teams would need to include a technical task similar to “run BIM clash report” during their implementation. Otherwise, the author would question whether the process map constitutes using BIM-based “3D Coordination”.
- Activities preceding the core activity: These are the activities that must occur before the core task for the core task to be completed effectively. For example, in a “3D Coordination” example, a possible preceding task could include “Gathering MEP models for 3D Coordination”.

- Activities following the core activity: These are the activities that occur after the core task. Additional activities depend on the type/result of core task. For example, a possible task that follows the core activity for "3D Coordination" might be "Defining responsible parties to move building components to avoid issues identified in clash report".
- Loop/Iteration: This refers to the decision point where the project team determines whether there is a need to repeat a task or tasks prior to proceeding with subsequent construction tasks. Ideally, students would demonstrate this iterative process through BPMN symbols with an arrow going back to prior tasks. This section of the rubric tasks a reviewer with identifying either the explicit iteration shown through BPMN language or implicit iteration suggested by activities on the process map. For example, an effective process map for "3D Coordination" might show an arrow that goes from a task after running a clash report back to a task prior to running the clash report to reduce model clashes. Alternately, a less effective process map might include an activity after running a clash report that states "resolve all clashes". Both methods show articulation of iteration in the process, but the former includes a higher level of granularity to specify what project stakeholders are expected to do to deliver this.

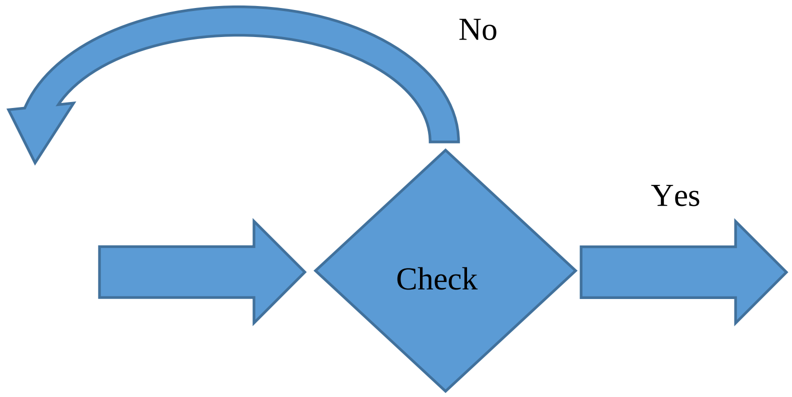

Figure 6: loop/iteration using BPMN symbols

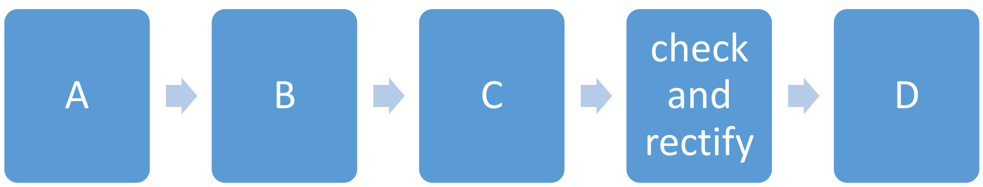

Figure 7: Loop/Iteration as a task

- Communication across the swim lanes: In process maps with more than 1 swim lane, there is a communication that occurs across the swim lanes. For every construction project, there is a need for coordination and communication among the stakeholders of the project. In a BIM process map, this would typically be illustrated through interactions of activities across the swim lanes. A well-illustrated communication section makes the process map more self-explanatory.

The developed rubric guides a reviewer through each of these five sections. Reviewers are tasked with evaluating the mere presence of each section, but they are also tasked with evaluating the quality of each section. This assessment can involve some level of subjectivity. Therefore, the following previously validated rubrics were used to generate the criteria language used for process map evaluators.

The rubric language for each section was developed from the previously developed rubrics. These rubrics were developed by Association of American Colleges and Universities. The rubrics were generated by teams of faculty experts representing colleges and universities across the United States. This was done through a process that examined many existing campus rubrics and related documents for each learning outcome and incorporated additional feedback from faculty.

Based on these rubrics, the grading scale was developed. For each criterion of the rubric, 5 different levels of performance were defined. The definition for each grade was developed from the previously developed rubrics (CITE). A grading system similar to the traditional five-grade letter grading system was adopted for this rubric. Each grade was named as A, B, C, D and E respectively.

Finally, after reviewers assessed each of the five sections of the BIM process maps, a single rating scale was provided to ask raters to assign a single grade to the entire process map. While this single rating scale includes potential subjectivity in the rating, it was included to determine if there was general agreement about the quality of the process maps between reviewers. Additionally, it helped to determine if there were any substantial discrepancies between the scoring of individual process map sections and the overall evaluation provided.

Rubric Validation: The validation of the rubric was done by evaluating the inter-rater reliability index between 3 graders. Twelve process maps, 3 from each semester, were chosen for the validation process. These process maps were selected randomly from each semester. This inter-rater reliability index compares the scores students' process maps earn when assessed by graduate students, faculty, and industry practitioners. The reviewers graded the same set of twelve process maps. The graders were given only the rubric and they had the freedom to interpret the rubric and the grading instructions in their own way. Graders having different backgrounds were selected to validate that the rubric can be interpreted in a single way, irrespective of the background of the grader.

For the validation process, Cohen's Kappa was calculated. Cohen's kappa is used to measure the agreement between two graders. In this study, the Cohen's kappa was calculated three times and the average value was found. The final value was compared to the standard values for Cohen's kappa. The inter-rater agreement was measured separately for each section of the grading rubric. For this study, a faculty member was considered as grader 1, an industry practitioner was considered as grader 2 and a student was considered as grader 3. Throughout the study, the consideration remained the same.

The rubric was also used to assess an industry-developed process map. The main intention of this was to identify whether the industry developed and successfully implemented process map does have all the five sections and whether the descriptions used for determining the effectiveness of each section are appropriate. This information can add value if this rubric is to be repurposed for assessing the industry process maps.

CHAPTER 4

DATA ANALYSIS AND RESULTS

RUBRIC DEVELOPMENT AND VALIDATION

A rubric was developed to analyze the process maps. The validation of the rubric followed the method given in the 'METHOD' section. The results of the validation process are given in table 2. A detailed validation of the rubric was conducted by calculating Cohen's kappa for each criterion given in the rubric (APPENDIX F)

Table 2: Results of Validation Process

	Exact Agreement	**Cohen's Kappa**
Grader 1 and Grader 2	50%	0.19
Grader 2 and Grader 3	33%	0.24
Grader 1 and Grader 3	50%	0.19

ANALYSIS OF ABITITY TO DEMONSTRATE

The author assessed process maps with the grading rubric to rate the ability of students to demonstrate their understanding and knowledge.

Table 3: Analysis of Process Maps

Semester	**Type of Activity**	**Percent of process maps scored A**	**Percent of process maps scored B**	**Percent of process maps scored C**	**Percent of process maps scored D**	**Percent of process maps scored E**
Fall 2015	Peer review	0	23.68	39.5	31.6	39.5
Spring 2016	Collaborative	0	8.33	8.33	58.33	25
Fall 2016	Non-BIM	0	60	20	20	0
Spring 2017	Non-BIM	17.2	17.2	27.5	24.1	13.8

In Fall 2015 0% of process maps scored A and 39.5% scored E i.e., failed. In Spring 2016 0% scored A, 25% scored E. In Fall 2016 0% of process maps scored A, which indicates that students were not able to demonstrate per the rubric definition of grade 'A'. None scored the grade 'E' which can be considered as a good impact on the students. In Spring 2017, 17.2% scored 'A' and 13.8% scored 'E.

PERCEPTION ANALYSIS

Table 4: p-value for the paired Questions

Paired Questions	Fall 2015 (n=37)	Spring 2016 (n=35)	Fall 2016 (n=32)	Spring 2017 (n=41)
Indicate your level of agreement with the following statement: I am fully prepared to create a level 1 process map	0.308	0.75	0.2427	0.06387
Indicate your level of agreement with the following statement: I am fully prepared to create a level 2 process map	0.109	0.110	0.5938	0.0362
Rate your ability to create Process Mapping Dialogue Box	0.008	0.000	0.100	0.0252
Indicate your level of agreement with the following statement: this process mapping activity improved my ability to organize parallel and overlapping activities.	0.260	0.4162	0.922	0.0264
Rate your ability to organize activities in sequence	0.19	0.19	0.0131	0.0011
Rate your ability to identify responsible parties in each BIM use	-	-	0.2427	0.0024

For the perception based analysis, a two-tail test was performed. Here a 5% significance was used. Any value less than 0.05 for a paired question indicates that there is 95% confidence that the students perceived an impact in that ability after the activity.

In Fall 2015, for the paired question ‘Rate your ability to create Process Mapping Dialogue Box’ the obtained p-value (Table 4), indicates a 95% confidence that the students are more confident in their ability to create a process mapping dialogue box after completing the BIM planning activity. For all other paired questions, the p-value obtained is higher than 0.05, which indicates that there is no 95% confidence in students perceiving a positive shift in their ability after the activity.

In Spring 2016, the p-value for the paired question ‘Rate your ability to create Process Mapping Dialogue Box’ is 0.000 which is less than 0.05 in magnitude. This shows that after the activity students perceived an impact on their ability to create Process Mapping Dialogue Box. For all other paired question, the p-value obtained is not within 95% confidence level.

In Fall 2016, the paired question ‘Rate your ability to organize activities in sequence’ has a p-value less than 0.05 in magnitude. It indicates that students perceive an impact on their ability to organize activities in sequence after the process mapping activity.

In Spring 2017, for all the paired questions except ‘Indicate your level of agreement with the following statement: I am fully prepared to create a level 1 process map’ has a p-value less than 0.05. This indicates that students perceived a positive shift in their ability after the activity. A detailed analysis of the perception shift was conducted (APPENDIX H).

CHAPTER 5

DISCUSSION

RUBRIC DEVELOPMENT AND VALIDATION

A grading rubric was developed to analyze the process maps. The rubric divided the process map into five sections-core activity, activities preceding the core activity, activities following the core activity, loop/iteration, and communication across the swim lanes. The rubric consists of 3 parts. The first section assesses the ability to demonstrate each section. The second part assesses the quality of each section. The final part rates the whole process. The validation of the rubric was done by finding the inter-rater reliability among three graders. In the validation process, the average Cohen's Kappa was found to be 0.21 which indicates a fair agreement between the graders. The main reason for this can be the criteria given in the rubric for the final grade, which is more likely a perception based grading.

DATA ANALYSIS

The grader adopted two different approaches for the evaluation of the process maps, i.e., perception based and demonstration based analysis. The perception based analysis was done with the help of the questionnaires and the ability of the students to demonstrate was assessed by assessing the process maps with the rubric.

The results obtained from the pre-and post-activity questionnaire indicates that there was a positive shift in students' perception about one or two aspects of the activity during each semester. But most the paired questions indicated no significant impact on the students' perception about their own ability. This can be due to lack of knowledge in using BPMN notations or due to lack of knowledge in the BIM process.

This can be also due to lack of ability to demonstrate the process within the given time frame. This can be also due to lack of influence on the students' perception. The feedback given by the students are mostly about the need for more explanation, more time for the activity and more detailed instructions for the activity. In Spring 2017, most of the paired questions had a significant impact on the students' perception about their own abilities. This indicates that out of all the approaches, students perceived the 'Non-BIM activity' approach as the most impactful one.

The process maps were assessed using the grading rubric. The results of the analysis imply that the percent of students who created a self-explanatory process map was in Spring 2017. Thus, it can be concluded that the non-BIM Activity approach had a positive impact on the students in creating process maps. In Fall 2015 none of the students scored an "A" grade and 39.5% students failed to develop a level 2 process map for the given BIM use. This can be because of the lack of understanding about the given BIM use or due to lack of understanding about the process mapping language. In Spring 2016, none of the students scored 'A' and 25% scored 'E'. In the feedback section, students mentioned time and lack of understanding in the process mapping language as the limitations. In Fall 2016, none of the students scored an "E" grade. Here all the students could create a process map. This may be because of the collaborative approach of the work, where students share their ideas and create a process map. The main feedback obtained from the students included a need for clear instructions for the activity, more time for performing the activity and lack of knowledge in process mapping language. In Spring 2017, 17% of students scored "A" grade and 13.8% students scored "E".

This shift in students scoring ‘A’ indicated a positive impact on the students’ ability to demonstrate their knowledge. This can be due to their prior knowledge in the given BIM use or process mapping. But in Spring 2017, not all students could create a process map.

CONCLUSION

The process mapping activity conducted in CON-453 over various semesters were analyzed as a part of this pedagogical study. The pre-and post-activity questionnaires were analyzed to interpret students’ perception about their own abilities before and after the activity. The process maps were analyzed to assess students’ ability to demonstrate their understanding of BIM process map. A rubric was developed to assess level 2 BIM process maps. The developed rubric can be restructured to assess any process maps.

The pre-and post-activity responses indicate that in Spring 2017 (non-BIM activity approach), students perceived a significant impact for most of the paired questions (Table 4). This may be because of the non-BIM approach that gave an idea about the process mapping language prior to the BIM process mapping activity.

The process maps were assessed using the grading rubric. In Fall 2016 (non-BIM approach), none of the students failed to create a process map. This indicates that all the students could demonstrate their understanding of BIM process. In Spring 2017 (non-BIM approach) students could create process maps that varied in grade from ‘A’ to ‘E’. This can be due to the non-BIM activity approach. But in this activity, some students failed to create a process map. The varying performance of students can also be due to their knowledge in the given BIM use. This can be also due lack of understanding of process mapping language, which indicates that the non-BIM activity had no significant impact on the students’ ability to demonstrate their understanding of the given BIM use.

The perception of the students was compared to the performance of students during the process mapping activity. It is observed that, here is a lack of tie between students' perception about their own ability to create a process map and their ability to demonstrate their understanding. This can be due to a change in their perception about their own abilities after participating in the activity. There is a chance that students might have underestimated their ability to create a process map before participating the activity in Spring 2017, which indicated a significant shift in students' perception upon participating in the process mapping activity. In Fall 2016, the perception based analysis indicates that, the activity had minimal impact on the students, but those none of those same students failed to create a process map. This can be also due to students overestimating their ability to create a process map before the activity. This can be also due to the collaborative approach that was adopted for the process mapping activity. In both these cases, the activity had an impact on the students' ability to demonstrate their understanding about BIM process mapping.

The grades scored by students in the class activity and in their class project were compared. From the results, it can be concluded that students could demonstrate their ability during the class project then during the class activity. This can be due to the approach used for the class activity and the guidance received from the PxP process mapping templates (APPENDIX J).

The inter-rater reliability index was calculated for the validation of the rubric. The inter-rater reliability index (Cohen's Kappa= 0.21) indicates a fair agreement between the graders (Landis, et. al 1977). A value less than zero indicates no agreement and 0–0.20 indicates slight agreement, 0.21–0.40 indicates fair agreement, 0.41–0.60 indicates moderate agreement, 0.61–0.80 indicates substantial agreement, and 0.81–1 indicates almost perfect agreement between two graders (Landis, et. al 1977). The detailed analysis indicates that there is minimal agreement between the graders for each criteria of the rubric (APPENDIX F).

Limitations Of The Work:

The major limitation of this work is the varying sample. As various approaches are implemented in different semesters, the students developing the process maps are different. Thus, the variation in the created process maps can be because of the knowledge of students in the given BIM use, their work experience and their previous knowledge about process mapping. Another limitation of the work is the varying BIM use for the process mapping activity. The BIM use given for the process mapping activity chosen for various semesters was 3D coordination for three semesters and 4D modeling for the first attempt. Students mentioned the time given for the process mapping activity as another limitation in their feedback section.

Another limitation is the low inter-rater reliability index. Even though the inter-rater reliability index is low, since the process maps are graded by the same grader for this research purpose, this limitation has a less of an impact on the results obtained.

The detailed inter-rater reliability index is another limitation of the work The inter rater reliability index obtained for each criteria of the rubric indicates a no/very low agreement for most of the criteria (APPENDIX F).

Not all the process maps created by the students were used for this study. Only those process maps created by who consent to use their work for this study was assessed. Thus, the results are based on a subset of the total sample.

The Major Contribution:

The major contribution of this work is the development of a grading rubric to assess BIM process maps. This rubric is developed to assess a level 2 BIM process map. There is no readily available tool to assess a BIM process map, thus development of this grading rubric can be a contribution for assessing level 2 BIM process maps. This can be restructured to assess a level 1 BIM process map. This can also be restructured for assessing any other process. Further research can be done on modifying this rubric to assess other processes.

Further approaches for process mapping activity can be adopted by addressing the shortcomings and findings of this study. A process mapping activity can be conducted for other BIM uses which are familiar to students. Any other familiar process can be adopted as a non-BIM activity which relates more to a construction process such as 'building a dog house'. A different approach can be adopted to familiarize students with process mapping language or the given BIM use by a visual display of process before the activity. This can lead to lesser assumptions. A modification to the rubric language can yield more credibility to the results.

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APPENDIX A
PRE-ACTIVITY QUESTIONNAIRE

EMERGING TECHNOLOGIES BIM LAB
660 S COLLEGE AVE
TEMPE, AZ 85281
480.727.4579

Informed Consent:

I am a professor in the Del E. Webb School of Construction in the School of Sustainable Engineering and the Built Environment at Arizona State University. I am conducting a research study to explore how an in-class Building Information Modeling (BIM) process mapping and collaborative activity can improve students' levels of understanding and comfort with planning for BIM in construction.

I am inviting your participation in this research, which will involve completing a pre- and post-activity questionnaire as well as the developed BIM process mapping activity. Each questionnaire will take between 5 and 10 minutes to complete and the process mapping activity will take the remainder of the class time. All students will be required to complete the process mapping activity regardless of whether or not they consent to allowing their data to be used for research. Therefore, this research will not require additional student effort outside of normal class participation.

To participate in this research, you must be a student enrolled in CON 453 / CNE 453 and you also must be 18 years or older. While all students are required to complete the process mapping activity, you have the right to not answer any question on the pre- and post-activity questionnaires. Additionally, you also have the right to not allow your provided responses to the process mapping activity to be used for research purposes, if you choose. Your participation in this research is voluntary. If you choose not to allow your responses to be used for research purposes, there will be no penalty.

The potential benefit to participants in this work is an improved understanding of BIM process mapping. There are no foreseeable risks or discomforts to your participation.

Your responses to the pre- and post-activity questionnaires will be anonymous to allow you to provide candid feedback, which will not be linked to your name. Instead, you will be asked to generate experimental identification by providing the first 3 letters of your mother's maiden name as well as the last four digits of your phone number. This will ensure that the instructors and researchers will not be able to link your pre- and post-activity questionnaire responses with your name, but will be able to understand any changes in your responses before and after completing the process mapping activity.

For the process mapping activity documents created, you will be asked to provide your name and indicate whether or not you are willing to allow your work to be used for research to understand the benefits of this format of education. Any dissemination of findings will not include student names, so you will never be personally linked to any of your responses. Additionally, these files will be collected and managed by a research assistant who is not involved with CON 453/ CNE 453 grading. This research assistant will inform the course administrators who completed the activity, but will not reveal who consented or declined to participate in the research.

If you have any questions concerning the research study, please contact Steven K. Ayer at sayer@asu.edu or 480-727-4579. If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

By completing the pre- and post-activity assessments, you are agreeing to allow your responses to be used for this research. For the process mapping activity, you will be asked to indicate whether or not you want your responses to be included in subsequent data analysis.

Experimental Identification:

First Three (3) letters of Mothers Maiden Name: _______________.
Last Four (4) digits of your phone number: _______________.

PROCESS MAPPING

Please take a few minutes to fill out this survey regarding your knowledge and awareness of BIM Process Mapping.

GENERAL STUDENT INFORMATION

WHAT IS YOUR ACADEMIC YEAR AND WHAT IS YOUR MAJOR:

☐ Freshman ☐ Sophomore ☐ Junior ☐ Senior ☐ Graduate Student

Major _______________________________________

DO YOU HAVE ANY INDUSTRY WORK EXPERIENCE:

☐ Yes ☐ No

ESTIMATE THE NUMBER OF YEARS AND MONTHS THAT YOU HAVE WORKED IN THE BUILDING INDUSTRY:

___________________YEARS ___________________MONTHS

RATE YOUR EXPERIENCE WORKING WITH BIM:

No Experience ☐ ☐ ☐ ☐ ☐ ☐ ☐ Very Experienced

DO YOU HAVE EXPERIENCE CREATING BIM PROCESS MAPS?

☐ Yes ☐ No

If so, please indicate your level of BIM Process Mapping experience

No Experience ☐ ☐ ☐ ☐ ☐ ☐ ☐ Very Experienced

PRE ACTIVITY QUESTIONNAIRE

RATE THE VALUE BIM PROCESS MAPPING ADDS TO THE OVERALL SUCCESS OF THE PROJECT:

No Value ☐ ☐ ☐ ☐ ☐ ☐ ☐ Very High Value

INDICATE YOUR LEVEL OF AGREEMENT WITH THE FOLLOWING STATEMENT: PROCESS MAPPING IMPROVES THE QUALITY OF COMMINICATION REQUIRED TO SUCCESSFULLY EXECUTE A PROJECT

Strongly Disagree ☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Agree

INDICATE YOUR LEVEL OF AGREEMENT WITH THE FOLLLOWOING STATEMENT: THIS PROCESS MAPPING ACTIVITY IMPROVED MY ABILITY TO ORGANIZE PARALLEL AND OVERLAPPING ACTIVITIES:

Strongly Disagree ☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Agree

RATE YOUR OVERALL INTEREST IN UNDERSTANDING BIM PROCESS MAPPING:

No Interest ☐ ☐ ☐ ☐ ☐ ☐ ☐ Strong Interest

RATE YOUR ABILITY TO CREATE A PROCESS MAPPING DIALOG BOX:

No Ability ☐ ☐ ☐ ☐ ☐ ☐ ☐ Extremely High Ability

INDICATE YOUR LEVEL OF AGREEMENT WITH THE FOLLOWING STATEMENT: I AM FULLY PREPARED TO CREATE A LEVEL 1 PROCESS MAP:

Strongly Disagree ☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Agree

INDICATE YOUR LEVEL OF AGREEMENT WITH THE FOLLOWING STATEMENT: I AM FULLY PREPARED TO CREATE A LEVEL 2 PROCESS MAP:

Strongly Disagree ☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Agree

RATE YOUR ABILITY TO ORDER BIM USES IN SEQUENCE:

No Ability ☐ ☐ ☐ ☐ ☐ ☐ ☐ Extremely High Ability

RATE YOUR KNOWLEDGE OF DEFINING INFOMRATION EXCHANGES THAT ARE NEEDED TO LINK BIM USES AND THE RESPONSIBLE PROJECT PARTIES:

No Knowledge ☐ ☐ ☐ ☐ ☐ ☐ ☐ Highly Knowledgeable

RATE YOUR ABILITY TO IDENTIFY RESPONSIBLE PARTIES IN EACH BIM USE:

No Ability ☐ ☐ ☐ ☐ ☐ ☐ ☐ Extremely High Ability

APPENDIX B

POST-ACTIVITY QUESTIONAAIRE

ASU

EMERGING TECHNOLOGIES BIM LAB
660 S COLLEGE AVE
TEMPE, AZ-85281
PH: 480.727.4579

Informed Consent:

By completing the post-activity assessments, you are agreeing to allow your responses to be used for this research.

Experimental Identification:

First Three (3) letters of Mothers Maiden Name: ________________.
Last Four (4) digits of your phone number: ________________.

POST ACTIVITY QUESITONNAIRE

INDICATE YOUR LEVEL OF AGREEMENT WITH THE FOLLOWING STATEMENT: PROCESS MAPPING INFLUENCES THE RESOURCE FORECASTING MODEL SUPPORTING A PROJECT:

Strongly Disagree ☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Agree

INDICATE YOUR LEVEL OF AGREEMENT WITH THE FOLLOWING STATEMENT: THIS PROCESS MAPPING ACTIVITY IMPROVED MY ABILITY TO ORGANIZE PARALLEL AND OVERLAPPING ACTIVITIES:

Strongly Disagree ☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Agree

RATE YOUR ABILITY IDENTIFY RESPONSIBLE PARTIES IN EACH BIM USE:

No Ability ☐ ☐ ☐ ☐ ☐ ☐ ☐ Extremely High Ability

RATE YOUR ABILITY TO ORGANIZE ACTIVITIES IN SEQUENCE:

No Ability ☐ ☐ ☐ ☐ ☐ ☐ ☐ Extremely High Ability

RATE YOUR ABILITY TO CREATE A PROCESS MAPPING DIALOG BOX:

No Ability ☐ ☐ ☐ ☐ ☐ ☐ ☐ Extremely High Ability

EMERGING TECHNOLOGIES BIM LAB
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INDICATE YOUR LEVEL OF AGREEEMENT WITH THE FOLLOWING STATEMENT: I AM FULLY PREPARED TO CREATE A LEVEL 1 PROCESS MAP:

No Ability ☐ ☐ ☐ ☐ ☐ ☐ ☐ Extremely High Ability

INDICATE YOUR LEVEL OF AGREEEMENT WITH THE FOLLOWING STATEMENT: I AM FULLY PREPARED TO CREATE A LEVEL 2 PROCESS MAP:

No Ability ☐ ☐ ☐ ☐ ☐ ☐ ☐ Extremely High Ability

INDICATE THE LEVEL OF ENJOYMENT YOU EXPERIENCED WHILE COMPLETING THIS PROCESS MAPPING ACTIVITY:

No Enjoyment ☐ ☐ ☐ ☐ ☐ ☐ ☐ Highly Enjoyable

RATE YOUR LEVEL OF INTEREST IN FURTHER UNDERSTANDING OF PROCESS MAPPING:

No Interest ☐ ☐ ☐ ☐ ☐ ☐ ☐ Strong Interest

WHICH OF THE FOLLOWING ADDED VALUE IN THE CLASS ACTIVITY TO DEVELOP A PROCESS MAP? MARK ALL THAT APPPLY.

☐ BIM Planning Lecture

☐ Collaboration between three group members

☐ Pre Activity Lecture

☐ Restaurant activity

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TEMPE, AZ-85281
PH: 480.727.4579

WHICH OF THE FOLLOWING SHOULD BE CONSIDERED IN FUTURE FOR A BETTER UNDERSTANDING OF PROCESS MAP? MARK ALL THAT APPLY.

- ☐ BIM Planning Lecture
- ☐ Pre Activity Lecture
- ☐ Restaurant activity
- ☐ Time for the Activity

What did you like most about this process mapping activity?

What did you like least about this process mapping activity?

What suggestions do you have for improving this activity?

Please list any other thoughts you may have related to this activity.

APPENDIX C

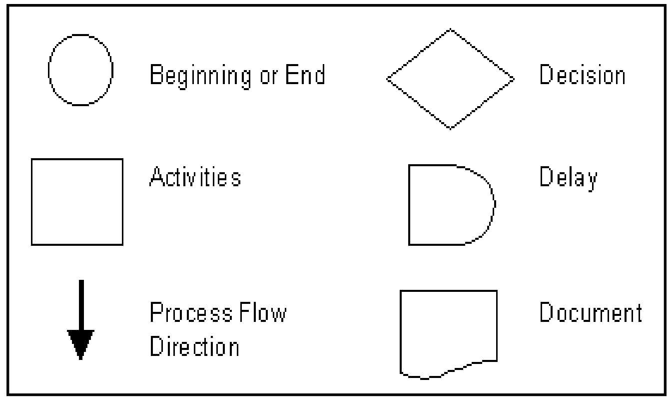
HANDOUT FOR THE CLASS ACTIVITY

CON 453: PROJECT MANAGEMENT I (SPRING-2017)

PROCESS MAPPING ACTIVITY

Introduction

- Process Map is a pictorial representation of a process showing inputs, outputs and steps involved.
- In a process map activities are written in the order of their occurrence (parallel/series).
- A process map can contain one or more swim lanes (In this activity its three, and they are: reference information, process and information exchange)
- A process map is created using Business Process Mapping & Notations (BPMN) symbols.



BPMN Symbols

Information you have

- Project Specifications:
    - Project Name: College Avenue Commons (CAVC)
    - Location: Tempe, Arizona
    - Project Conditions: 140 K sq.ft., Mixed Use
    - Total Project Cost: $55MM
    - Project Duration: 1 year
    - LEED Certification: Gold

Deliverables

- Create a process map:
    - Level 1 process map (high-level BIM uses and how they relate to one another)
    - Level 2 process map for 3D coordination (Detailed BIM use)

Key requirements

- Use BPMN symbols (Minimum 3)
- Acceptable logic in the flow of activities
- Connect all activities
- Include data transfer across the swim lanes
- Mention relevant stake holders

Required BIM Uses:

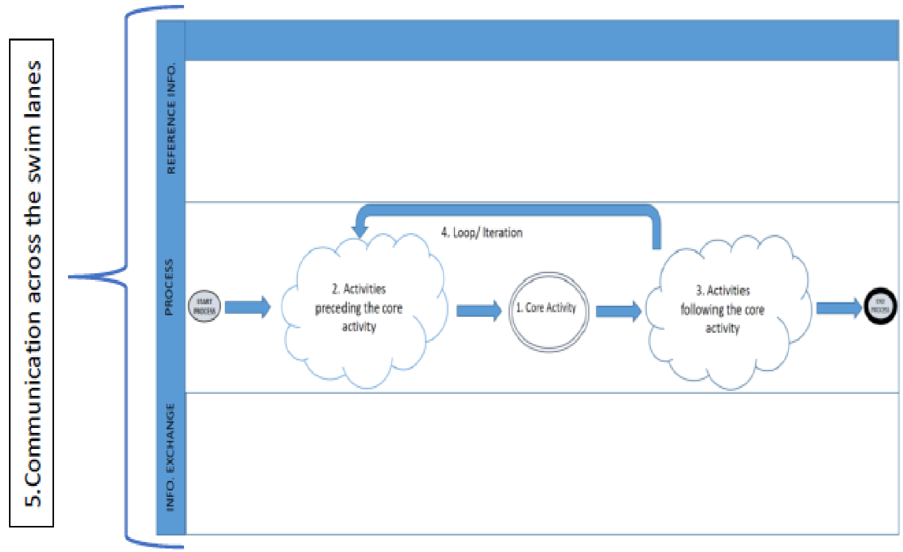
The following BIM Uses have been determined to add value to the CAVC project. You will need to incorporate these into your process maps.

BIM use case	**Definition**	**Value Provided to CAVC Project**
Building Maintenance	A process in which the functionality of the building structure (walls, floors, roof, etc.) and equipment serving the building (mechanical, electrical, plumbing, etc.) are maintained over the operational life of a facility. A successful maintenance program will improve building performance, reduce repairs, and reduce overall maintenance costs.	100% uptime Reduced Total Cost of Ownership (TCO) for the client Keep building operating smoothly to reduce classroom issues, to enable SSEBE research to succeed.
Design Authoring	A process in which 3D software is used to develop a Building Information Model based on criteria that is important to the translation of the building's design. Authoring tools create models while audit and analysis tools study or add to the richness of information in a model	Opportunities to use model for downstream BIM uses, but also for educational uses.
Design Review	A process in which stakeholders view a 3D model and provide their feedbacks to validate multiple design aspects.	Multiple stake holders Arch / MEP / Structural coordination Design Review in coordination with compressed schedule
Phase Planning (4D Modeling)	A process that utilizes an information model to layout facility assemblies or automate control of equipment's movement and location. The information model is used to create detailed control points aid in assembly layout	Directly influenced the ability of the contractor to hit the one-year project duration.
3D Coordination	A process in which Clash Detection software is used during the coordination process to determine field conflicts by comparing 3D models of building systems. The goal of clash detection is to eliminate the major system conflicts prior to installation.	Visible Mechanical, electrical, and plumbing services on 4th and 5th floors. Need flawless coordination. Core Drilling in stair wells

APPENDIX D

GRADING RUBRIC

GRADING RUBRIC



Grading Process:

1. Identify the 5 sections in the process map as per the given classification (refer the figure)

- Core activity: This is the task that needs to occur irrespective of the flow of the process. This is the task that demonstrates the implementation of the process. This task occurs regardless of how companies implement the process. (Example: using clash detection software to identify clashes could be a core task for the BIM use of "3D coordination")
- Activities preceding the core activity: These are the activities that occur before the core task. These activities lead to the core task. These are the pre-requisite activities for the core task.
- Activities following the core activity: These are the activities that occur after the core task. Additional activities depend on the result of core task.
- Loop/Iteration: This refers to the decision point where there is a need to repeat a task/tasks. This can be well demonstrated by showing a loop that goes back to any of the preceding task but some activities imply an iteration even if it is not shown explicitly through an arrow but it can be demonstrated as a separate task.
- Communication across the swim lanes: In process maps with more than 1 swim lane, there is a communication that occurs across the swim lanes.

1. In part 1, rate the **ability of students to demonstrate each section** based on the given criteria.
2. In part 2, rate the **quality of the process for each section** based on the given criteria.
3. In part 3, rate the process map as a single process

Sl. No	CRITERIA	DEMONSTRATION (part1)	QUALITY (part 2)	Overall rating (part 3)
1	Core Activity	A B C D E	A B C D E	A B C D E
2	Activities preceding the core activity	A B C D E	A B C D E	
3	Activities following the core activity	A B C D E	A B C D E	
4	Loop/Iteration	A B C D E	A B C D E	
5	Communication across swim lanes	A B C D E	A B C D E	

Part 1

Sl. No	Criteria	A	B	C	D	E
1	Core task	The core task is identified and mentioned as a single activity.	The core task has been mentioned as a combination of two or more activities.	The core task is mentioned, but with minimum consideration of the contextual factors.	The student demonstrated awareness of the core task but failed to mentioned as a task/s. It is assumed to occur somewhere in the process.	NO DEMONSTRATION
2	Activities preceding the core task	Clear demonstration of student's perception about the activities that occur before core task by considering all relevant contextual factors.	Demonstration of student's perception about the activities by considering most relevant contextual factors.	Demonstration of student's perception about the activities by considering limited contextual factors.	The student demonstrated awareness of this section.	
3	Activities following the core task	Clear demonstration of student's perception about the activities that occur before core task by considering all relevant contextual factors.	Demonstration of student's perception about the activities by considering most relevant contextual factors.	Demonstration of student's perception about the activities by considering limited contextual factors.	The student demonstrated awareness of this section.	
4	Loop/Iteration	An iteration process is included and documented clearly using BPMN notations. The iteration process is clearly demonstrated with BPMN symbols.	An iteration process is included but not documented clearly with BPMN notations. It can be demonstrated as a single task.	An iteration process is demonstrated, but it ignores the contextual factors.	An iteration process is not present anywhere on the process map, but it is assumed to occur somewhere in the process.	
5	Communication across the swim lanes	Communication across swim lanes are included by considering all relevant the contextual factors of the process and it is documented clearly using BPMN notations	Communication across swim lanes are included by considering most of the relevant contextual factors and it is documented clearly using BPMN notations	Communication across swim lanes are included but it ignores the contextual factors.	No clear demonstration, but it is assumed to occur somewhere in the process map.	

Part 2

Sl. No	Criteria	A	B	C	D	E
1	Core task	Mentioning of the core task with a thorough understanding of the context. There is adequate consideration of purpose, context and stakeholders.	Mentioned with an adequate consideration of contextual factors.	Demonstrates awareness about the core task.	Demonstrates an attempt to identify the core task	IRRELEVANT TO THE GIVEN PROCESS
2	Activities preceding the core activity	Activities are demonstrated by using appropriate and relevant content throughout the section and it clearly demonstrates the process to any individual. It is demonstrated in a way that contributes to a further or deeper understanding of each task.	Activities are demonstrated by using appropriate and relevant content through most of the section.	Activities are demonstrated with an awareness about the section.	Demonstrates an attempt to identify activities.	
3	Activities following the core activity	Activities are demonstrated by using appropriate and relevant content and it clearly demonstrates the process to any individual. It is demonstrated in a way that contributes to a further or deeper understanding of each task	Activities are demonstrated by using appropriate and relevant content through most of the section.	Activities are demonstrated with an awareness about the section	Demonstrates an attempt to identify activities.	
4	Loop/Iteration	An iteration process is present to demonstrate the mastery of the subject. It is demonstrated in a manner that addresses thoroughly and deeply the current context.	An iteration process is demonstrated in a manner that addresses required understanding of the process.	An iteration process is demonstrated in a manner that addresses minimal understanding of the process.	Demonstrates an attempt to include iteration process.	
5	Communication across the swim lanes	Communication across swim lanes are included and it demonstrates the process to any individual with clarity and fluency.	Communication across swim lanes are demonstrated to convey the process to any individual.	Communication across swim lanes are demonstrated to convey the process to any individual., although it may contain some errors.	Demonstrates an attempt to include communication across swim lanes	

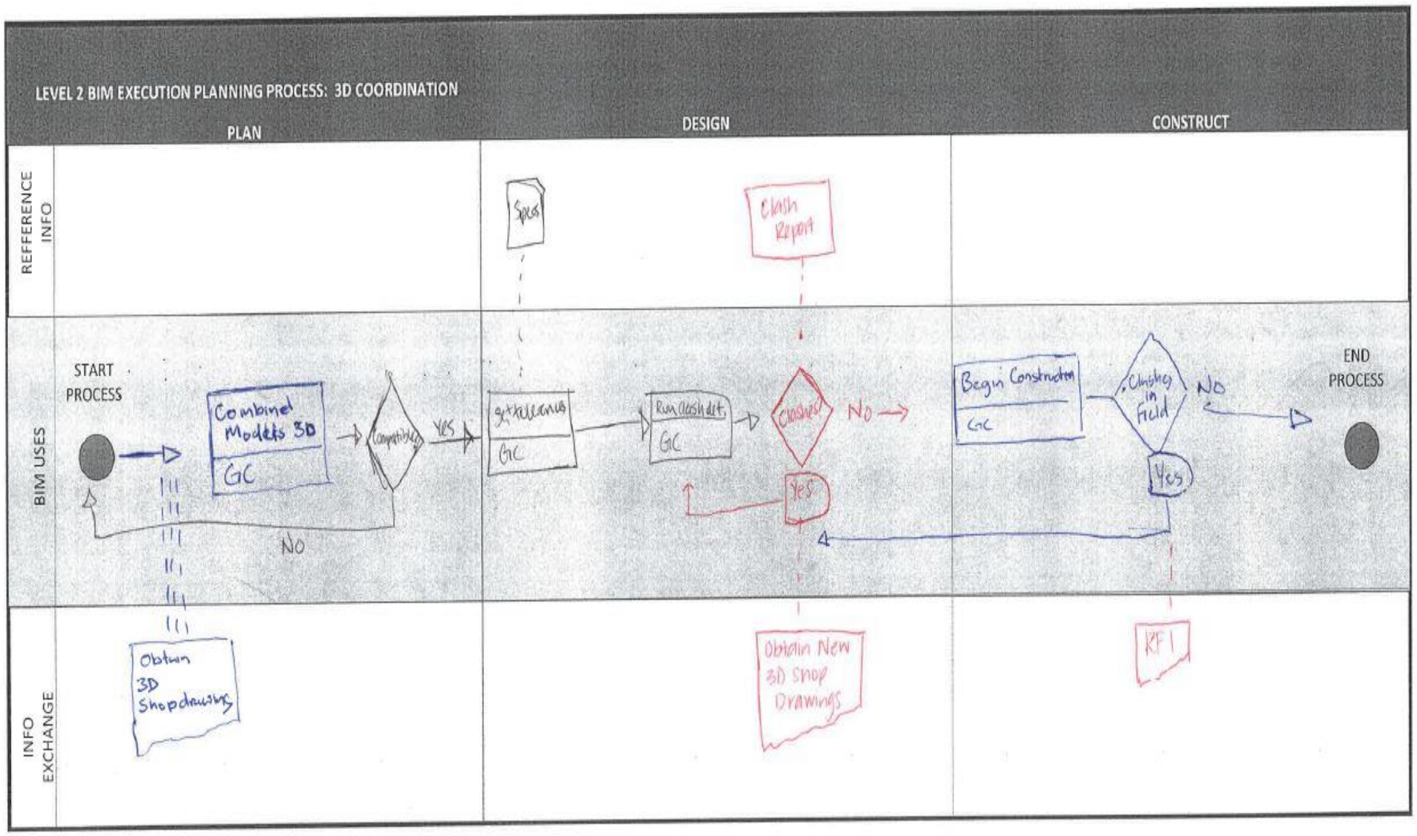
APPENDIX E

SAMPLE PROCESS MAPS DEVELOPED BY STUDENTS(FULL MAPS)

By completing the pre and post activity assessments, you are agreeing to allow your responses to be used for this research.

☐Red ☐Blue ☐Black: I consent to allow my work to be used for research and dissemination purposes

☐Red ☐Blue ☐Black: I do not consent to allow my work to be used for research and dissemination purposes

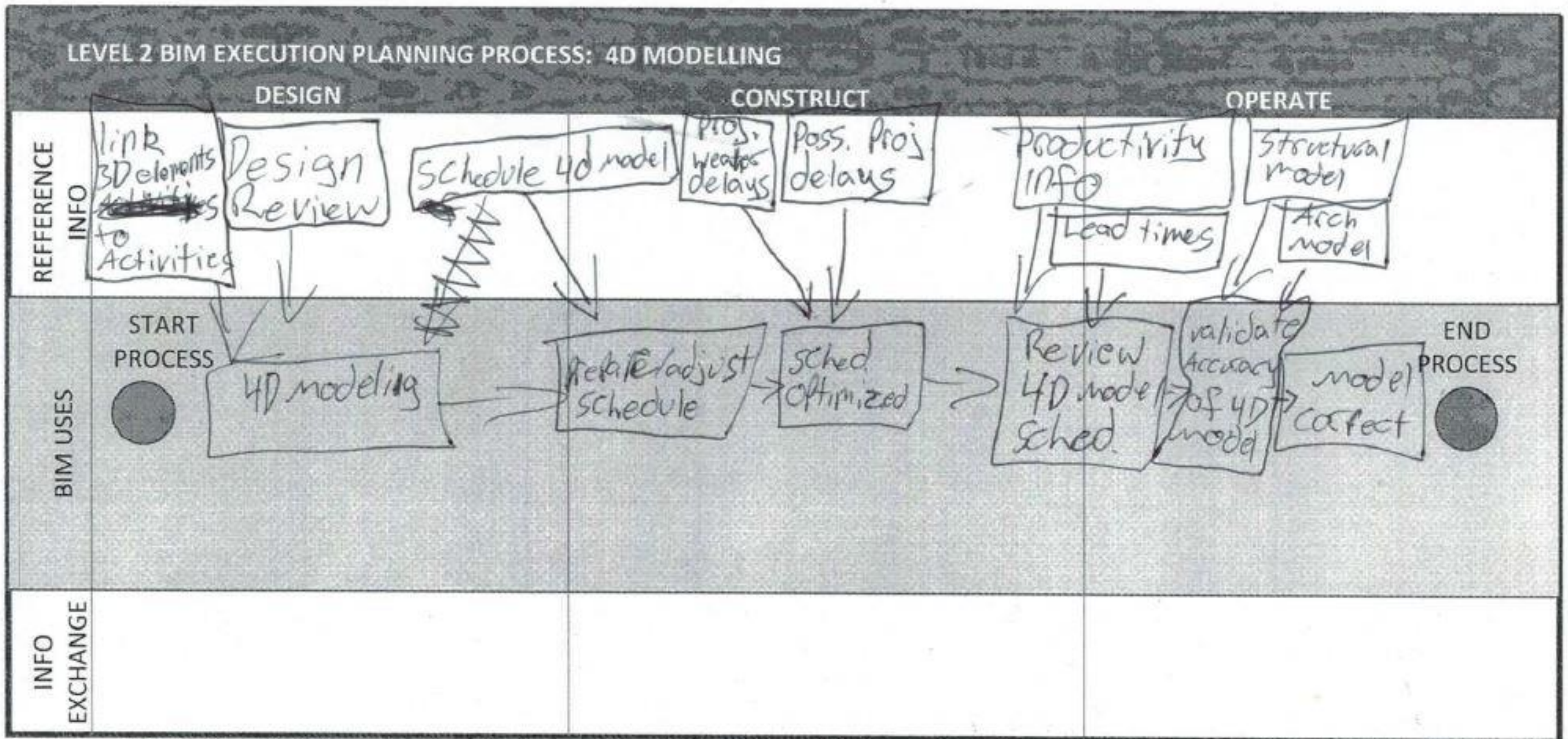


Information Modelling execution planning guide by the Penn State CIC Research

By completing the pre and post activity assessments, you are agreeing to allow your responses to be used for this research.

☒ I consent to allow my work to be used for research and dissemination purposes

☐ I do not consent to allow my work to be used for research and dissemination purposes



Information Modelling execution planning guide by the Penn State CIC Research.

By completing the pre and post activity assessments, you are agreeing to allow your responses to be used for this research.

☑ I consent to allow my work to be used for research and dissemination purposes

☐ I do not consent to allow my work to be used for research and dissemination purposes

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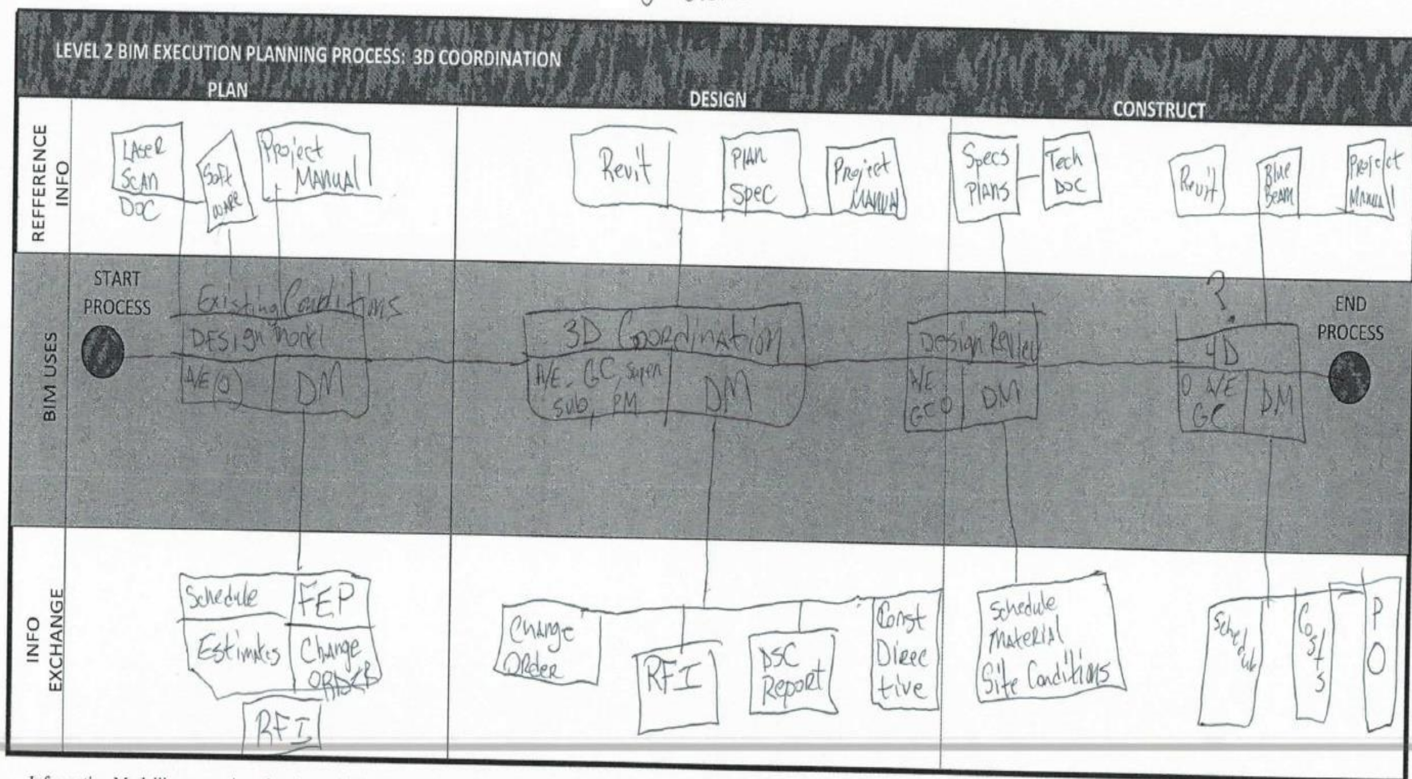

Information Modelling execution planning guide by the Penn State CIC Research

By completing the pre and post activity assessments, you are agreeing to allow your responses to be used for this research.

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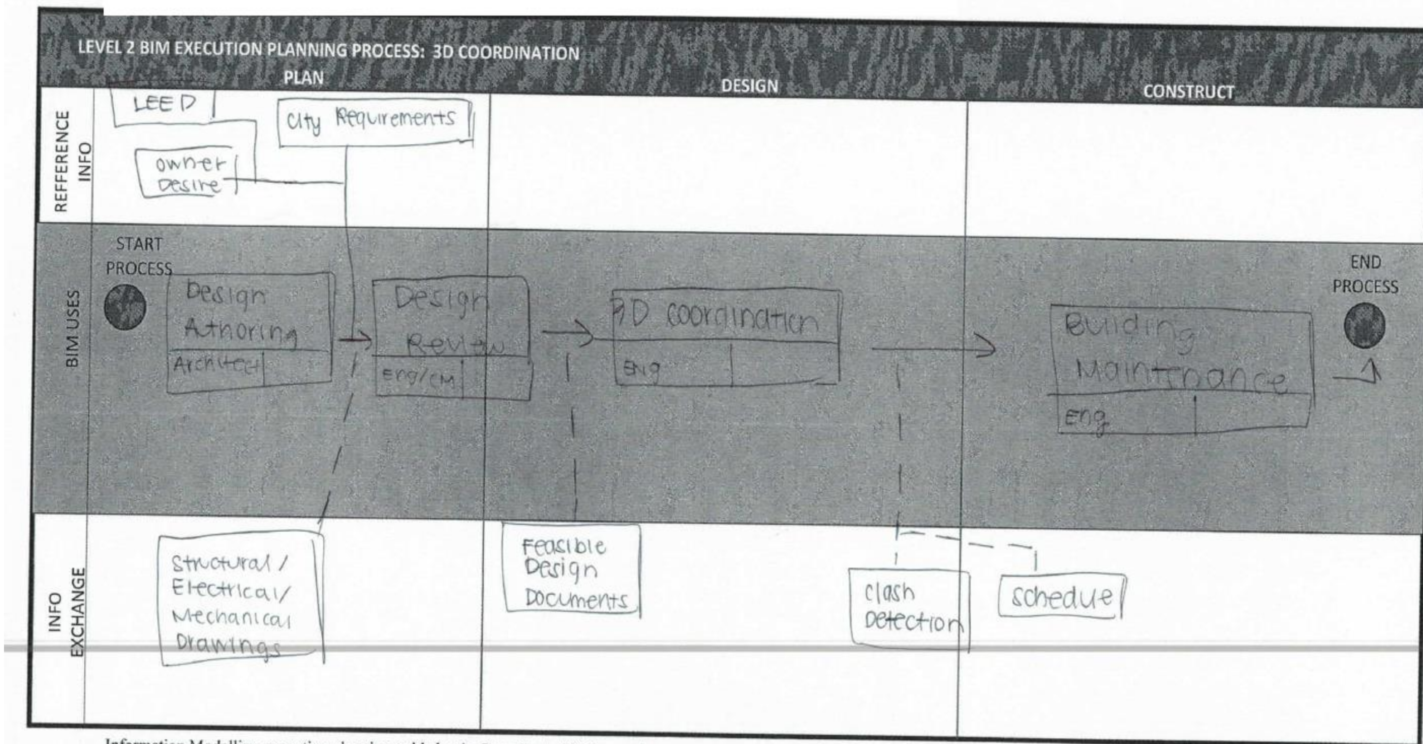

Information Modelling execution planning guide by the Penn State CIC Research.

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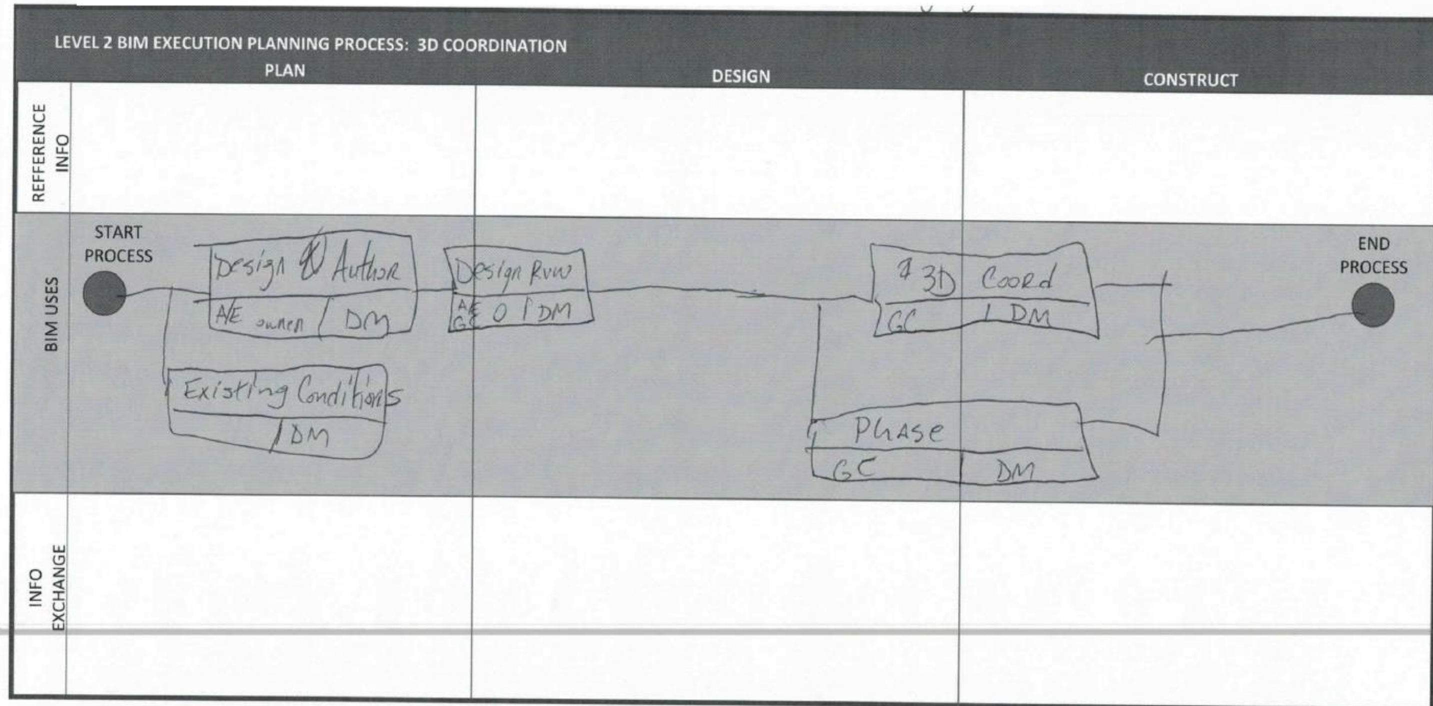
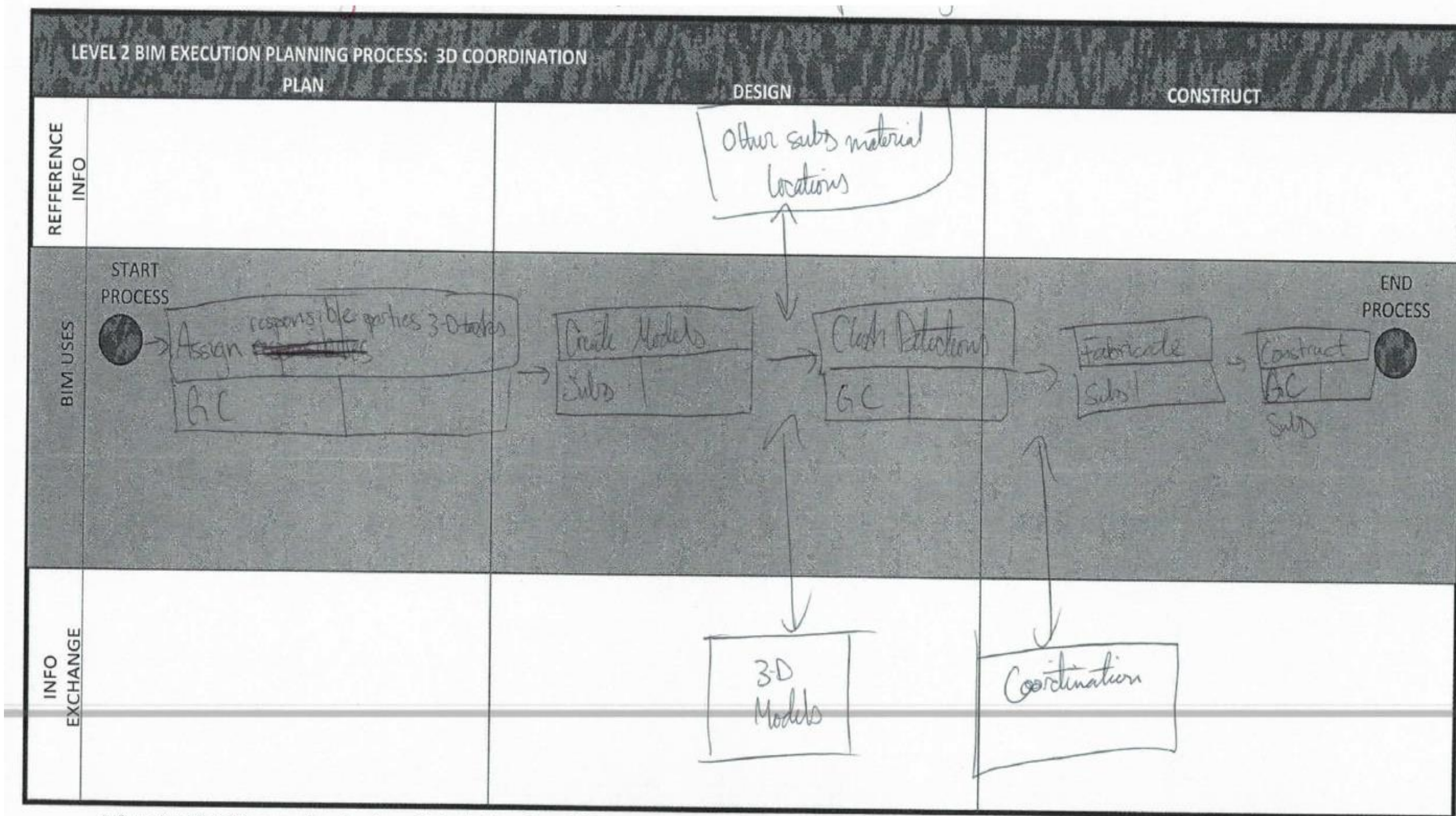


Information Modelling execution planning guide by the Penn State CIC Research.

By completing the pre and post activity assessments, you are agreeing to allow your responses to be used for this research.

☑Red ☑Blue ☐Black: I consent to allow my work to be used for research and dissemination purposes

☐Red ☐Blue ☐Black: I do not consent to allow my work to be used for research and dissemination purposes



Information Modelling execution planning guide by the Penn State CIC Research.

APPENDIX F

DETAILED RUBRIC VALIDATION

Criteria	section	Cohen's Kappa		
		Grader 1 and 2	Grader 2 and 3	Grader 1 and 3
Core Activity	Section 1	0.16	0.16	0.15
	Section 2	-0.15	0.14	-0.25
Activities preceding the core activity	Section 1	0.16	0.46	0.12
	Section 2	0.13	0.17	-0.17
Activities following the core activity	Section 1	0.08	0.45	0.04
	Section 2	-0.07	0.26	-0.2
Loop/Iteration	Section 1	-0.12	0.43	-0.07
	Section 2	-0.14	0.76	-0.10
Communication Across swim lanes	Section 1	-0.26	0.46	0.13
	Section 2	-0.21	0.17	0.32

Grader 1: Faculty Member
Grader 2: Industry Practitioner
Grader 3: Student

APPENDIX G

SAMPLE GRADED RUBRIC

Sl. No	CRITERIA	DEMONSTRATION (part1)	QUALITY (part 2)	Overall rating (part 3)
1	Core Activity	~~A~~ B C D E	A B ~~C~~ D E	A B ~~C~~ D E
2	Activities preceding the core activity	A ~~B~~ C D E	A B ~~C~~ D E	
3	Activities following the core activity	A B ~~C~~ D E	A B ~~C~~ D E	
4	Loop/Iteration	A B ~~C~~ D E	A B ~~C~~ D E	
5	Communication across swim lanes	A B C ~~D~~ E	A B C ~~D~~ E	

APPENDIX H

DETAILED ANALYSIS OF PERCEPTION

Direct Impact	Fall 2015 (%)	Spring 2016 (%)	Fall 2016 (%)	Spring 2017(%)				
				q1	q2	q3	q4	q5
Positive Shift	53	56.6	53.1	57.22	52.5	59.6	61.93	57.13
Neutral	23.5	18.4	25	14.2	28.5	14.2	21.4	26.2
Negative Shift	23.5	25	21.8	28.5	19	26.2	16.67	16.67

APPENDIX I

ANSWERED PRE-AND POST-QUESTIONNAIRES

EMERGING TECHNOLOGIES BIM LAB
660 S COLLEGE AVE
TEMPE, AZ 85281
480.727.4579

Informed Consent:

I am a professor in the Del E. Webb School of Construction in the School of Sustainable Engineering and the Built Environment at Arizona State University. I am conducting a research study to explore how an in-class Building Information Modeling (BIM) process mapping and collaborative activity can improve students' levels of understanding and comfort with planning for BIM in construction.

I am inviting your participation in this research, which will involve completing a pre- and post-activity questionnaire as well as the developed BIM process mapping activity. Each questionnaire will take between 5 and 10 minutes to complete and the process mapping activity will take the remainder of the class time. All students will be required to complete the process mapping activity regardless of whether or not they consent to allowing their data to be used for research. Therefore, this research will not require additional student effort outside of normal class participation.

To participate in this research, you must be a student enrolled in CON 453 / CNE 453 and you also must be 18 years or older. While all students are required to complete the process mapping activity, you have the right to not answer any question on the pre- and post-activity questionnaires. Additionally, you also have the right to not allow your provided responses to the process mapping activity to be used for research purposes, if you choose. Your participation in this research is voluntary. If you choose not to allow your responses to be used for research purposes, there will be no penalty.

The potential benefit to participants in this work is an improved understanding of BIM process mapping. There are no foreseeable risks or discomforts to your participation.

Your responses to the pre- and post-activity questionnaires will be anonymous to allow you to provide candid feedback, which will not be linked to your name. Instead, you will be asked to generate experimental identification by providing the first 3 letters of your mother's maiden name as well as the last four digits of your phone number. This will ensure that the instructors and researchers will not be able to link your pre- and post-activity questionnaire responses with your name, but will be able to understand any changes in your responses before and after completing the process mapping activity.

For the process mapping activity documents created, you will be asked to provide your name and indicate whether or not you are willing to allow your work to be used for research to understand the benefits of this format of education. Any dissemination of findings will not include student names, so you will never be personally linked to any of your responses. Additionally, these files will be collected and managed by a research assistant who is not involved with CON 453/ CNE 453 grading. This research assistant will inform the course administrators who completed the activity, but will not reveal who consented or declined to participate in the research.

If you have any questions concerning the research study, please contact Steven K. Ayer at sayer@asu.edu or 480-727-4579. If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

By completing the pre- and post-activity assessments, you are agreeing to allow your responses to be used for this research. For the process mapping activity, you will be asked to indicate whether or not you want your responses to be included in subsequent data analysis.

Experimental Identification:

First Three (3) letters of Mothers Maiden Name: PAN

Last Four (4) digits of your phone number: 6286

PROCESS MAPPING

Please take a few minutes to fill out this survey regarding your knowledge and awareness of BIM Process Mapping.

GENERAL STUDENT INFORMATION

WHAT IS YOUR ACADEMIC YEAR AND WHAT IS YOUR MAJOR:

☐ Freshman ☐ Sophomore ☐ Junior ☑ Senior ☐ Graduate Student

Major CM

DO YOU HAVE ANY INDUSTRY WORK EXPERIENCE:

☑ Yes ☐ No

ESTIMATE THE NUMBER OF YEARS AND MONTHS THAT YOU HAVE WORKED IN THE BUILDING INDUSTRY:

10 YEARS 4 MONTHS

RATE YOUR EXPERIENCE WORKING WITH BIM:

No Experience ☐ ☐ ☑ ☐ ☐ ☐ ☐ Very Experienced

DO YOU HAVE EXPERIENCE CREATING BIM PROCESS MAPS?

☐ Yes ☑ No

If so, please indicate your level of BIM Process Mapping experience

No Experience ☐ ☐ ☐ ☐ ☐ ☐ ☐ Very Experienced

PRE ACTIVITY QUESTIONNAIRE

RATE THE VALUE BIM PROCESS MAPPING ADDS TO THE OVERALL SUCCESS OF THE PROJECT:

No Value ☐ ☐ ☐ ☑ ☐ ☐ ☐ Very High Value

INDICATE YOUR LEVEL OF AGREEMENT WITH THE FOLLOWING STATEMENT: PROCESS MAPPING IMPROVES THE QUALITY OF COMMINICATION REQUIRED TO SUCCESSFULLY EXECUTE A PROJECT

Strongly Disagree ☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Agree

INDICATE YOUR LEVEL OF AGREEMENT WITH THE FOLLLOWOING STATEMENT: THIS PROCESS MAPPING ACTIVITY IMPROVED MY ABILITY TO ORGANIZE PARALLEL AND OVERLAPPING ACTIVITIES:

Strongly Disagree ☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Agree

RATE YOUR OVERALL INTEREST IN UNDERSTANDING BIM PROCESS MAPPING:

No Interest ☐ ☐ ☐ ☐ ☐ ☐ ☐ Strong Interest

RATE YOUR ABILITY TO CREATE A PROCESS MAPPING DIALOG BOX:

No Ability ☐ ☐ ☐ ☐ ☐ ☐ ☐ Extremely High Ability

INDICATE YOUR LEVEL OF AGREEMENT WITH THE FOLLOWING STATEMENT: I AM FULLY PREPARED TO CREATE A LEVEL 1 PROCESS MAP:

Strongly Disagree ☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Agree

INDICATE YOUR LEVEL OF AGREEMENT WITH THE FOLLOWING STATEMENT: I AM FULLY PREPARED TO CREATE A LEVEL 2 PROCESS MAP:

Strongly Disagree ☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Agree

RATE YOUR ABILITY TO ORDER BIM USES IN SEQUENCE:

No Ability ☐ ☐ ☐ ☐ ☐ ☐ ☐ Extremely High Ability

RATE YOUR KNOWLEDGE OF DEFINING INFOMRATION EXCHANGES THAT ARE NEEDED TO LINK BIM USES AND THE RESPONSIBLE PROJECT PARTIES:

No Knowledge ☐ ☐ ☐ ☐ ☐ ☐ ☐ Highly Knowledgeable

RATE YOUR ABILITY TO IDENTIFY RESPONSIBLE PARTIES IN EACH BIM USE:

No Ability ☐ ☐ ☐ ☐ ☐ ☐ ☐ Extremely High Ability

ASU

EMERGING TECHNOLOGIES BIM LAB
660 S COLLEGE AVE
TEMPE, AZ-85281
PH: 480.727.4579

Informed Consent:

By completing the post-activity assessments, you are agreeing to allow your responses to be used for this research.

Experimental Identification:

First Three (3) letters of Mothers Maiden Name: RAV
Last Four (4) digits of your phone number: 9004

POST ACTIVITY QUESITONNAIRE

INDICATE YOUR LEVEL OF AGREEMENT WITH THE FOLLOWING STATEMENT: PROCESS MAPPING INFLUENCES THE RESOURCE FORECASTING MODEL SUPPORTING A PROJECT:

Strongly Disagree ☐ ☐ ☐ ☒ ☐ ☐ ☐ Strongly Agree

INDICATE YOUR LEVEL OF AGREEMENT WITH THE FOLLOWING STATEMENT: THIS PROCESS MAPPING ACTIVITY IMPROVED MY ABILITY TO ORGANIZE PARALLEL AND OVERLAPPING ACTIVITIES:

Strongly Disagree ☐ ☐ ☐ ☒ ☐ ☐ ☐ Strongly Agree

RATE YOUR ABILITY IDENTIFY RESPONSIBLE PARTIES IN EACH BIM USE:

No Ability ☐ ☐ ☐ ☐ ☒ ☐ ☐ Extremely High Ability

RATE YOUR ABILITY TO ORGANIZE ACTIVITIES IN SEQUENCE:

No Ability ☐ ☐ ☐ ☒ ☐ ☐ ☐ Extremely High Ability

RATE YOUR ABILITY TO CREATE A PROCESS MAPPING DIALOG BOX:

No Ability ☐ ☐ ☐ ☐ ☒ ☐ ☐ Extremely High Ability

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INDICATE YOUR LEVEL OF AGREEEMENT WITH THE FOLLOWING STATEMENT: I AM FULLY PREPARED TO CREATE A LEVEL 1 PROCESS MAP:

No Ability ☐ ☐ ☐ ☒ ☐ ☐ ☐ Extremely High Ability

INDICATE YOUR LEVEL OF AGREEEMENT WITH THE FOLLOWING STATEMENT: I AM FULLY PREPARED TO CREATE A LEVEL 2 PROCESS MAP:

No Ability ☐ ☐ ☒ ☐ ☐ ☐ ☐ Extremely High Ability

INDICATE THE LEVEL OF ENJOYMENT YOU EXPERIENCED WHILE COMPLETING THIS PROCESS MAPPING ACTIVITY:

No Enjoyment ☐ ☐ ☒ ☐ ☐ ☐ ☐ Highly Enjoyable

RATE YOUR LEVEL OF INTEREST IN FURTHER UNDERSTANDING OF PROCESS MAPPING:

No Interest ☐ ☐ ☐ ☒ ☐ ☐ ☐ Strong Interest

WHICH OF THE FOLLOWING ADDED VALUE IN THE CLASS ACTIVITY TO DEVELOP A PROCESS MAP? MARK ALL THAT APPPLY.

☒ BIM Planning Lecture

☐ Collaboration between three group members

☒ Pre Activity Lecture

☐ Restaurant activity

ASU

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WHICH OF THE FOLLOWING SHOULD BE CONSIDERED IN FUTURE FOR A BETTER UNDERSTANDING OF PROCESS MAP? MARK ALL THAT APPLY.

- ☐ BIM Planning Lecture
- ☐ Pre Activity Lecture
- ☒ Restaurant activity
- ☒ Time for the Activity

What did you like **most** about this process mapping activity?

LECTURE

What did you like **least** about this process mapping activity?

UNCLEAR

What suggestions do you have for improving this activity?

MORE INFO

Please list any other thoughts you may have related to this activity.

APPENDIX J

GRADES FOR CLASS PROJECT

Grade	Fall 2015(%)	Spring 2016(%)	Fall 2016(%)	Spring 2017(%)
A	75	30	64.4	69.2
B	0	7	7.1	0
C	8	30.2	7.1	7.7
D	0	16	7.1	7.7
E	16.67	16	14.2	15.4