



Student Experiences and Perceptions on the Evolving Nature of Digital Tools in the Architecture Classroom

Ms. Shahnaz J. Aly, Western Kentucky University

Shahnaz Aly, OAA, LEED AP, M. Arch, is a licensed Architect in India and Canada and Assistant Professor in the Department of Architectural and Manufacturing Sciences at Western Kentucky University. She has 10 years professional experience in the architecture and construction industry in residential, commercial and mixed-use projects. She has 5 years of experience in teaching and research in areas of architectural design, sustainable design, historic preservation and BIM.

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Introduction

Drawings and physical models are the means of communication for students and professionals of architecture. Conceptualization of ideas is one of the first steps in the design process; during this phase designers and architects in consultation with project stakeholders work on initial concepts for the project and create powerful imagery, drawings and models; either physical or virtual or a combination of both. Architects present all of the work done during this phase to the client and once the design concept has been finalized and approved, architects proceed to complete design development and construction documents for the project. Traditionally hand drawings were the primary means for “design ideation” [1] and for the creation of construction drawings. While hand drawings and sketching are still considered very important for conveying design ideas, with the advent of computer-aided design (CAD) tools in the late 1980s the focus shifted away from hand drawing to the use of CAD for two-dimensional (2D) drawing. Now a days it is impossible to conceive of an architectural practice where CAD tools are not used right from initial design conceptualization to the creation of construction drawings for a given project. Architecture schools have incorporated into their program curricula, the use of digital tools, for 2D drafting as well as for the generation of three-dimensional (3D) models. While the early 2000s saw the use of AutoCAD (ACAD), SketchUp, 3D Max and rendering tools, in recent time the use of BIM has grown in the fields of architecture, construction and engineering. BIM encompasses, not just the creation of the 3D model that focusses on visual aspects, but seamlessly builds an information laden model that can be shared with and used by the designer, engineer and contractor to build and add relevant information, contributing towards the completion of the model in its entirety and enabling coordination among all partners in a project.

In the Architectural Documentation II class, a core course of the Architectural Science (AS) program at Western Kentucky University, the faculty of the course has noticed a shift in the use of digital tools by students. When the course was first introduced in 2008 students used ACAD in order to create the required drawings but since then students have moved away from CAD tools to BIM based tools for creating designs as well as construction documents. In the fall 2014 documentation class, a number of students used BIM based tools. While some of the students had formal training in BIM, a large number of students were self-taught. This posed unique challenges for the students and the faculty alike. It was observed that a number of students used these tools merely to generate 3D models and did not utilize the full potential of BIM.

Students were surveyed about the tools they used for the documentation class and the reasons for using them. The students who used BIM were further asked about the perceived advantages to using BIM tools as well as the major problems they faced. This paper will discuss the current trend in the application of digital drawing tools available to students, the shifting trend from the use of 2D CAD based tools to BIM tools and will investigate the question of students utilizing the full potential of available digital tools. The paper will also highlight student perceptions as well as the end product generated in the course and challenges faced by both the students and faculty alike.

From Hand Drawing to CAD to BIM

Architects and designers use various methods and techniques to deliver drawings to clients and contractors. Typically these are a combination of analog and digital tools; the analog being hand drawings and sketches using mediums of pencils, markers and water colors among others while the digital tools encompass SketchUp, CAD, BIM, 3DS MAX, Photoshop and other available visualization tools. Drawing with hand was once the only way through which design ideas were generated and conveyed to the client. Hand drawings were also used for creating required construction drawings. But this wasn't the case till the Renaissance period. According to Pérez-Gómez and Pelletier prior to Renaissance, architectural drawings were rare, the practice was mostly "constructive" and construction was carried out through well-established traditions and geometry that was applied directly on-site [2]. The renaissance period saw the invention of the linear perspective and its widespread use by artists in drawings and paintings [2] which contributed to the development of early engineering drawings that were more often works of art. More formalized engineering drawings which relied on the T-square, triangles, scales and drawings instruments began to evolve in the "late 18th century and picked up speed with the Industrial Revolution of the 19th century" [3]. While computer development began in the 1940s, the CAD industry began to take shape in the 1960s [3], [4]. The use of CAD became widespread in architectural practice in the 1990s. Initially CAD was mainly used for 2D drafting, "emulating traditional hand drafting practices" [3] while at the same time enabling editing and revisions of drawings without the need to redo the entire drawing [5]. With advancements in research in industry as well as universities CAD evolved to 3D using wireframe geometry [3]. The widespread use of CAD in industry has led to training in CAD tools becoming an integral part of architecture and engineering curricula.

According to Andia, computers affected architectural education in five distinct ways that were interrelated, but divergent at the same time [6]. The first one called "design methods" [6] focused on the creation of software that changed the way traditional design occurred. The second "CAD visualization" [6] involved utilizing CAD more as a visualization tool and is one that is predominantly used across architecture schools. The third termed by Andia as "paperless architecture" [6] where architecture schools in design studios started to use digital tools enhanced by high-end rendering software to create complex designs and solve problems encountered instantaneously thereby eliminating the use of paper. Professionals dismissed this as "eye candy", where the realized designs were unbuildable [6]. The fourth and fifth paradigms were focused on developing architectural professionals that delved into and conducted extensive research on CAD and digital media; the latter (virtual studios) enabled collaboration between different architecture schools that were geographically distant as well as the involvement of professionals in architecture education through virtual communication.

Since the early 2000s there has been a rapid movement from CAD to BIM in the architecture, engineering and construction (AEC) industry. BIM is a paradigm shift, a new way of collaboration and sharing of information between the various stakeholders during an architectural project. In a recent survey directed at accredited architecture, architectural engineering, and engineering programs it was found that schools of architecture and accredited architectural engineering programs have been quicker to adopt BIM courses in their curriculum than engineering programs [7]. Students are not only acquiring the requisite knowledge about BIM but are now utilizing BIM tools in a number of courses. The survey also found that even though a number of architecture schools had adopted BIM in their curriculum there were still

other architecture programs that expected their students to acquire BIM skills by themselves. The survey also indicated that engineering programs introduced BIM in the freshman and sophomore years while architecture programs typically introduced BIM when students were of more senior standing in the program [7].

The Technology Trends & Innovation Survey report published by Design Intelligence for 2014 highlighted the trends on digital tools and the use of BIM in the AEC industry. The majority of respondents of the survey were architectural firms. ACAD was the most used digital tool among the respondents with 75% of the firms surveyed using it. This was followed by SketchUp with 71% and REVIT Architecture being the next most used digital tool with 69% of respondents using the software. According to the survey the number of firms using BIM had grown from 65% in 2011 to 72% in 2014. In 87% of firms who responded to the survey architects drove the decision to use BIM. The aspects of BIM most utilized by respondents included creation of the 3D model for visualization and conceptual design, creation of contract documents, clash detection and detailed modeling. Firms surveyed indicated that the use of BIM had increased project coordination, document quality and communication, accuracy of construction and decreased errors and change orders to name a few [8].

Curriculum in the Architectural Science Program

The Architectural Science (AS) program in the Department of Architectural and Manufacturing Sciences at Western Kentucky University is a four year program. The program “is a bridge between design theory and construction practice” [9]. “The program in Architectural Science is designed to provide graduates with a practical architectural education combining an understanding of the philosophy of building design with an applied technical knowledge of construction systems and materials” [9]. The program offers core courses in drafting, design, visualization, construction documentation and construction methods and materials. One of the mainstays of the AS program in the AMS department is a series of documentation courses that is offered right from the freshman level. The first course in the sequence is AMS 163; Architectural Drafting, where students are taught architectural projections, dimensioning and modeling using both hand sketching as well as AutoCAD (ACAD) [10], this course is taken by students in their freshman year and it here that they are introduced to computer-aided drafting (CAD). AMS 163 is followed by AMS 263; Architectural Documentation I, where students plan and create construction drawings for a residential structure [11]. AMS 273; Architectural detailing, follows AMS 263 focusses on details for buildings in terms of function, contractibility, and aesthetics [12]. This course helps students tie in the intricate details associated with the residential and commercial structures that student are exposed to in the curriculum. The final required course in the sequence is AMS 363; Architectural Documentation II. In this course students plan and create construction drawings for a simple commercial building [13]. AMS 463; Architectural Documentation III is an elective course in which students plan and create construction documents for the rehabilitation of existing structures.

The sequence of courses discussed above give students not only a strong foundation to tackle different building typologies but also training and extensive exposure to CAD tools. There are two aspects to the three documentation courses AMS 263, AMS 363 and AMS 463; designing the structure and creation of construction drawings. Students use a combination of hand drawings and digital tools during the documentation courses; hand drawings and SketchUp are typically used in the design phase while ACAD is used for the creation of construction drawings. Since

2008 when the documentation courses were first offered, the preferred tool for creating hard lined drawings had been AutoCAD. This was mainly due to the fact that students were trained in CAD tools right from their freshman year. BIM till recently was taught as an elective course in the AS program with Autodesk REVIT being the platform for the course. Content of the course includes BIM concepts, creation of the information laden 3D model and generation of construction drawings from the 3D model. The course had a low enrollment initially, which has since increased due to student awareness of the advantages and the industry trend regarding BIM and is now a required course in the program.

AMS 363-Objectives and Tools

In AMS 363; Architectural Documentation II students are introduced to commercial building design and construction typology. During the semester students' work on designing and creating construction drawings for a commercial facility typically having an area between 18,000-20,000 square feet. They are provided a program and site for the facility, the program includes mercantile and business spaces on the first level and the second level consists entirely of business spaces. The primary reason for a two story project is that students understand the elements of vertical circulation. Students are taught about building codes related to a commercial facility, construction typology and materials appropriate for a commercial building along with the required construction drawings. The semester begins with the design of the facility which takes about two weeks during this time they are introduced to relevant zoning regulations and building codes. Following this they determine construction type and appropriate structure for the facility. The project then moves into design development/ construction drawings during which students create site improvement plans, floor plans and reflected ceiling plans, flooring plans, elevations, sections, details (stairs, elevator and washroom), schedules, code compliance drawings and a cover sheet. The construction drawings contain appropriate room sizes, corridor and stair widths, door sizes, wall types, structural elements, annotation among other requirements. Figure 1 & 2 show examples of student work created in AMS 363.

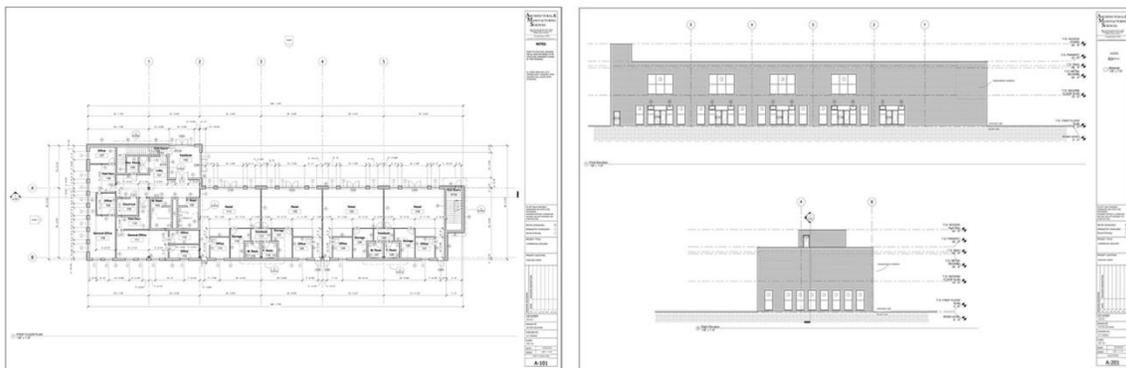


Figure 1: Construction Drawings of floor plans and elevations

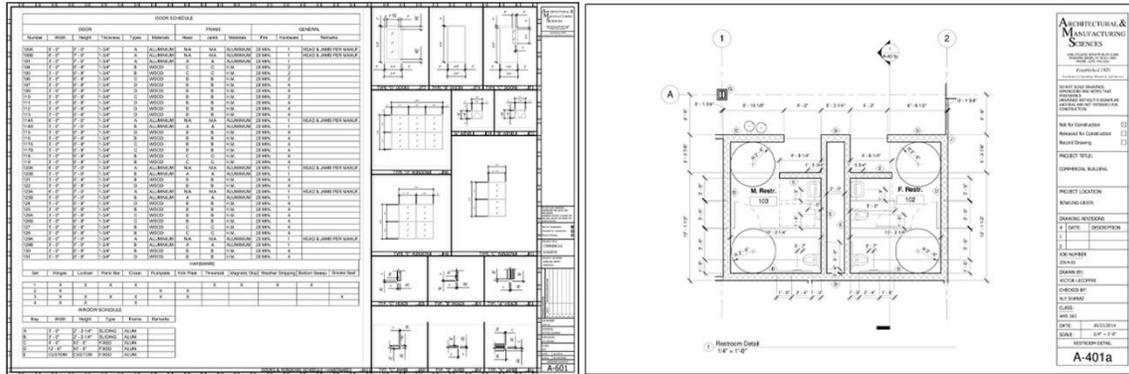


Figure 2: Construction Drawings of schedules and details

Knowledge of digital drawing tools is a pre-requisite for AMS 363 and hence students are not instructed on these tools during the course. AMS 363 was first offered in 2008; shortly after the faculty noticed a shift in the use of digital tools in the classroom; students began using BIM based tools for the creation of construction drawings for assigned projects. Initially of the 20 students in the course only a handful of students used BIM tools, but in the fall of 2014 (when the course was last offered) the faculty noted that this ratio had shifted with the number of students using ACAD and BIM for the creation of construction drawings for assigned projects becoming almost about the same. With students wanting to use and using BIM based tools in AMS 363 primarily to generate 2D drawings from the 3D model, the faculty encountered a new challenge: during class meeting questions were not limited to just core course content but were also about using the REVIT platform.

Even though AMS 363 underscores a design focus rather than a focus on digital tools the challenge posed to faculty (discussed above) demanded that the faculty examine the underlying reasons for the problems encountered by students in using advanced digital tools in the course. A questionnaire was sent out to students who had taken AMS 363 in the fall of 2012, 2013 and 2014 and spring 2013. 34 students responded and provided feedback. The questionnaire consisted of two major components; the initial portion explored the general level of knowledge of available digital tools, querying whether students had received formal training in the use of different digital tools and the courses towards which these tools were applied. The second specifically focused on AMS 363 and the tools students used during the course to create construction drawings for the project. There were specific questions directed to students who used ACAD or BIM or a combination of the two tools. Students were queried on the different aspects of BIM to gain an insight about the familiarity and level of comfort exhibited by students in these areas.

Results and Discussion

Students were asked about the digital tools that they were familiar with and the tools that they used on a regular basis in technical courses and design studios. As seen in figure 3 the first column for each digital tool indicates familiarity with the digital tools, the second column indicates the usage of the tool by the students in technical courses and the third column indicates the usage of digital tools in design studios. AutoCAD, REVIT and SketchUp were the tools that students were most familiar with and the most used in courses.

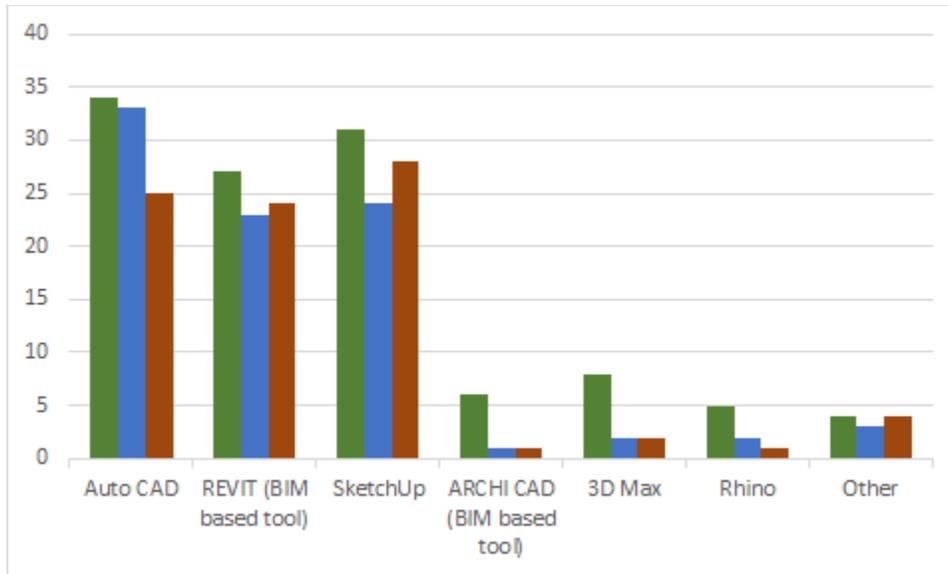


Figure 3: Digital tools used by students in the Architectural Science Program (Y-axis indicates student count)

Since architectural drafting is taught at the freshman level most respondents had formal training in ACAD while about 50% had taken the BIM course. Students who had not taken the BIM course but still used BIM in other courses in the major were self-taught relying on you tube videos, tutorials, and colleagues in the AS program for help and guidance as seen in figure 4.

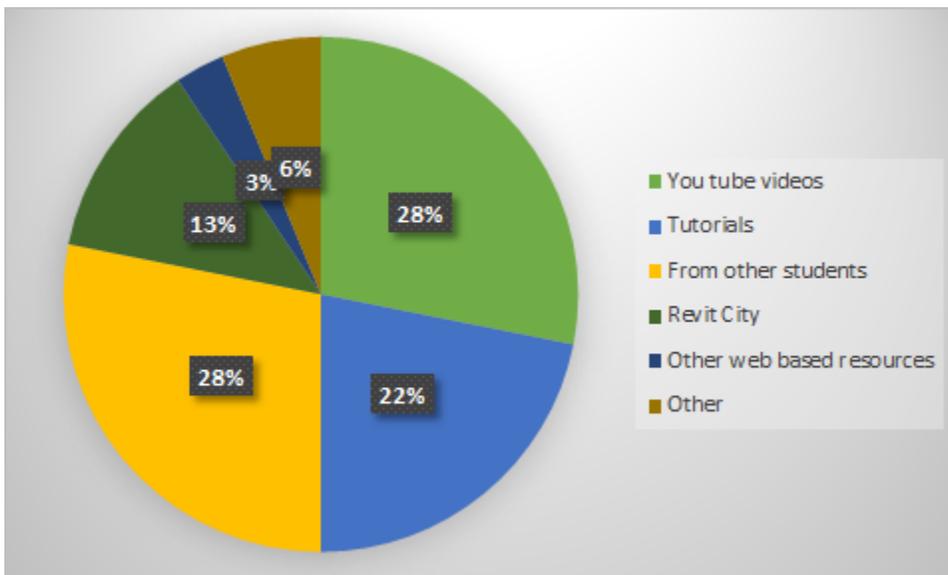


Figure 4: Sources used by students who had not taken the BIM course to learn BIM based tools

Students were queried about their knowledge of different aspects of BIM; these included 3D modeling, scheduling, cost and facilities management. Figure 5 shows student proficiency in various aspects of BIM; as indicated in the graph students were most proficient in the 3D modeling aspect of BIM. While students had some knowledge of scheduling using BIM, a majority of them had no knowledge of the cost and facilities management aspect of BIM.

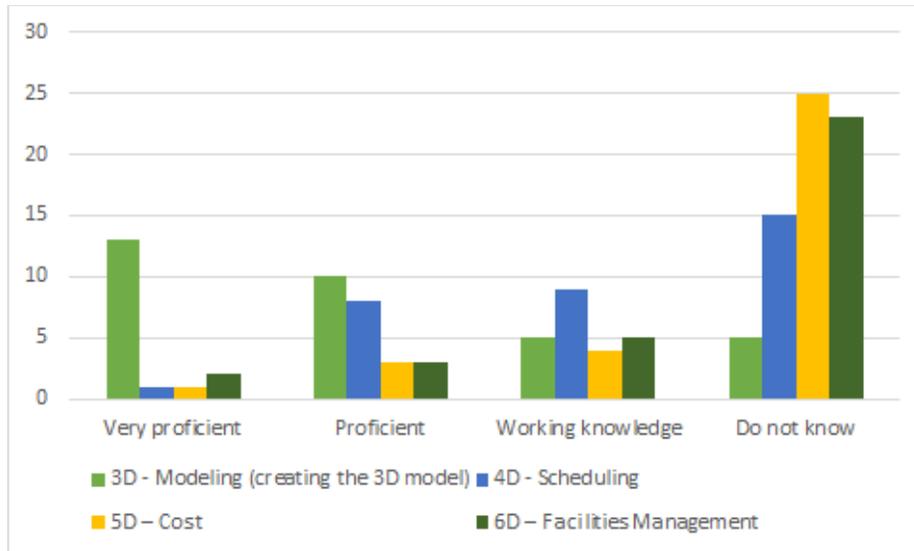


Figure 5: Proficiency of students in various aspects of BIM

The second part of the questionnaire focused in particular on the AMS 363 course. Figure 6 shows the semesters during which students who responded to the questionnaire took the course.

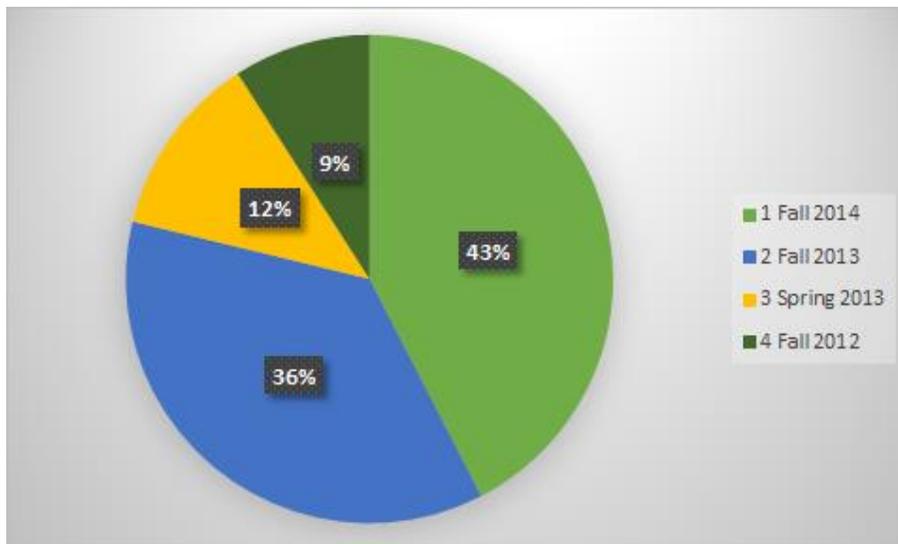


Figure 6: Semester during which students took AMS 363

Over the course of the last few semesters, 22 students used ACAD to create construction drawings for the course, 9 students used REVIT and 2 used a combination of ACAD and REVIT. Students who used ACAD in AMS 363 for the creation of construction drawings did so as they were proficient with the specific digital tool, had used it in a number of other courses and wanted to keep improving their proficiency in ACAD. Reasons for using ACAD can be seen in figure 7. Students who used REVIT primarily did so due to the ease of creating the model, rectifying mistakes and the ease of generating 2D drawings. Only a small percentage of students were of the opinion that it was easy to create schedules for the project in REVIT. Results of the question (reasons for using REVIT) can be seen in figure 8. Most of the students who did not use REVIT

to create the construction drawings for AMS 363 said that since they had not taken the REVIT course, they did not feel comfortable using it in the documentation course.

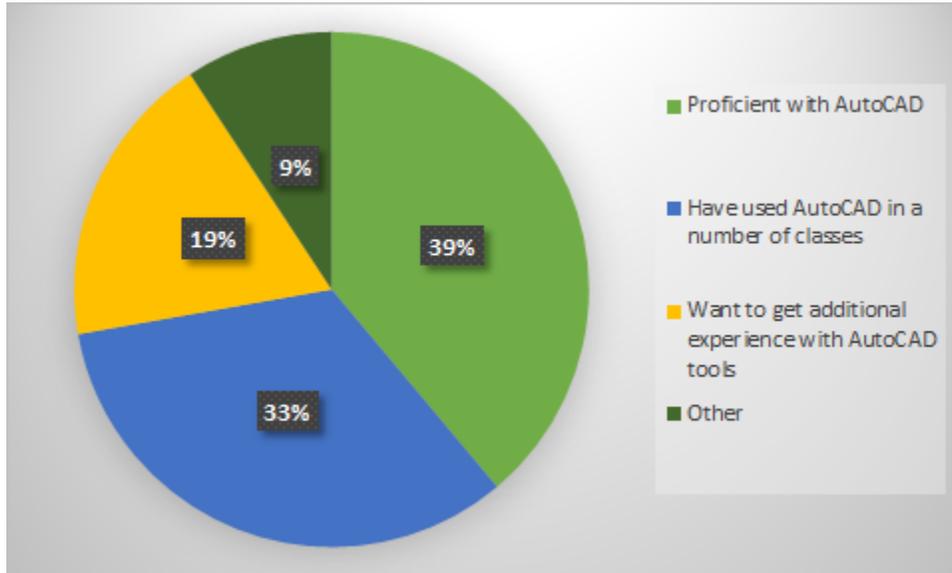


Figure 7: Justification for using ACAD in AMS 363

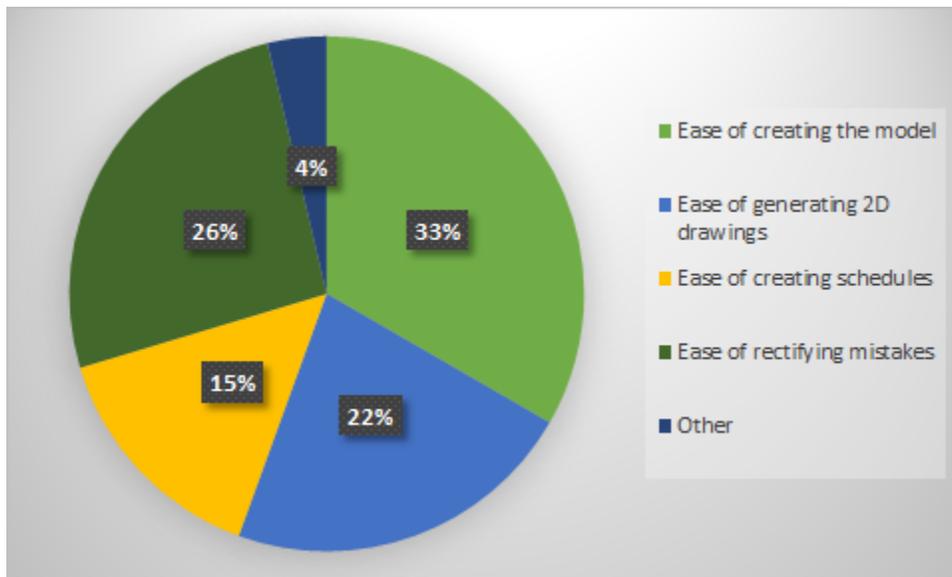


Figure 8: Justification for using REVIT in AMS 363

Students who used REVIT were also asked about the difficulties they experienced while using the digital tool in AMS 363. Figure 9 shows the various areas where students experienced difficulties. A number of students had difficulty with modeling complex forms and custom objects and about 17% of students experienced difficulty in generating schedules. Additionally, since in the AMS 363 course students design and generate construction drawings simultaneously, at times they did not have sufficient data to input into their models.

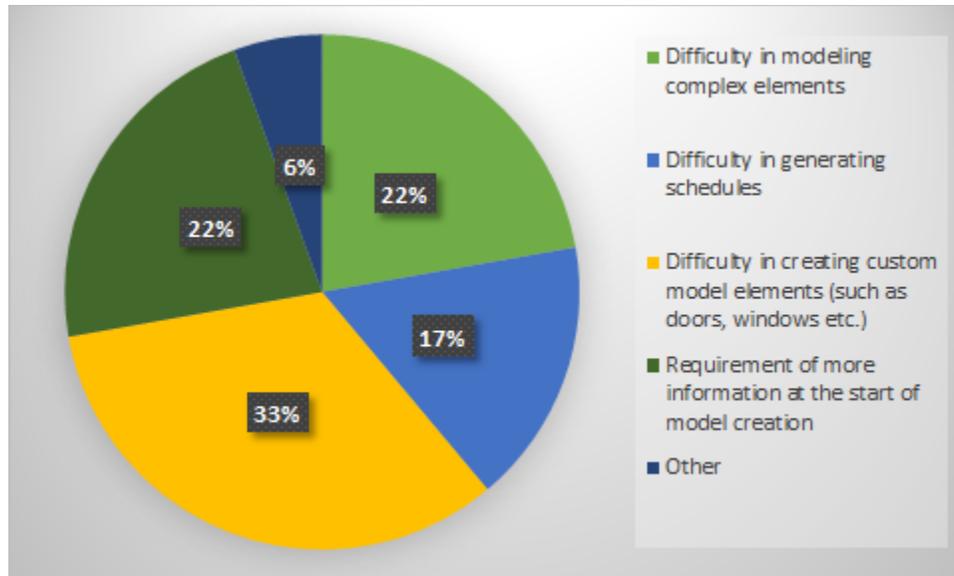


Figure 9: Difficulties encountered by students using REVIT in AMS 363

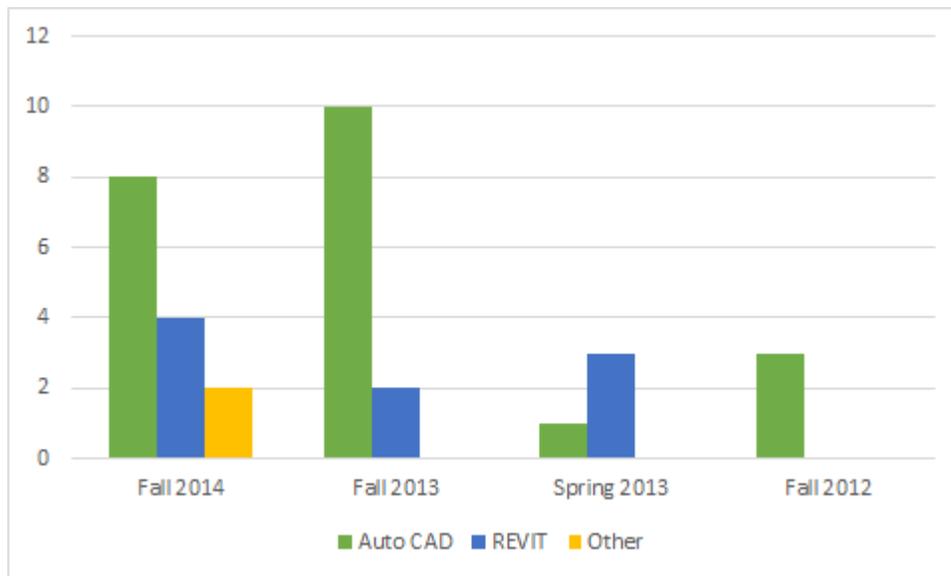


Figure 10: Use of BIM based tools in AMS 363 in different semesters

The faculty further analyzed the responses received by the students to find trends in the use of BIM tools in the architectural documentation course. From figure 10 it can be seen that in fall 2012 all students used ACAD for creating construction drawings, in spring 2013 the data suggests that more students used REVIT than ACAD, but it needs to be noted that of the 20 students who took the documentation course that semester only 4 students responded to the questionnaire and of the 4 students 3 used REVIT and 1 ACAD. In fall 2013 more students began to use REVIT for creation of construction documents and this number increased once again in fall 2014. Some of the students who took the course in fall 2014 used both REVIT and ACAD to create the construction drawings which is indicated under “Other” in figure 10.

Conclusion

Two broad conclusions can be drawn from the data gathered; one related to the AMS 363 course and the other moving beyond to the BIM course offered in the AS program.

The data collected points towards ACAD, BIM and SketchUp as the digital tools most widely used by students in the AS program. Students are introduced to ACAD and SketchUp early on in the program, as a result they are most familiar and comfortable in using these two tools in technical and design studios. In the AS curriculum REVIT is the platform for BIM based tools and students usually take the BIM course in their junior or senior year. As highlighted by Becerik-Gerber, Gerber and Ku in their survey of accredited architecture and engineering schools, architecture schools introduce BIM in upper level classes as compared to engineering schools which introduce BIM in lower level classes [7]. The data leads to the conclusion that the AS faculty needs to review course sequence to enable the introduction of BIM early in the curriculum so that students become proficient in BIM tools and are able to use it in other courses in the curriculum. The introduction of the BIM course early in students program of study would help mitigate challenges which faculty face in AMS 363 where students want to use BIM and would enable faculty to focus on core course content (building typology, codes, construction drawings) while giving students the advantage of using desired tools (ACAD/ REVIT) in core courses over a longer period of time.

BIM is a shift in the way of approaching a design solution. The solution now has an additional dimension: The information model. This “dimension” is itself multidimensional in that each stake holder has a different informational interest in the model. The shift from using ACAD to a BIM platform is thus more challenging and complex since a student now models not just a structure but significant amount of additional information that comes along with the structure. According to Markling, a number of smaller firms in the AEC industry are using BIM for 3D modeling, visualization, imagery, walk-throughs and to produce 2D construction drawings similar to other CAD software, but a number of these BIM models contain little to no information that can be used beyond design and further [14] which is suggested by the data gathered. In the future the BIM course will need to move beyond the 3D modeling aspects and integrate to a greater extent the information laden aspect of BIM. While currently the BIM course covers all topics related to the information laden aspect of the model, this will need to be driven home in a more forceful manner to the students through smaller projects where students are expected to build a model which will contain information that can be used not just during the design and drawing generation phase of the project but can move into the construction phase and beyond, making complex architectural projects easier to manage through the entire cycle of design, construction and facilities management.

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