

Deciphering Drawings: A Student Guide to Construction Documents

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Abstract—This paper discusses the development of an interactive electronic book that focuses on helping undergraduate engineering students to learn to read, interpret and work with engineering and construction drawings. The iBook is use the 3D imagery, construction drawings, shop drawings and photographs associated with the AISC Steel Sculpture. Included are the results of a survey asking department heads and chairs to comment on how important they feel this topic is and how well they are preparing their graduates in this area.

Keywords—construction drawings, engineering drawings, interactive electronic books, 3-D images, structural steel components, AISC Steel Sculpture, iBooks Author.

I. INTRODUCTION

Construction drawings are the central communication tool for the architectural and engineering design of a construction project. Construction drawings have a language of their own and each person involved with the project must be able to read, accurately interpret and work with the project drawings.

“It is crucial for anyone involved in construction and manufacturing projects to have the ability to read and understand blueprints and building plans. Whether you're in the field or in the office, you need to know how the site plan affects the building plan, ...” [1]

“Working drawings are critical to construction work. It is essential that everyone in the building team is able to understand and interpret them as appropriate to their needs.” [2]

At one time most civil engineering programs had a course dedicated to drafting and learning to read and interpret construction drawings. In some cases it was part of a course or two. Today drafting courses have been replaced by CAD courses that focus primarily on the skill of using the software (AutoCAD, Revit, etc.) and much less on learning to read drawings (construction drawings, shop

drawings, as-builts, etc.) and understanding their components (sections, details, schedules, notes).

The objectives of this paper are:

- Report the results of a survey of civil engineering department heads and chairs that focused how the topic of reading, interpretation and working with construction drawings is incorporated (or not) into their undergraduate civil engineering curriculum.
- Discuss from an undergraduate point of view the rationale behind the development of the interactive learning tool for construction drawings.
- Discuss an iBook that is being developed to help undergraduate engineering students learn to read, interpret and work with engineering and construction drawings. The iBook incorporates 2-D images, 3-D images, virtual reality models, drawings and photographs into an interactive learning environment. The AISC Steel Sculpture was the example used for this project.

II. SURVEY RESULTS

In October 2013, notification of a Construction Drawing Survey was sent to all the department heads and chairs that are registered with the Department Heads Council (DHC) of ASCE. The purpose of the survey was to gather information about how civil engineering programs in the United States instruct their undergraduate students how to read, interpret and use engineering and construction drawings.

Forty (40) departments responded to the survey which based upon an ASCE report would be approximately 16% response rate. [3] While this is not as large as we would have liked, we were able to extract some interesting information for the data provided. Table 1 shows some key aspects of the demographic data.

Of all the questions asked as part of the survey the two most relevant were: “1 - Your department believes that the

ability to work with construction drawings is an important skill for all students graduating from your undergraduate

engineering program” and “4 - Your department believes that this is an important topic and needs to be included in the

Table 1 – Survey Demographic Data

School Type	# of Responses	Ph.D. or M.S. programs	Student Majors >200	No Courses Offered
Private	7	57.1%	14.3%	14.3%
Public	33	87.9%	66.7%	15.2%
Combined	40	82.5%	57.5%	15.0%

Table 2 – Responses to Opinion Questions - All

Opinion Questions	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1-...is an important skill for all your undergraduates.	30.0%	50.0%	15.0%	5.0%	5.0%
2- Graduates are adequately prepared to work with...	2.5%	50.0%	25.0%	20.0%	2.5%
3-...more could / should be done to better prepare...	10.0%	62.5%	12.5%	12.5%	2.5%
4-...this is an important topic and needs to be included...	22.5%	32.5%	35.0%	5.0%	5.0%

curriculum for your undergraduate engineering program” (Table 2).

The majority of the departments responding to the survey felt (either agreed or strongly agreed) that the skill of being able to read, interpret or use construction drawings was important for civil engineering undergraduate to have upon graduation. Interesting to note that while 80% felt the skill was important only 55% felt that it should be included in the civil engineering undergraduate curriculum. This difference is more distinct for the responses from the private institutions: 85.7% for important topic versus 42.9% for should be included in the undergraduate curriculum. One should take into account that only 7 private institutions responded.

Another interesting response was that 85% felt that the instructional process of teaching a student to work with construction drawings could / should be improved. Of those that indicated that improvement was needed 45.7% stated that the topic should be integrated into more courses. Their comments included:

- More exposure, internships, real world projects
- More interaction with engineers in practice and coverage in more classes,

- A more coherent process rather than bits and pieces here and there,
- Provide a solid introduction to construction documents in a required course and then incorporate exposure to and/or use of actual construction documents into as many courses as possible.

A concern was mentioned that integrating this topic into more courses might have to come by sacrificing some other topic. Some general comment received include:

- The basic core curriculum is so large that the last two years cannot adequately cover all required civil engineering material.
- One key: a ready supply of "real" drawings from actual projects helps tremendously
- Whether or not a student learns about, is exposed to, and/or uses construction documents to any practical degree is very hit-or-miss in our curriculum.

The general feeling expressed by the departments that responded to the survey was that more could be done to integrate this topic into all levels of the civil engineering curriculum. Many expressed that this topic should be spread

throughout the undergraduate program. While not stated explicitly, one gets the impression that some departments felt that students could and should obtain this skill through internships and other forms of work experiences: not through add material in the curriculum. Others felt that this topic could be integrated into several required courses within a program.

Two additional survey questions that might of interest dealt with what software the departments are using for CAD and structural analysis courses. It is no surprise that 70% of the respondents are using Autodesk (AutoCAD and Revit) software for CAD. (Table 3) The choice of software for structural analysis courses did not have a single favorite. (Table 3)

Table 3 – Software Used By Departments

CAD Software		Structural Analysis Software	
Software	%	Software	%
AutoCAD	60.0%	STAAD	37.5%
None	17.5%	SAP 2000	35.0%
Revit	10.0%	Risa	25.0%
Bentley	10.0%	GT Strudl	15.0%
Solidworks	5.0%	Visual Analysis	10.0%
		Other	10.0%

Note: % adds up to more than 100% because departments often reported more than one package for each category.

III. THE PROJECT

A. How it all began:

When looking on the web it appears that the educational support material available for students is limited to textbooks [9], YouTube© videos [7], on-line courses [8], on-line help areas [4], web sites [11, 12], documents [5, 6, 10], and brick and mortar classes. What we did not find was an e-book that provided a student with an interactive learning environment that integrated construction drawings, sections, details, schedules and terminology with 2-D images, 3-D virtual models, photographs and definitions.

B. Benefits of an e-book:

Interactive educational material: A student using an e-book has the ability to learn the materials associated with construction drawing by exploring words, pictures, 2-D drawings, 3-D virtual models and videos within an interactive, self guided learning environment. This interactive e-book environment is a way to supplement the information provided by the teacher. Where a 2-D picture can only show you an object from one angle an interactive,

3-D virtual model allows a student to see object from any angle in real time. One can even "zoom in" for specific details as needed.

For example, typically a teacher would talk about a kind of weld (i.e. fillet weld), point to the symbols indicating the weld type on a construction drawing, maybe show a picture or two of a similar weld and then move on to the next topic. An interactive book allows a student see the weld symbol on the construction drawing, read about the variety of available welding options, see a picture of a typical weld, view the weld on the structure from several angles with a virtual model of the structure and view a video demonstrating how a particular type of weld is constructed. Then the student will be able to relate this type of weld on a construction drawing with its appropriate field symbol and have a visual image of what the weld symbol means.

The 3D interaction enables the student to hone in on her / his visual imaging skills via the 3-D manipulations in order to make it easier to develop a robust and lasting mental picture of the "term" being explored.

Accessibility: An interactive e-book has an immense amount of information stored all in one place and it is all just a hyperlink away. Prior to having an interactive e-book available, a teacher would need to provide the students with the supplemental materials in a variety of formats: paper, video files, web sites, book references, etc. The access to the supplemental materials might be via a CMS (course management system that would be available to the students in the course. Now all the supplemental material (a key for symbols, a picture of the finished product, etc.) are integrated into e-book and at the student's fingertips (literally). Much of the information in the interactive e-book would be difficult for a teacher to provide.

Less daunting: Typical teaching methods also included long manuals [5, 6, 10] on how to read a construction drawing. For example, the manual on the AISC Connections Teaching Toolkit [10], while thorough, can be difficult for an inexperienced student to filter through. It has a lot of useful information and it tries to help one visualize the material. Unfortunately a reader who is not familiar with the AISC Steel Structure or most of the terminology can get easily overwhelmed. For example, one part of the guide references a double angle connection being similar to a single angle connection, but the single angle connection description is not located nearby. The reader is left to search through the pages of the guide in order to locate information on the single angle and then make the comparison. With the iBook this will not happen. An interactive e-book would be easily searchable and enable the student quickly find the desired information and conveniently make the comparison. An e-book is an expansive tool hidden in a small, less-daunting application.

IV. STUDENT INTEREST IN DOING THIS PROJECT: PERSONAL PERSPECTIVE

A. Why the students were interested:

In this section of the paper we are going to highlight why the two student authors were interested in working on the interactive e-book for the AISC Steel Sculpture. The ideas expressed by Kayla Santello in the following paragraphs reflect the perspectives of both student authors.

As an environmental engineering intern on Pease Air Force Base this past summer, there were some days when I would find myself sifting through hundreds of old construction drawings looking for one specific detail, like the floor thickness in a hangar. As I would filter through these documents, sometimes I would not even know if I was looking at a cross-section or plan view and I realized a few things: I had very little knowledge of how to read these drawings, I had to rely on my busy co-workers for help, and there was no support material available or comfortable way for me to learn how to handle these documents. As I struggled through the pages, I saw the value in knowing how to read and work with a construction drawing, which is why this project appealed to me. The opportunity to create an interactive electronic book that provides instruction on this very topic seemed like the perfect way to face my problem head-on. Besides working with peers and my professor, building the AISC Steel Sculpture iBook is a chance for me to personally become proficiency with reading and using construction drawings as an engineer. Additionally there is the challenge and excitement from the added pressure of being able to provide others with a teaching tool via a 3-D interface. The Book is designed to be comfortable and easy to use for all audiences regardless of their existing knowledge on the subject.

This project also captivated me because I recognize that the world is continually advancing in a digital direction where electronic books are becoming more pervasive in both the educational and professional realms. I wanted to take this unique opportunity to develop my technology skills especially since I usually consider my computer savvy to be less than I would like. This aspect of the project is proves to be just as challenging, but also as rewarding as cultivating my knowledge of construction drawings.

I am engaged in this project because I see it's potential. My hope is that this book is the first in a series of interactive books which I can help author. As an environmental engineer, I am personally very interested in creating a book that pertains to environmental engineering topics such as drinking water treatment, waste management, bioremediation of polluted groundwater etc. This project enables me to do a few things I love most: learn new things, work on a team and help others acquire new knowledge.

B. How our knowledge has been expanded:

I had firsthand experience of trying to navigate and work with construction drawing without the benefit of any support material while interning at the Pease NH Air Force Base. While I was faced with deciphering codes and symbols, a myriad of questions populated my mind. It was these questions that became the foundational objectives when we started to produce the book. The answers to my questions manifested themselves as the main topics and chapters in the iBook. I used myself as a personal barometer to assess if we were being thorough with our explanations of drawings. The locations where I got lost or confused, we assumed a typical reader would encounter a similar response. When reading guides and looking at 2-D pictures I often found that I would get confused and did not know what part of the picture was being referenced: *is that the weld? What is a weld? Is that the connection they're referring to?* Being engaged in this exploratory adventure has enabled me to contribute ideas on how to reduce or minimize the confusion and what needs to be in the book. The process of asking questions, finding answers and then constructing a presentation of a concept in my own words solidifies the information in my mind and is in itself a valuable educational / learning tool.

C. The future:

The first version of AISC (American Institute of Steel Construction) Steel Sculpture iBook is on track to be finished by June 2014. It continues to evolve each day as more content is added, more questions are discovered and more answers are found. As a team we collaborate weekly and brainstorm ways to enrich the value and usability of the book. For example, only a few days ago I had the idea that the book should have an option to either make notes or flag certain information; then the reader be able to search for those notes or flags for faster information navigation. I look forward to the upcoming months as we continually challenge ourselves, push further, think of new enhancements and plan for future potential books.

V. WHY IBOOK AUTHOR FOR THIS PROJECT

In order to display the information about the AISC Steel Sculpture and its associated construction drawings, we decided to use iBooks Author [13] as our e-book authoring application. This approach significantly reduced the number of programming challenges we would face. Using iBooks Author allows one to “drag and drop” items so that we could focus on developing the core topic details (figures, photographs, descriptions, 3D imagery, etc.) and producing the most aesthetic layout for our information blocks. One widget embedded within the program creates an interface that enables a user to manipulate a 3-D model within the interactive page. Widgets are pre-programmed tools that can be embedded with one's iBook. The AISC Steel Sculpture iBook uses several additional widgets to activate

pop-up windows, navigate to another page and link to a variety of media. It is difficult to illustrate this feature in a still snapshot (Fig. 1). In an iBook the user is able to rotate the model in real-time and view the object from any angle.

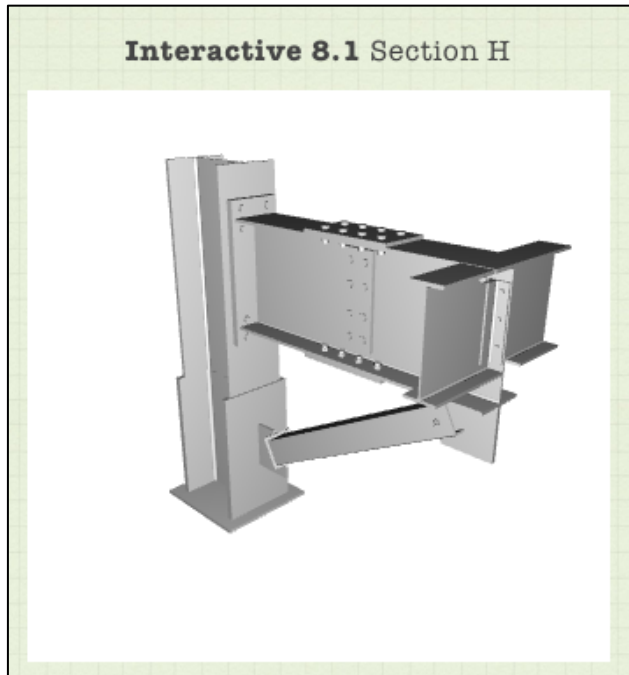


Figure 1: Still View of 3-D Widget

Another positive feature of iBooks Author is the ability to produce an e-book that can utilize a touch screen environment. With the rise of tablets and touch screen laptops, more and more operating system and applications are catering to touch screen features. iBooks Author was originally designed to create an e-book that facilitates a touch screen environment, and as such, it automatically creates a user friendly interface.

There are several useful widgets within iBooks Author that help to develop an interactive learning environment for the end user. One widget that we are using often is a “pop-up” window. Tapping or clicking on a small colored square toggles the “pop-up” window. A pop-up window, which contains additional information about the object of interest, will appear on the same page. This information is hidden until the colored box is toggled. The pop-up window can hold text, images, web links, hyperlinks, and more. The window also has the capability of automatically adding a scroll bar if the text overflows the size specified for the pop-up. The downside to using pop-up windows is that there is no way to position where they pop up and often the windows obscure the part of the picture that one is trying to describe.

This is not the only problem we have run into while using iBook Author to create our e-book. It turns out that the up side of not having to use a more traditional programming

environment also comes with many restrictions and they can become quite frustrating. The first problem we encountered and needed to resolve was in creating bookmarks, an important navigational tool. In order to move to different locations within the book we decided to rely heavily on hyperlinks. An example being that a user could click on the notation “NS & FS” and a hyperlink would take them to a bookmark in another part of the e-book. Here one would find a definition of the term along with associated images to help explain what the term means.

Initially we were having problems creating bookmarks and it was not intuitive as how to solve the problem. After much time and research, we discovered that iBooks Author requires a main text flow. All of the text boxes have to be linked by blue connecting lines as seen in Fig. 2.

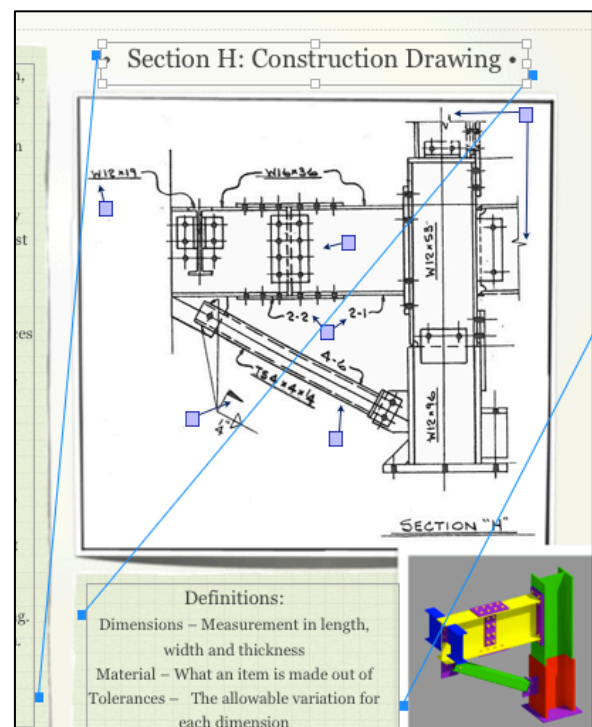


Figure 2: Connecting Lines for Main Flow Text

This allows the text to flow from one text box to the other. The way to control this text flow is by adjusting the sizes of the text boxes so that when one text box runs out of space, the text will continue into the next consecutive text box as determined by the blue line links. This requires constant resizing and placement manipulation of the boxes in order to ensure that everything is laid out properly.

Another major concern was that, since the information is being laid out as a book, there might not be any way to use “forward” and “back” buttons as you can when using a web browser. We were pleased to discover that an e-book published from iBook Author automatically remembers where you have just hyperlinked from and allows you to

click on the “back” button that pops up at the bottom left hand corner of the page (Fig. 3).

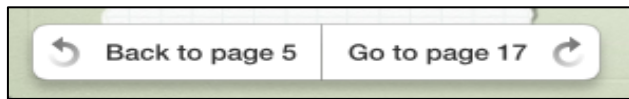


Figure 3: Forward and Back Buttons

However, this button only flashes there for a short amount of time, leaving us to wonder if users will notice this button or if they will be confused as to how to use this navigational tool within an iBook. Without usability test data from a focus group of college students and professors, we will not know whether or not we need to include a chapter on basic functions of using an iBook.

The AISC Steel Sculpture iBook is still in development with an anticipated publication date of June 2014 for the first version. It will be available from a variety of web locations at no cost.

VI. ACKNOWLEDGEMENTS

This project is the culmination of several undergraduate research projects and independent studies. A key participant is Timothy Nash, Civil Engineering undergraduate student at University of New Hampshire. He is responsible the majority of the 3-D graphics that is part of this paper and will be part of the AISC Steel Sculpture iBook. He created a 3-D model of the AISC Steel Sculpture in Autodesk Revit as part of a SURF (Summer University Research Fellowship) grant from the University of New Hampshire Hamel Center.

REFERENCES

1. *Construction Blueprint and Plan Reading*, (2014), UC Davis, Continuing & Professional Education, from http://extension.ucdavis.edu/unit/business_and_management/course/description/?type=I&unit=bm&CourseID=14235&prgList=cnm
2. *Trowel Occupations: Module 3 (of 5) – working with drawings*, Excellence Gateway collections, 2005, from <http://www.excellencegateway.org.uk/node/22363>
3. *AC 2011-1453: What Does the Civil Engineering World Look Like? Let's Show it by the Numbers*, James J O'Brien, Jr, C. Ping Wei, Dion K. Coward, American Society of Civil Engineers, (ASCE).
4. *Blueprint Reading, Construction Knowledge.net*, http://www.constructionknowledge.net/general_technical_knowledge/general_tech_basic_blueprint_reading.php#1
5. *Blueprint Reading and Sketching*, NAVEDTRA 14040, Non-resident Training Course, Naval Education And Training Professional Development And Technology Center, May, 1994
6. *Carpentry Field Manual*, FM 5-426, Headquarter, Department of the Army, October, 1995

7. Morrison, Andrew, *Be Your Own Contractor Training*, Blueprint Reading, <http://beyourowncontractortraining.com/trainingplans>
8. Ramaswamy, J.N., *Reading and Interpreting Construction Drawings*, <http://www.pdhsite.com/>
9. Huth, Mark, *Understanding Construction Drawings*, 6th Edition, Cengage Learning, Higher Education, 2014.
10. Green, P.S., Sposito, T. and Veltri, P., *Connections Teaching Toolkit, a Teaching Guide for Structural Steel Connections*, AISC.
11. Ellifrit, Duane, University of Wyoming, <http://www.uwyo.edu/ceas/classes/connections/>
12. *Connections, Tools and Tips for Steel Erectors*, Purdue University, <https://engineering.purdue.edu/~strsteel/toolsheets/connections.htm>
13. iBooks Author (version 2.1.1) [software]. (copyright © 2011-2013 Apple, Inc.)

