TEACHING HOW TO READ 2D DRAWINGS USING VIRTUAL CONSTRUCTION

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Abstract

The two-dimensional (2D) drawings used in the construction industry are communication tools developed to explain the architect's intentions to the builder. The build interprets the 2D drawings of the building produced by the architect and connects them to each other to grasp the three-dimensional (3D) geometry of the structure to be explained by the architect.

It takes a considerable amount of education and experience to be able to interpret architectural drawings. The knowledge that links the lines, dimensions, and symbols in 2D drawings to a structure in 3D space is not something that can be obtained by memorizing. This ability is often cultivated more effectively through training in reconstructing the information acquired in 2D drawings into an object in 3D space. This training is the process of understanding the differences between the objects we have reconstructed in our minds and the actual objects. An educational program that does not provide students with the opportunity to do this kind of thinking is likely to be unable to cultivate the ability to read the drawings.

This paper presents new teaching method to foster the ability to interpret 2D drawings through 3D computer modelling. This teaching method does not enforce students memorize anything. Traditional methods are therefore difficult to use in assessing student achievement. This paper also introduces two methods of assessing academic achievement that we applied experimentally. There were still many improvements to our teaching method. This paper introduces lessons learned through our experimental application.

Keywords: 2D Drawing, 3D Model, Active Learning.

1 INTRODUCTION

The 2D drawings used in the construction industry are communication tools developed to explain the architect's intentions to the builder. In order to express a 3D structure in 2D drawings, architects draw the shapes of a structure in 2D plane when the structure is viewed from various positions. The architect completes the 2D drawing by adding appropriate dimension lines to the shape of the building represented in this 2D plane. The builder reads several drawings produced through this process, and connects the various 2D shapes of the building in the 3D space, and figures out the 3D shape of the structure to be explained by the architect. The ability to read the drawings and to understand the 3D shape of the structures the architect wishes to describe requires a significant amount of training and experience.

Some higher education institutions in the United States, educating construction professionals, teach students how to interpret drawings. Students learn about the various lines and symbols used in 2D drawings, and how to represent orthogonal 3D objects. They also learn about the unique features of structural, architectural, and mechanical drawings. After learning about these rules that we use to produce 2D drawings, students are trained to find the size of a specific window or the length of a specific wall in a drawing. This type of education has been developed on the assumption that if students have the ability to extract the necessary information from the drawings, they have the ability to interpret the drawings and reconstruct a 3D structure as intended by the architect.

However, the ability to find specific information in the drawings is not necessarily related to our ability to figure out the shape of the 3D structure that the architect is trying to describe. This ability is often cultivated more effectively through training in reconstructing the information acquired in 2D drawings into an object in 3D space. This training is the process of understanding the differences between the objects we have reconstructed in our minds and the actual objects. Through this exercise, we get the ability to read the 2D drawings correctly. An educational program that does not provide students with the opportunity to do this kind of thinking is likely to be unable to cultivate the ability to interpret the drawings.
In reading the drawings, how do we get the best opportunity to understand the difference between what we have guessed and the real structure? Perhaps we can have the best opportunity by building real structures. When we construct a real building, we have the opportunity to verify that the shape of the structure we guessed during the reading of the drawings is consistent with the actual. Of course, we may have the opportunity to fix what we misunderstand. Through this process, we have the opportunity to even understand the ambiguity and abstraction of 2D drawings. This proves how powerful the opportunity to build actual buildings is in teaching effective ways to read the drawings.

However, it is almost impossible to provide students with an opportunity to actually build buildings in the field of higher education. Therefore, drawing interpretation courses are aimed at training students to extract specific information from 2D drawings. If we recognize that the experience of actually building a building is the best way to cultivate the ability to read the drawings, we need to find ways to provide students with the opportunity to build buildings without any special preparation or cost. How about building a building in a virtual space? We believe that 3D computer modelling can provide students with such opportunities.

2 3D COMPUTER MODELING OF BUILDINGS

One way we gain knowledge is to memorize what we hear from someone. Thus, traditional teaching methods have been developed to help students better understand and memorize what the instructor delivers in class. This teaching method assumes that a student who memorized more contents delivered by the instructor gains more knowledge. So, students who have memorized more get better scores. Did the student who memorized more gained more knowledge? How long will they remember what they have memorized?

Sometimes what we experience personally is transformed into our knowledge. The knowledge that links the lines, dimensions, and symbols in 2D drawings to a structure in 3D space is not something that can be obtained by memorizing. This is knowledge that can only be gained through the experience of linking the shape of a structure in 2D drawings to an actual 3D structure.

Therefore, having students to memorize all rules associated with the 2D drawing production cannot be an effective way of teaching. Instead, teaching how to interpret 2D drawings should be a systematic guide for students to have experiences connecting 2D drawings and a 3D structure. The instructor should guide students to experience connecting 2D drawings and a 3D structure.

In order to apply this method of education, we need to discuss how students acquire knowledge. Learning is the process by which knowledge is created through the transformation of experience [1]. It is up to instructors to let the students have some experience, but it is their personal responsibility to transform their experience into knowledge. Therefore, the time required for students to have an experience, and the time it takes them to convert this experience into knowledge, should be different [2].

We have developed a new way of teaching that allows students to experience this through 3D computer modeling. The process of building a 3D computer model of a building is not much different from constructing an actual 3D structure. The process of creating a 3D computer model is based on the process of reading the outline and corresponding dimensions of the target structure represented in the drawing and imagining the shape of the structure in 3D space. This process is similar to the process by which we read drawings and make decisions in order to construct structures. Therefore, when students are instructed to create a 3D computer model of a building in the same order as building structures in the actual field, students will be able to experience indirect experiences that seem like construction. This is completely different from traditional learning, where students passively memorize what they have heard in class. Instead, it guides students to actively create 3D computer models of residential houses and learn how to read 2D drawings themselves.

3 GOAL ORIENTED ACTIVE LEARNING (GOAL)

The teaching method we developed can be broadly summarized as: 1) giving students a goal to achieve, 2) teaching them how to use the tools they need to reach this goal, and 3) encouraging students to reach that goal. The instructor helps students find suitable buildings to build in a 3D model. The instructor teaches students how to use the computer application needed to build a 3D computer model of the building. The instructor creates an atmosphere in which students can view this 3D computer modeling as an interesting competition among their peers.
To teach students how to read the drawings, we instruct students to create a 3D model of a simple residential house using SketchUp. To our judgment, residential buildings are the right size for students to handle in a semester, and SketchUp is one of the easiest computer applications students can learn. 3D modeling of residential buildings is conducted in the following order.

1. Students select a residential house to be produced in a 3D model and obtain corresponding drawings.
2. The instructor explains the symbols and conventions used by architects when producing 2D drawings.
3. Students produce the 3D models of foundations and frames of residential houses. This work is done as homework between classes.
4. Students present their 3D models in class.
5. Students produce 3D models of architectural components of residential houses such as windows.
6. Students present their 3D models in class.
7. Students build a 3D model that integrates structural and architectural components.
8. Students present their integrated 3D models in class.

As shown in the above process, 3D modeling work is done between classes. So, it is important to motivate students to work between classes. The method we use for this motivation is to have students present their 3D models in class. By letting students see the 3D models produced by their peers, students have the opportunity to learn for themselves what needs to be improved on their 3D models. The instructor has the opportunity to evaluate the quality of the 3D models produced by the students. The instructor encourages students to continue to focus on the project by evaluating the 3D model in class.

This class project was experimentally applied to Spring 2019. We anticipated that an individual student alone would be able to carry out this project well. So, each student was instructed to produce 3D models and presentation documents. We wanted students to make the most of their 3D models for this presentation. So, we taught them some techniques to produce rendered images of 3D models. For example, we taught students how to cut out a portion of the SketchUp model and expose the interior of the house. The following figures are examples of a 3D model and document produced by students during a class project.

![Example 3D model produced by students through a class project.](image)
4 ASSESSMENT OF KNOWLEDGE ACQUISITION

It is not possible to evaluate students' ability to interpret 2D drawings through traditional tests, since a person who memorizes drawing production rules does not necessarily guarantee that he or she has an excellent ability to interpret a drawing. The reason for developing an active learning method is that the ability to interpret 2D drawings cannot be obtained by memorizing the rules that produce the drawings. Therefore, assessing how much knowledge students have acquired is completely different from traditional methods.

It is not easy to measure students' ability to interpret 2D drawings in a short time. In traditional teaching methods, for that reason, we measure how well students are able to memorize the rules related to drawing production, how well they can extract specific information from the drawing, and use them to guess students' ability to interpret the drawings. It is not possible to evaluate the knowledge gained by students through traditional exams because the methods of teaching using 3D computer modelling do not instruct students to memorize anything.

So, the new evaluation method we developed is to measure how accurately a student can produce a 3D computer model of a structure. All students participating in this test are given the same amount of time for a fair assessment. The target structure must be sufficiently simple to be made into a 3D model within a given amount of time. The structure we chose for this evaluation is the toy block tower shown below.

![Figure 3. 3D model of the toy block tower used in the evaluation.](image-url)
Although this toy block tower is not a complex structure at all, it can be quite confusing if it is expressed in 2D drawings. We therefore expect this structure to be used effectively to measure the ability of students to interpret 2D drawings. Students are instructed to read the 2D drawings shown in Figure 4 and to create a 3D model shown in Figure 3. The computer application that students used to do this is SketchUp. For this 3D modelling, there are only three types of blocks that students need to create in SketchUp. After creating three blocks, what they do is just copy this block and move it to the desired location. Therefore, even the novice user of SketchUp can build a 3D model of the toy tower. Thus, the use of 3D computer applications can not interfere with the process of demonstrating the ability of students to read their 2D drawings.

This assessment method was applied experimentally in Spring 2019. This test was very different for students. So, we wanted them to be fully prepared for this extraordinary test. Students already had experience creating 3D models using SketchUp prior to testing. The students had enough explanation in advance of how the test would proceed. For a short amount of time, students even had the opportunity to see the drawings to be used for this test. Nevertheless, this pilot application gave us an unexpected result. A total of 26 students participated in the test, and only four students created the 3D model correctly. None of the students had any problems with computer applications. The remaining 18 students obviously did not understand the drawings properly. This was an amazing result for the instructor, but the students themselves seemed more surprised. Before the test, the students seemed to think that they had sufficient ability to interpret 2D drawings. Students felt that the 2D drawing course was a waste of time. However, the test results made the students aware that their judgment was wrong.

We were also surprised by the test results. We did not expect that the number of students who could successfully pass the test would be so small. It is too early to judge whether the test method is inadequate or the students' ability is that much. None of the students complained about the test method during the test. Therefore, it does not seem to be a problem with the way the test is conducted. A more long-term, careful approach is needed to determine if this test properly assesses students' ability to interpret 2D drawings. Testing with a wider variety of structures may prove that our test method is reliable.

One thing is for sure, that after this test, the students participated in the class project without complaint. It appears that this experiment gave students a belief that the class project would cultivate them the ability to read 2D drawings.

The class project required two things. It required students to create a 3D model of their chosen residential house, and to produce a presentation document describing their 3D models. The evaluation
was made on the quality of the 3D model and the amount of information contained in the presentation document. First of all, for the 3D model, we evaluated whether the 3D model faithfully contains the structural components such as the frame and the architectural elements such as the window or the wall. As for the presentation documents, we evaluated how well they describe the target residential house using a 3D model.

We do not expect that this type of assessment can directly measure students’ ability to interpret 2D drawings. This evaluation method only serves to encourage students to work diligently to create a 3D model and to publish the document. Nevertheless, the reason why we use our evaluation methods is because there is no other way to evaluate students’ true capabilities in a short time.

The evaluation method we used has the disadvantage that it takes time to grade. In order to make sure that the 3D computer models that students submit have both structural and architectural components, the instructor has to open all 3D models and check them one by one. This takes a lot of time, but there is no other way. If we have some rules that make it easier to review 3D models, we may be able to save some time to evaluate them. For example, if we instruct students to classify structural and architectural components using specific layers in SketchUp, we can see what you want more easily by turning each layer one and off.

5 CONCLUSION

This paper presents a new way to teach how to interpret 2D drawings. This teaching method instructs students to create a 3D computer model of a target residential house. It enables students to experience the visual representation of a structure in 3D space. We believe that students transform their experiences in class into knowledge by themselves.

The reason for developing this active learning method is that the ability to read the drawings cannot be obtained by memorizing the rules that produce the drawings. It is not possible to evaluate students’ ability to interpret 2D drawings using traditional exams, since a person who memorizes drawing production rules does not necessarily guarantee that he or she has an excellent ability to interpret 2D drawings.

This paper experimentally applied two methods for evaluating students’ ability to interpret 2D drawings. The first was to instruct students to create a 3D model of the toy block tower in a limited amount of time. This attempt, however, gave the students and the instructor what they had never expected. Only 15% of the students who took the test correctly created the 3D model of the toy tower. This test provided students with good reasons why they should learn how to interpret 2D drawings. Through this experiment, we confirmed the possibility of a new method of evaluation suitable for active learning. Repeated applications with various structures are expected to increase the reliability of our proposed method.

The second way is to instruct students to build a 3D model of the residential house. Students’ ability to interpret 2D drawings was measured using the completeness of their 3D models. Documents produced by students to present a 3D model helped facilitate this evaluation. This assessment method cannot directly measure students’ ability to interpret 2D drawings. However, if the completeness of the 3D model is related to students’ ability to interpret 2D drawings, some degree of indirect evaluation may be possible.

REFERENCES
