Using LEGOs® to Reinforce Basic Parametric Modeling Practices

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Abstract

Incorporating design intent and the use of appropriate naming strategies are fundamental concepts of efficient parametric modeling. A class of primarily junior level engineering and technology students, most of whom were having their first experience with parametric modeling, was struggling with these basic concepts. Although the students had received instruction on the importance of naming their files, features, and sketches and incorporating design intent into their models, they were not implementing these practices into their projects. To help reinforce basic concepts and get students to realize that in the real world, more than one person may work on a design file, it was decided to introduce a LEGO® modeling project into the course. This project required the students to model three or four parts of a LEGO® backhoe. The individual files were collected by the instructor and redistributed to the students so they could each assemble the complete model. If a part did not fit properly into the assembly and needed editing, each student made a decision to either fix the part or recreate it if editing was not feasible. The students were required to keep track of which parts worked, and which needed editing in order to complete the assembly. This paper focuses on the outcome of the project and includes feedback from the students on what they learned from the experience and their comments on working on a team project. Also included are graphic examples of the assembled LEGO® backhoe both before and after editing the individual parts.

Introduction

Some of the most fundamental concepts of efficient parametric modeling are incorporating design intent through the use of dimensions/parameters and having an appropriate naming strategy for planes, features, and parts in order that future editing of the model can be accomplished by someone other than the originator. In Pro/DESKTOP, the software used in the course discussed in this paper, if the default names are not changed, each new feature, plane, or design file is named with a generic name such as; workplane1, revolution1, extrusion1, or design1. These default names do not give another user enough information to easily edit the part, as would names such as; hole pattern plane, cap profile, thru hole, or tractor tire. Also, the dimensions/parameters on the sketches are important because these parameters define the geometry and allow features to be edited.

In a junior level CAD course, most students were not implementing the basic concepts of naming and fully dimensioning their sketches in their projects although they had been instructed about their importance, taken written tests where they showed an understanding of the concepts, and had points deducted on homework assignments for not following good modeling practices. Prior to this course, most of the students had little or no exposure to parametric modeling but had at least two courses in 2D drafting and some CSG modeling using Boolean operations. Initial instruction in the basic parametric modeling concepts was accomplished by: demonstration of use of the parametric modeling software, in this case Pro/DESKTOP 8.0; step-by-step tutorials; homework projects where students were given specific naming strategies to use on the planes, features, and models; handouts and textbook readings; and in-class quizzes and exams.

When queried in class about the lack of use of the basic practices, the verbal reply from students often included: "What does it matter? I'm the only one looking at the file and I knew what I meant to do." "If I mess up the part and need to change it, I'll just start over instead of editing, I have plenty of time to finish." "Well, the part looks right, doesn't it? So does it really matter how I built it?" and "I removed most of the dimensions from the sketch because it was getting messy, I'll put them back if I need to change anything."

To help reinforce basic parametric modeling concepts and get students to realize that in actual working practice, more than one person may work on a design file and thus need to understand the originator's naming strategies, modeling intent, and so on, it was decided to introduce a LEGO® modeling project into the course. The use of LEGO® projects, such as those done by Branoff [1] and Buchal [2] has been shown to be effective in teaching some of the basics of parametric modeling and teamwork. Even though a LEGO® toy was used in this project, any similar object composed of rather simple yet discrete parts would have been appropriate for use as long as the parts and their connectors were standard so the parts would be interchangeable. When using a toy, such as the LEGO® backhoe, it introduces an element of fun into a serious project that the students seemed to enjoy. The subjects in this study also had shown lower than average visualization abilities [4] and it was anticipated that the haptic nature of this assignment, physically manipulating and creating a virtual model of a familiar object, would serve the ancillary purpose of improving their visualization skills because previous research has indicated that a majority of engineering and technology students have high haptic tendencies [3].

The Assignment

A LEGO® backhoe (Figure 1) was chosen for the assignment because the number of parts and the complexity of the overall model were appropriate for the class. Parts were sorted by the instructor and three or four parts, depending on the complexity, were placed into separate envelopes then randomly distributed to the students. All parts that were necessary to build the backhoe shown in Figure 1 were assigned except for the construction worker. Even duplicate parts, such as the tires and rims, were modeled by different students with the intent that this would demonstrate to students that there was often more than one "correct" way to model a part. Students used calipers to measure their individual parts and consulted with each other to ensure consistency. Any discrepancies in measurements were worked out between the students with minimal instructor input.

Figure 1. LEGO® backhoe instruction sheet illustration

The instructions for the assignment were as follows:

- You are to draw, using metric units, the LEGO® pieces that you were given in class; name them with descriptive names and your initials
- You can not take these parts home with you and must always return them to your instructor before the end of class in order not to lose any of the parts
- When all parts are completed, electronic copies will be turned in to your instructor and they will be copied into one folder
- You will then receive a copy of the folder with all the parts and are to assemble the backhoe as shown in the handout
- When you are creating the assembly, take notes on which files work and which do not
- If a part does not fit properly into the assembly, you are responsible for editing the part, and you may not "duplicate" correct parts; for example, if one tire works and the other does not, you must edit the tire that does not work instead of using the "correct" tire twice
- You also need to turn in a file (Word, Excel, etc.) that contains your notes on which parts worked, which parts did not, and what you had to do to fix them – part of your grade will be determined by how well the parts you created fit into the assembly

The Assembled Backhoe

The assembly that was created from the initial set of parts had several problems including parts that were not fully completed and parts that did not fit. Figure 2 shows an example of the initial assembly file. Figure 3 shows some detail of parts that did not fit or were missing geometry that did not allow them to be properly assembled. The graphic on the left side of Figure 3 shows that the hood was not created at the correct height/thickness and the circular fasteners on the part below it protrude through the top of the hood. The graphic on the right shows that the scoop was missing the feature that would allow it to attach to the extendable arm, thus the fastener on the arm projects into the scoop without any viable form of attachment.

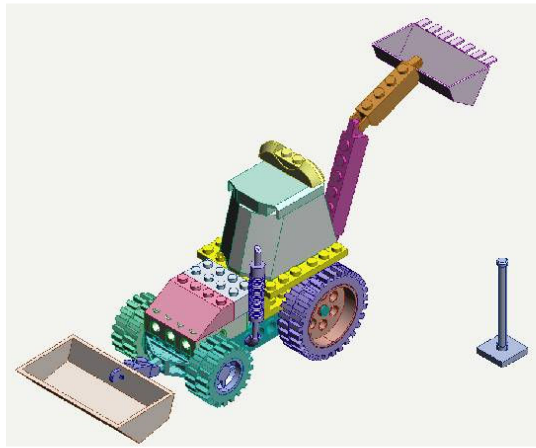
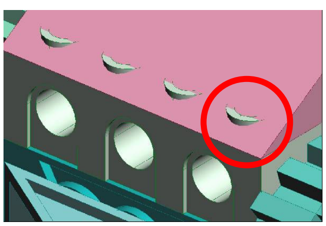


Figure 2. Initial backhoe assembly



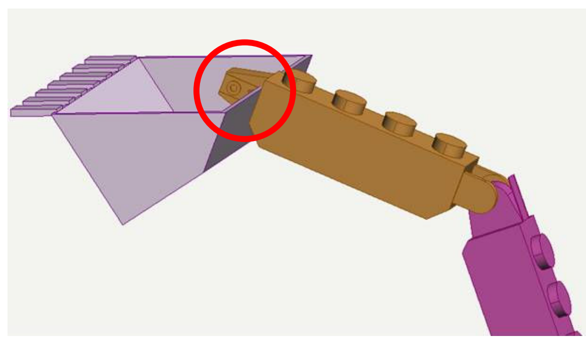
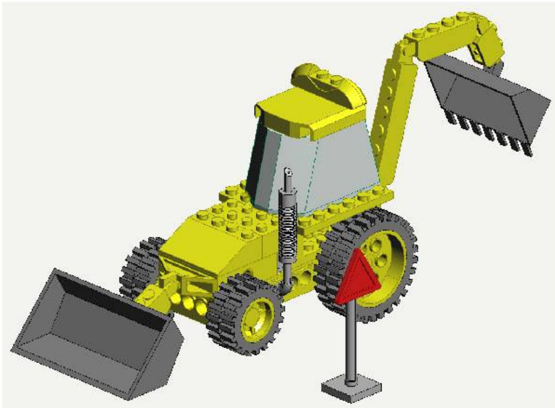


Figure 3. Examples of incorrect parts on initial assembly

Of the original 29 parts, 21 had problems ranging from minor edits to complete recreation. Two parts were not completed by the student to whom they had been assigned and had to be created by each individual student to add to their own assembly. Students edited the problem parts with varying amounts of success. Figures 4 and 5 show two different completed assembly files which were created with the revised parts. Some students changed the colors of each part to more accurately match the actual LEGO® backhoe as shown in Figure 4, and others left the parts in system generated random colors as shown in Figure 5.



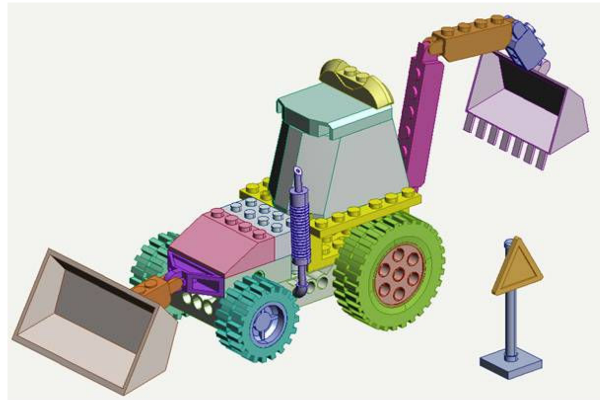


Figure 4. Completed assembly example 1

Figure 5. Completed assembly example 2

Naming Strategies

The students were instructed to name the parts with a descriptive name and also to include their initials in the name of the part to indicate who had originally drawn the parts. Each sketch, workplane, and feature should have been given a descriptive name also. Previous instruction and class exercises emphasized the necessity of having an appropriate naming strategy for ease of editing. In Figure 6, which shows the features browser window of an individual part, note that none of the feature names were changed from their default names. With all of the extruded features named "extrusion 1," "extrusion 2," "extrusion 3," and so on, unless a particular feature is selected in the browser window and subsequently highlighted on the part, it is virtually impossible to tell one feature from the other. Also, incorrect features have simply been suppressed instead of deleted or fixed, making it even more difficult to efficiently edit and update the part. The part shown in Figure 6 was one of the parts that needed extensive editing to fit into the assembly. Student comments on having to edit parts such as this one are included in the feedback section.

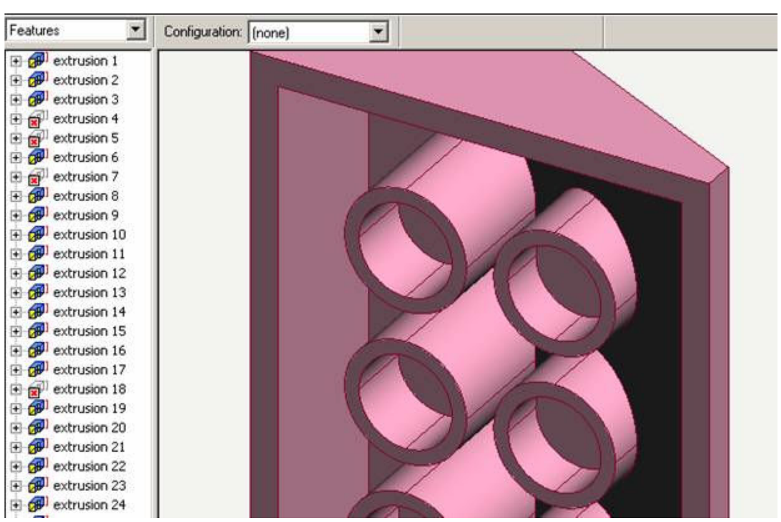


Figure 6. Example of incorrectly named features within an individual part

Figure 7 shows the browser window of workplanes and sketches of another individual part. Although some of the sketches and planes have been named other than their default names of "sketch 1," or "workplane 1," there is not enough descriptive detail included for someone to intuitively edit the sketches and workplanes. Names such as "frt," "tre," and "circle 10" do not give sufficient information to the person editing the model to know which feature(s) the sketches refer to.

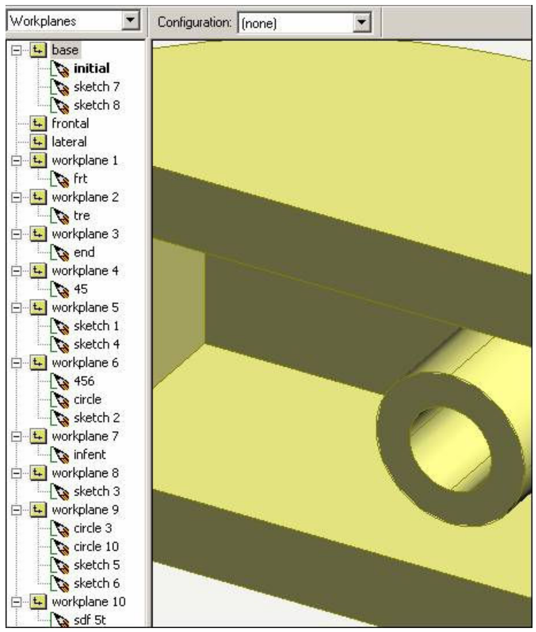


Figure 7. Example of incorrectly named sketches and workplanes within an individual part

In Figures 8 and 9 are examples of more appropriate naming strategies. Figure 8 shows the features browser of a part where the student used descriptive names for the features that were created such as "projection front left slot" and ".7 round side." Also note that there are no suppressed or unregenerated features in the browser window. The part whose features browser is shown in Figure 8 did not need to be edited in order to fit into the final assembly.

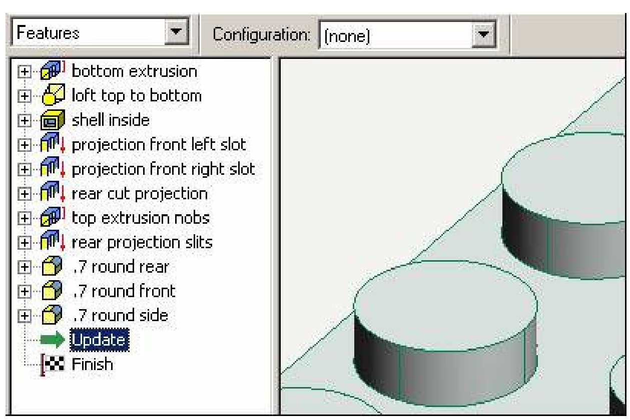


Figure 8. Part with appropriate feature naming strategy

Figure 9 shows a part with descriptive names for workplanes and sketches. This part, as it is shown, was not one of the original parts, it was created by a student to fit into his assembly. The student to whom it was initially assigned did not complete the part and each individual student had to create their own version of the part to fit into the final assembly.

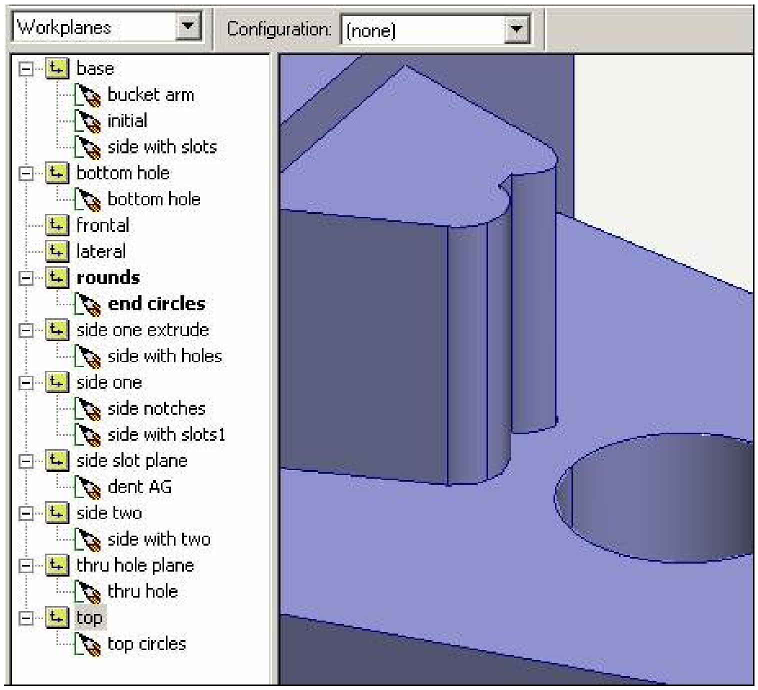


Figure 9. Part with appropriate sketch and workplane naming strategy

Student Feedback

The students were required to keep notes of which parts needed editing while they were creating their final assemblies. Of the 29 parts which were originally assigned to the students, 23 either needed editing or were not completed by the student to whom they were assigned. The necessary edits ranged from simple changes of height or diameter to complete recreation of some parts because editing was not possible or would take longer than starting over.

Along with supplying feedback on individual parts of the assembly, the students were also required to list and describe in detail what they considered the four most important things they learned from this LEGO® project. A summary of the answers is listed below and duplicate or similar answers were paraphrased.

- It can be very difficult to work on other peoples drawings
- It is extremely important to name sketches and workplanes because how are you supposed to know which sketch or plane goes with a feature if you need to fix it
- Now I know why you keep telling us to name everything and especially not delete the dimensions because if it's hard to figure out what someone else meant to do with their part

- It is bad when people just suppress all of the wrong features they created because then you can't update the part without getting rid off all the wrong stuff first
- Dimensions are the most important part in an assembly
- You need to try to be as precise as possible
- It is best to complete drawings in a manner that is generally understood so it limits the difficulties for others
- There are numerous ways to do similar drawings
- It was interesting to see how different everybody's styles of construction are and if they don't name everything, editing is hard
- Working with other people can be stressful when doing a big project
- Don't put big projects off to the last minute because if you don't get your work done, other people get mad when they have to finish what you didn't
- Some people did not seem to take their work as seriously as others and did not care if their parts were right
- Not everybody's work will be perfect or right / nothing is perfect when working with other people
- Assemblies only work if every part is right
- Almost everything is fixable if you don't give up
- Communication, responsibility, and teamwork are necessary to make sure the dimensions are uniform
- If working on real projects at a job is anything like this, then it's going to be difficult

The students were also asked to submit anonymously whether they thought the project was beneficial to them and if similar projects should be done in future offerings of the course. Most of the answers were positive and included:

- I think all future classes should be required to do a similar project based on working with a group of people to get a whole assembly done on time because that is what the work force is about, working together.
- This project was extremely beneficial. It should be done more in the future because it is sort of on the job training which is one of the reasons why we attend university. Thanks for making us do this project.
- I think the project was beneficial but a challenge at the same time. I think it should be done in future offerings of the course because it is new and different and other students should feel the pain I went through.
- I do not think it would be a good idea to work on other projects like this one because some people are not serious about their work and that makes it difficult to finish projects. However I must say that this project was beneficial because it improved my teamwork skills.

Discussion and Conclusions

The feedback from the students indicated their realization of the importance of modeling accurately, incorporating design intent, and using appropriate naming strategies to make editing easier. One of the biggest frustrations for most of the students, as noted in the feedback and from observation of the instructor, was dealing with models that could not be easily edited and especially the parts that had to be recreated. In-class comments often referred specifically to lack of dimensions, improper naming, and there was much discussion over who was "right" when similar parts, or mating parts, made by different students, were different sizes when they should have been the same. The actual LEGO® parts were brought to each lab session so students could re-measure the parts and come to a consensus decision.

Another factor that caused difficulty for the students was the problem that is inherent in most group work, lack of participation by members of the group. A significant part of each student's grade on the project was determined by their correctly completing all of their assigned parts but grades are not motivating factors for all students. For the assembly, if a part was not completed by the student to whom it was assigned, the rest of the students had to create their own version of the part.

This project was of a scale that was larger and had slightly more complicated and detailed parts than any of the projects the students had completed previously in the class. Initially the instructor assumed the students would build on previous knowledge and combine different modeling techniques to create the new parts but the students seemed to be struggling with some of the more advanced concepts that had previously been only briefly addressed in class. Because of this, the original due date for the initial creation of the parts had to be extended so time could be taken in class to include further instruction in some of the more advanced modeling techniques. In the future, a project using fewer or simpler parts may be implemented earlier in the semester, because of the importance of an early emphasis on the use of proper naming strategies, design intent, and so on, and a similar LEGO® project would be implemented later in the semester when the students are more knowledgeable about and comfortable with using the software.

The positive results from the project were, as intended, increased modeling and assembly skills, and also improved teamwork as noted in the students' feedback and the instructor's observations. The students seemed to retain the skills they learned from this project throughout the rest of the semester, but that only entailed two more projects including the final project. This is the final modeling course in the series of mechanical related CAD courses for these particular students but follow-up data will be collected from those students who choose to use a parametric modeler as part of the design work in their senior project to see if students maintained good modeling practices after the course in this study. In the future, similar projects will be implemented in this course because of the positive results. Initial post project data from testing the students' visualization skills also showed some improvement, this data will be analyzed further and compared to outcomes of previous courses which did not implement a similar LEGO® project to see if the project had any significant effect on students' visualization skills.

References

[1] Branoff, T.J. (2003). Using LEGO® group projects to increase student understanding of constraint-based solid modeling and other engineering graphics concepts. *Proceedings of the 58th Midyear Meeting of the Engineering Design Graphics Division of the American Society for Engineering Education, Scottsdale, Arizona, November 16-19, 2003.*

[2] Buchal, R.O. (2001). *Incorporating solid modeling and team-based design into freshman engineering graphics.* The Engineering Design Graphics Journal, 65(1).

[3] Study, N.E. (2001). *The effectiveness of using the Successive Perception Test I to measure visual-haptic ability in engineering students*. Unpublished doctoral dissertation, Purdue University.

[4] Study, N.E. (2003). A comparison of test scores of minority vs. non-minority students on the Purdue spatial visualization test: Visualization of rotations. *Proceedings of the 58th Midyear Meeting of the Engineering Design Graphics Division of the American Society for Engineering Education, Scottsdale, Arizona, November 16-19, 2003.*

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