CONTS

Assessment Using Technology: A Case Study in Computer Aided Drafting

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Abstract

This paper is a case-study report about assessing with technology in a small (n=12) middle school mathematics class. The goal was to assess students understanding of proportional reasoning, in a problem based approach, using a Computer-Aided Drafting program for creating Lego™ structures (MLCAD). Students first explored the proportion concept on a concrete level through the comparison of different scale building materials. To demonstrate their understanding of proportional reasoning, students were guided to: (1) create a design on a computer drafting program and give dimensions of the finished product in the three scales of building materials, (2) build a structure based on the design given to them by a peer. Project assessment consists of two parts, the student's computer aided design and predicted measurement correctness and their ability to accurately build a structure from a given design, or find possible flaw in that design. Both quantitative and qualitative data available are analyzed in the spirit of naturalistic research paradigm. Additional deliberations include consideration of information technology skills and concept developed, emphasizing those necessary for utilizing computer algebra systems (CAS).

Introduction

Paradigm shift in teaching and learning induced by new discoveries in the theory of learning as well as emerging technologies contribute to the view that the learning environment in school mathematics is changing into a more technological one. Information and communication technology (ICT) integration is bringing new challenges to teachers' understanding of key mathematical ideas and how to teach them to new generations of pupils born and growing up surrounded with emerging technologies. For many teachers, understandings of these ideas are grounded in the ways they have learned them before this paradigm shift. They are aware of current changes and many of them are involved in the processes of these changes in their schools (Alagic, 2003).

This paper reports on a project, utilizing Lego™ - based computer-aided drafting, facilitated in a middle-level mathematics classroom. The goal was to increase students understanding of proportional reasoning, geometric similarity, and abstract spatial relations utilizing easily accessible technology-based tools. The students completed several parts of the project exploring and experimenting with the geometric relationships between three different sizes of Lego™ bricks. The culminating assignment was a required design on a computer-aided drafting program (MLCAD, computer aided design created specifically for Legos™). During this process the students had opportunities to problem solve and develop additional abilities and skills, such as visualization, connections between two-dimensional representations and three-dimensional structures, computer-based modeling, and problem solving. Parts of this study, focused on developing an understanding of geometric similarity through visualization are reported in Rayl (2004).

In general terms, the topic of proportional reasoning was chosen for its all-encompassing content. Proportional reasoning is one of the cornerstones of high school mathematics and algebra, the National Council of Teachers of Mathematics states that students' proportional reasoning ability "is of such great importance that it merits what ever time and effort must be expended to assure its careful development (NCTM, 1989, p 82). Future mathematical success in dealing with percent, ratio, rates, similarity, scaling, slope and linear equations hangs in the balance with students gaining proportional reasoning skills before they proceed on from middle school into algebra.

Lego™ Bricks were selected both for motivational reasons and to provide concrete experience with proportional materials, the inherent relationships between the different sizes of bricks helped facilitate the development of proportional knowledge.

To summarize, the unit on proportional reasoning was selected for this study because of (a) students lack of conceptual understanding of ratios, (b) an inherent idea that providing appropriate experiences for students can facilitate successful learning for all, and (c) motivational and practical reasons related to the CAD learning environment.

The Problem

The National Council of Teachers of Mathematics (NCTM, 2000) poses challenges for both teachers and students. Related to the proportional reasoning, NCTM states that "Instructional programs from pre-kindergarten through grade 12 should enable all students to apply appropriate techniques, tools, and formulas to determine measurements and apply transformations and use symmetry to analyze mathematical situations" (p. 232). Following this, for grades 6–8 expectations include the following indicators: (a) solve problems involving scale factors, using ratio and proportion, (b) describe sizes, positions, and orientations of shapes under informal transformations such as flips, turns, slides, and scaling, and (c) examine the congruence, similarity, and line or rotational symmetry of objects using transformations (p. 240).

In line with the above requirements and technology integration requirements (NCTM, 2000) problem-based learning (PBL) appear to be an appropriate approach to teaching and learning in today's classrooms; to "learn how to learn". Emphasizing both problem solving and acquiring core content is in the heart of PBL (Gallagher, 1997). As we implement more problem based learning activities in the classroom, our methods of assessment of the skills learned are often still based in a traditional paper and pencil test. However, if the students learn concepts through application, it only seems prudent to test their knowledge through a problem-based assessment. The challenge then is to create problem-based learning units that also serve as assessment tools. Lego™ Bricks were selected both for motivational reasons and to provide concrete experience with the concepts of *proportional reasoning*.

Review of the Literature

Relevant literature for this study was narrowed down to selecting (a) framework for instruction in mathematics classrooms, to include discovery/problem-based learning approaches and motivational factors, (b) conceptual orientation in technology-oriented environment and (c) appropriate research paradigms. The following findings shaped the approach to both this study and this report.

Framework for Instruction

Problem Based Learning. PBL, at an essential level, is an instructional strategy that implements real-world scenarios as a vehicle for student learning through problem solving. The meticulously constructed open-ended problems combine curriculum with appropriate resources to develop essential content knowledge through the use and development of critical thinking skills. Students work to seek solutions to problems and more importantly to develop skills necessary for independent learning (Gallagher, 1997). The ability of students to work together takes a very significant place in PBL effectiveness (Peterson, 1997). Problem-based learning also benefits student motivation to learn and resource management skills (Moursund, Bielefeldt, & Underwood, 1997), the students want to learn new concepts to meet new challenges and they must learn to use time and effort wisely to complete a solution.

Van Hiele's Educational Theory. Van Hiele (1986) identifies a hierarchy of levels of thinking: Recognition/Visualization, Analysis, Informal Deduction, Deduction and Rigor. He emphasizes that despite some natural development of spatial thinking, deliberate instruction is needed to move students from one level to another or through several levels of geometric understanding and reasoning. In addition to describing levels of thinking, as guidance for facilitating instruction, van Hiele offers the following *stages/phases of learning:*

- *Information*: getting familiar with the domain of exploration
- *Inquiry and guided orientation*: exploring while guided by tasks with different relations of the "big picture"
- *Explication:* becoming conscious of the relations, trying to express them in words; describing properties of the concept
- *Free orientation:* learning by general/complex tasks to find their own way in the network of relations; recognizing by given properties: class inclusion; relations; implications
- *Integration:* building an overview of all they have learned of the subject; reflects on their action forming a new network of available relations

Conceptual Orientation. Students demonstrate conceptual understanding in mathematics when they provide evidence that they can (a) recognize, and generate examples of concepts, (b) use and interrelate varied representations of concepts via different tools, (c) know and apply facts and definitions, (d) identify and apply principles, compare, contrast, and integrate related concepts and principles, and (e) recognize, interpret, and apply symbols and terms used to represent concepts (NCTM, 2000). Focusing on multiple representations and connections among them in technology-oriented environment provides a rich resource for teachers facilitating learning and variety of experiences for students to acquire desired conceptual understanding (Alagic 2003).

Assessment. Assessment is recognized as a tool for making instructional decisions and enhancing students' learning. The Assessment Principle states that "Assessment should support the learning of important mathematics and furnish useful information to both teachers and students" (NCTM, 2000, p. 22). The National Research Council (1993) provides three guiding principles for assessment: Content – what is most important for students to learn; Learning – enhance learning and support instructional practice; Equity – support every student's opportunity to learn.

Technology-Oriented Environment. MLCAD was originally designed by Michael Lachmann, in 1999, for creating designs in Windows based software using Lego™ building materials. LDraw, a DOS based program for Lego™ design, already existed and Lachmann uses the existing parts libraries from LDraw for elements in MLCAD (Courtney, 1999). Lachmann maintains a website for his software company, were he provides free download access to his computer drafting program. The availability of his software and the user-friendly format of his program made it convenient and appropriate for educational use in this project. Lachmann has included MLCAD tutorials in eight languages on his site to encourage use by a diverse population. MLCAD allows the students to design with three interchangeable views and one three-dimensional perspective, which can be rotated for any viewing angle. The drag and drop parts bin permits students to quickly adapt to the virtual environment.

The research on using computer-aided design in middle school classrooms has been confined predominately to either technology courses or as a support for vocational classes. Studies have shown that designing in a virtual environment does not inhibit student project creativity (Michael, 2001), and there are various studies and reports about differing technology course curriculums and methods of implementation.

The Naturalistic Research Paradigm

The naturalistic research paradigm allows for continual modification of the research design, to allow for factors emerging during the process of researching and collecting data. It also focuses more on observations and data collection in the natural context of the classroom, without the need for control groups and educationally 'antiseptic' conditions. In fact, the context, or setting, of the research is a big part of understanding the population and the future applications of the research outcomes. Three research principles guide a naturalistic research study: (a) multiple viewpoints of an event are essential in order to understand the learner's existing base of knowledge, (b) connecting theory verification to theory generation and (c) studying cognitive activity in context (Moschkovich & Brenner, 2000).

The above brief summary of the literature review points to choices in the delivery of the selected curriculum relative to the existing context: Problem-based learning within van Hiele's educational framework with focused attention given to both formative and summative assessment in a CAD learning environment. Furthermore, it clarifies selection of an unobtrusive research paradigm setting in which data is collected along the way to inform instruction in the process of facilitating students' learning.

Design

Sample and Method of Population Selection

The research method for the study followed the naturalistic paradigm framework (Moschkovich & Brenner, 2000). The study was conducted in a public school seventh grade “mathematics intervention” classroom in an urban Midwestern city. Students, participants in this study, were enrolled in this class in addition to their regular seventh grade curriculum in order to increase their skill level in mathematics. They are enrolled in this class in place of an elective course. In addition to an instructor, a paraprofessional was provided to enhance the personal contact time with the students and meet the requirements of students Individualized Education Plans (IEPs). Students who were enrolled in the intervention class had either failed the fifth grade district benchmark, and continued to perform poorly on mathematics assessment, or received a borderline score and also performed poorly on assessments after the benchmark. The district benchmark assessment is a facsimile assessment created by the school district to mirror the state mathematics assessment. There is not a district provided curriculum and the areas of focus are left entirely to the instructor’s discretion. Many activities are done on an individual basis depending on the needs of the students, in some cases however, there are topics which merit whole class instruction or activities. Students often work in collaborative groups and are given opportunities to experiment with concrete materials.

Initially the class consisted of 12 students. One student was expelled at the very beginning and never completed any of the activities, and another student was permanently suspended, she started the activity, but did not complete the final project. Another student transferred into the class from another school, and started the projects later and but did not complete the majority of the projects. Therefore, ten students, four females and six males, participated fully in this study. The class included one Asian-American student and two African-American students. Two of the students were receiving special education services and eight of the ten students were actually in the eighth grade and repeating seventh grade mathematics. The socioeconomic status of the group varied from poor to middle class.

Data Sources and Analysis

Measurement Instruments. District assessments on proportional reasoning were given before the students embarked on this project and after they had completed the project. Theses assessments were part of the standard mandated curriculum in the students’ regular mathematics class. The post-test was given the last week of school, so it also hinted at the retention level of the material.

The project also included an authentic assessment of the concepts learned in a final project designed to incorporate all the knowledge students had gained during the entire process. Student artifacts and reflections were also reviewed for formative information and instructional decision making throughout the progression of the projects. Instructor reflections, questions, and comments were also kept for informational purposes as well as defining future direction.

Design for Collecting Data. Lego™ Bricks were selected both for motivational reasons and to provide concrete experience. Activities were designed so that appropriate scaffolding of the process was provided for students. The instructional decision making was guided by principles of problem based learning, conceptual orientation in teaching mathematics and van Hiele's educational theory. Activities are presented here in the context of van Hiele's general theory of mathematics education, as closely as possible to actual process of facilitation of the project. This framework is also described in Rayl (2004). Additional information about the actual activities is included in the Appendix.

Information. The project started with a base exploration of three differing sizes of Lego™ Bricks (standard size, Duplo, and Lego™ Soft Bricks) and an exploration of MLCAD (Lachmann, 2003). The students were allowed to build small structures of eight to ten pieces and then replicate them in other sizes and design them in the MLCAD environment. Students worked to replicate their own designs and those of other students; they shared ideas and began to develop a common vocabulary. As they explored the bricks they began to discover that there were relationships between the different sizes.

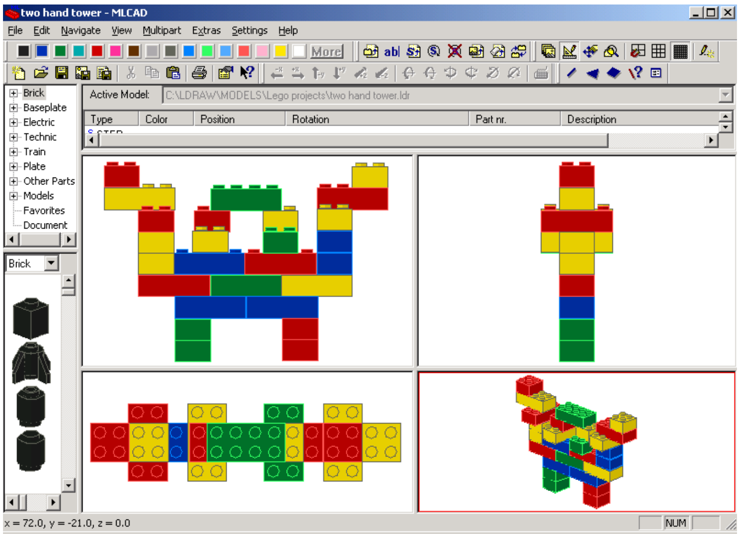

Figure 1: *MLCAD design screen with four perspectives of a student project*

Guided Orientation. Students familiarized themselves with the software and building materials then began a series of specific activities to shift their discovery toward the final project. Students were presented with specifically prescribed activities that concentrated on the proportional aspects of the materials. They began to ask questions and develop their own vocabulary to describe the materials and their proportional relationships. They recorded characteristics of different sizes and shapes of bricks for comparisons, and began a dialogue with their peers about their observations.

Explication. Through group interaction the students discovered a need for a common vocabulary and began comparing notes on the various terms used. The instructor pointed out appropriate vocabulary and expanded it to include additional information that will be needed. Students then began to communicate with each other, testing this new vocabulary and integrating it into their discussions and reflections.

Free Orientation: Lego™ Communication. Student explorations now became more complicated, they were required to take what they had learned and apply it to the current activities. They then were encouraged to draw conclusions about an abstract object by comparing it to a concrete object, instead of just experimenting with a concrete example. There was a higher level of precision involved and students were more challenged to associate what they had learned and to bring a specified task to completion. The first set of activities dealt with communicating building instructions to other students in various formats (i.e. verbal, written, pictorial.) The final step involved creating pictorial instructions for their model in the MLCAD software.

Free Orientation: Lego™ Proportion. Students explored pairs of models at different stations examining their relationships and discovering whether they were similar and then supported those conclusions with measurements and proportions. In this exploration students discovered the scale factors between the different sizes of Lego™ bricks.

Free Orientation: Lego™ Scaling. Students concretely designed and built structures, then measured the dimensions of the structure to the nearest millimeter. They then applied the proportional relationships they discovered in the previous exploration to predict the measurements of their models, which would be constructed in the two remaining sizes of bricks.

Integration: Final Project. Students now took everything that they previously learned and demonstrated an integrated knowledge about proportion and the building materials. They expressed their understanding of the topic through an integrated project in a virtual environment, without the need for concrete examples, and reflected on the entire activity and what they learned. Students designed a structure entirely in the MLCAD atmosphere, created the three perspective drawings with scale factors, and labeled the appropriate dimensions lines for all three scales of bricks. The students worked entirely without teacher assistance for the duration of the final project.

Teacher/researcher (the first author) kept copies of the materials used, assessments performed, students' reflections, and personal notes and reflections collected during the implementation of the project. Researcher (the second author) participated in the planning of the project and ongoing discussions about the implementation, instructional decision making and data analysis. In addition to the benchmark results included below (Table 1), assignments with grading rubrics, formative assessments, final projects, students' reflections, teacher's observation and reflections as well as researcher's notes recording conversations with the teacher were available for data analysis.

Results

Results are summarized in both quantitative and qualitative manner. Benchmark tests were administered by the school district, before and after the unit on ratios and proportions was implemented. Those constitute part of the quantitative data for the study and they are presented in the Table 1. Sample questions from the assessments are included in the appendix. Qualitative results are authors' interpretations of data collected, verified as much as possible through the available data/evidence.

Findings: Discussion

Students had previously covered proportional reasoning in their regular mathematics class inside of the standard curriculum but, for the most part, had done poorly on the district summative assessment (pretest results in the Table 1). However, posttest results (Table 1, second row) show that each student made significant progress. One student transferred late to the class and did not complete all of the prescribed activities. However, he (student I) made a progress in his score from 35% completed to 60% completed assessment.

Students	A	B	C	D	E	F	G	H	I	J	K
Pretest (%)	33	50	55	45	40	55	50	40	35	45	35
Posttest (%)	65	70	80	80	85	100	75	75	60	70	70

Table 1. Benchmark results

Two of the students (E & G) had played with the Lego™ materials at home and were experienced with building different structures and three others (B, C, & K) had some exposure at the houses of friends. Two students (D & H) had used them once in a vocational class to build a model and the remaining four (A, F, I, & J) had little or no experience with the materials, but had seen them or heard of them.

Most students were familiar with basic computer skills and software, word processing and internet research. None of the students had ever worked with a computer-aided design program of any kind and were not even aware that a design program specifically for the Lego™ building materials existed. Two of the students (C & J) were not comfortable with computer technology at all, and were resistant to the idea of using the design software.

Scaffolding of the instruction is described in more details in the Data Sources and Analysis section. Summative in-class assessment consists of two parts, the student's computer aided design and predicted measurement correctness and their ability to accurately build a structure from a given design, or find possible flaw in that design. For the final project students designed a structure entirely in MLCAD without using the concrete materials, printed instructions, produced the three perspective drawings, and labeled the appropriate dimensions lines for all three scales of bricks. The students worked independently for the duration of the final project. They could seek advice from each other, but not from the instructor.

Students completed their projects independently then worked with peers to build and critique each other and help fine-tune their projects. Five of the students, (students C, D, E, F, & H) didn't need any revision or had simple errors (i.e. forgot one measurement label, didn't label the drawing with which brick size it should have been.) The remaining five students had one or more errors that required a rework on their calculations or scaling. Three (A, J, & K) made measurement errors on their drawing which lead to calculation errors in their scaling that the peer editors discovered and had mistakes when reducing the ratio, and two (B & G) needed to reevaluate their dimensions. When they turned in the final project the results were impressive. Most of the students had made the appropriate corrections and had a flawless drawing; some of them didn't make minor corrections for whatever reason. One of the students (B) turned in only two of the three required perspectives; she couldn't seem to find the remaining drawing in her folder, however, her two submitted drawings demonstrated a clear understanding of proportion and scale factors. A few samples of student work from both ends of the spectrum are available within the Appendix.

Even though students did well on the assessments (both district benchmarks and in-class projects) and are able to apply proportional reasoning, after reading some student remarks, it is apparent that they are not always aware of their learning. Student E commented that the projects were entertaining, but that he did not see the point of them, even though his scores on the district created assessment on proportional reasoning show one of the largest increases. Moschkovich and Brenner (2000) when discussing the truth value of research in a naturalistic paradigm, consider the process as a form of member checking, to allow the participants to comment on the tentative findings of the research to check their perceptions and conclusions as part of the research process. A discussion of the findings of the project and the related test scores might help to better facilitate the future student's reflection into what they actually learned in the process of completing the projects.

How did students' experience shape their understanding?

We focus on two aspects: Students' understanding of proportional reasoning and their understanding/use of technology. As the students progress through activities, their ability to predict the dimensions of proportional objects became stronger. Instead of needing to prove it concretely, they learned to depend on what they experienced in previous attempts. After the scaling activity, some students stopped using a ruler to measure the structures they designed and built. They relied on their knowledge of the size of the building components and multiplied by the appropriate scale factors. As their peers took notice of this, the concept began to spread through class. A couple of students continued to use the ruler, but by the end of the project they were able to make predictions without having to see the concrete object. The rate at which they were liberated of concrete experiences illustrates the students differing levels. While some students adjusted naturally to proportional thinking, many students needed the scaffolded experiences, because it appeared that they were not until now thinking that way. To illustrate, one student even built a 2X2 soft brick from the Duplo to see if they were congruent, using three 2X2's and twelve 2X4's of the Duplo size, they created a structure that was congruent to the larger soft brick. The student's discovery was later included as one of the stations in the proportion station activity (Figure 2).

Figure 2: Left – 2X2 Lego Soft Brick & Right – congruent figure made from Duplos made by a student during discovery process

Figure 3. Symmetry and patterns in addition to proportionality

During the scaling activity, when it was her turn to use a ruler to check another student's measurement predictions moving from a standard brick to a soft brick, Student F replied, "I don't need a ruler, I know it's like 1 to 6, so I **know** it's right." She convinced me that her calculation was sufficient, and the ruler was superfluous. Another student always designed with symmetry and color patterns so the builder could more easily follow instructions and check their work (Figure 3).

.In the process of working on this project, the students' lack of in-depth computer skills was definitely a factor in the beginning. It appeared that often the student's comfort level with the CAD program was directly related to their ability to think about geometric properties abstractly. They would pile all the pieces of the set on the virtual design board and then begin putting them together into a structure. This made the process of adding steps to the design more complicated, and the students who used this method decided to try a more ordered approach in the next activity of the project.

Students' collaboration and communication emerged as a powerful support during the activities. They worked with each other quite often at the beginning of the project. They made their own pairings and they varied depending on the challenges that they encountered at the different levels. Over the course of the different projects one student emerged as a leader in the group. It wasn't the student that was originally the most adept at proportional reasoning, but the other students often worked their way up a "chain of command." Student F often had the "final word." By the end of the process, she could have explained the steps to another group of students. For another example, at the beginning of the project, one student (student J) was very vocal about her lack of abilities to use computers. However, a week later, when someone else encountered a roadblock, it was that student that ran to the computer saying, "I know what to do!" It was surprising how well the students became more independent learners in the provided environment. They usually asked their peers when they encountered trouble and they facilitated each other's learning better than the teacher had ever anticipated.

How did CAD environment help the process?

The inherently proportional relationships between different sizes bricks helped facilitate the development of proportional knowledge. With the added technology the project actually became easier to facilitate both in terms of assessment of the students learning and additional challenging avenues. CAD environment seems to push the students much farther up the ladder of understanding proportion and basic geometric reasoning. The CAD software has many features that made the *assessment* of the designs quick and easy. For instance, the piece count feature allowed the drawing to be opened in the program and quickly checked to make sure that the students had the correct combinations of building materials so that their structures could actually be built concretely with the delineated classroom sets of bricks that were available. The three-dimensional rotation window facilitated an interference check, to make sure that the pieces were connected without overlapping interference, and to check the overall dimensions of the students' structures. The student-printed final products, only took a glance to check for accuracy, because of the neatness provided by the computer-generated drawings. Overall, the technology facilitated quick assessment, whose conclusions were supported by the district administered unit tests over proportional reasoning.

Findings: Implications

This paper contributes in understanding of middle school students' learning about proportionality in a CAD learning environment. More generally, the paper provides a framework for conceptual orientation in teaching about proportionality, interweaving concrete pictorial and abstract representations while utilizing Legos™ and MLCAD. Furthermore, consideration is given to the development of skills and concepts necessary for successful work with computer algebra systems (CAS).

What next?

Extensions of the activities described in this paper may incorporate valuable mathematical standards and increase students' understanding of the mathematical connections linking adjustments in dimension with the resultant changes in area and volume. There are several functions in MLCAD such as piece count that would facilitate in investigating those effects. Students could generate models and then multiply the brick dimensions, then investigate the effects on the volume or surface area. It would also be interesting to see if some of the students could be encouraged to create all finished products on computer. Reflections could be pasted directly into drawings and dimension lines could be drawn right into the directions for a more professional finished product. That experience would better replicate a real-life rendering that an engineer would employ.

How is what students learned in CAD environment going to facilitate their further progress in technology-based environment, more specifically their work within computer algebra systems?

During this process the students are developing additional information technology abilities and skills, such as visualization, connections between two-dimensional representations and three-dimensional structures, computer-based modeling, and problem solving. One of the benefits of the CAD program was working in an abstract, but pictorially supported environment, and troubleshooting some types of problems that occur in computer algebra systems. Students had to navigate their way around various menus, trying different commands to achieve the desired effects. Other than the drag and drop method of adding a piece, and the hot button to add a step, the students found their own way around the MLCAD program. They quickly began to familiarize themselves with the organization of the various menus and commands. This is often a situation they encounter in computer algebra systems. Students also had to find a way to deal with sizing of windows and solve any problems they encountered when the viewing windows were too small to see the whole picture, or to large to see specific enough detail to correctly seat a brick into the currently forming structure.

Advocates of CAS in the classroom emphasize the need and opportunity to shift teachers' and students' attention from algorithmically-centered approaches to those that focus on conceptual understanding, with the computer taking on the burden of the algebraic manipulations. The goals of mathematics lessons and instructional approaches are changing. Classes using CAS often involve much more student writing than traditional courses. Courses based on CAS generally use a constructivist approach, and frequently incorporate some form of cooperative learning. All of these characteristics are visible in the approaches used in this study and we recognize them as prerequisites for the future work with CAS.

References

Alagic, M. (2003). Technology in the mathematics classroom: Conceptual orientation. *Journal of Computers in Mathematics and Science Teaching (JCMST),* 22(4), 381-399.

Courtney, T. (1999). MLCAD: Hip new Windows software uses LDraw parts library. Centralized LDraw Resources. Retrieved June 18, 2004 from http://www.ldraw.org/OLD/community/reviews/mlcad.shtml

Gallagher, S. A. (1997). Problem-Based Learning: Where did it come from, what does it do, and where is it going? Journal for the Education of the Gifted, 20, 4, pp. 332-62.

Lachmann, M. (2003). MLCAD (Version 3.00) [Computer software]. Vienna, Austria: LM-Software. Retrieved February 18, 2004 from http://www.lm-software.com/mlcad/

Lincoln, Y. & Guba, E. (1985). *Naturalistic Inquiry.* Beverly Hills, CA: Sage.

Michael, K. (2001). The effect of computer simulation activity versus a hands-on activity on product creativity in technology education. *Journal of Technology Education.*13, 1, p31-43.

Moschkovich, J. N., & Brenner, M. E. (2000). Integrating a naturalistic paradigm into research on mathematics and science cognition and learning. In A. E. Kelly & R. A. Lesh (Eds.), Handbook of research design in mathematics and science education (pp. 457-486). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Moursund, D., Bielefeldt, T., & Underwood, S. (1997). Foundations for the road ahead: Project-based learning and information technologies. Eugene, OR: ISTE.

National Council of Teachers of Mathematics. (1989). Curriculum and evaluation standards for school mathematics. Reston, VA: NCTM.

National Council of Teachers of Mathematics. (2000). Principles and standards for school mathematics. Reston, VA: Author. (http://standards.nctm.org/document/, retrieved June 2, 2004)

National Research Council. (1993). *Measuring what counts: A conceptual guide for mathematics assessment.* Washington, DC: National Academy Press.

Peterson, M. (1997). Skills to enhance Problem-based Learning. *Med Educ Online [serial online] 2, 3.*

Rayl, N. (July 2004). Lego Design and Computer-based Drafting: Geometric Similarity. Bridges for Teachers Teachers for Bridges. Winfield, KS, August 2004.

Van Hiele, P. (1986). *Structure and Insight: A Theory of Mathematics Education*. Academic Press, Inc.

Waters, Robert and McCracken, Michael, *Assessment and Evaluation in Problem-Based Learning,* Frontiers in Education Conference, Pittsburgh, PA, Nov 1997. (Retrieved June 2, 2004, http://fairway.ecn.purdue.edu/~fie/fie97/papers/1454.pdf).

APPENDIX

Lego™ Communication

- ☐ Level 1

  You and your partner must sit on opposite sides of a visual barrier. One student (student 1) will have a structure built. Their partner (student 2) must then replicate the structure without looking at student 1's structure. Student 1 will give verbal directions to student 2 so that they can build the duplicate structure. Neither student may look over the barrier to what the other student has built or is building. Student 2 may ask questions but they cannot 'show' each other anything.

  After you have completed this exercise you need to write a reflection over any roadblocks you encountered, what would have made this exercise simpler, what made this exercise more difficult, how would you change the way you approach the activity the next time you complete it?

- ☐ Level 2

  After your partner has successfully built your structure you must then try to create written step-by-step instructions for someone else to follow and build your structure. Refer to your reflections from Level 1 to make your directions as easy to follow as possible. After you have completed the instructions level you can trade and check directions with someone other than your partner from Level 1. If the directions are not clear enough you need to discuss with the builder you chose and make the necessary alterations.

  Once someone has successfully replicated your structure you need to write a reflection over the process of writing instructions. Compare the results and successes to that of giving verbal instructions (as in Level 1) while someone is actually building the structure. What roadblocks did you encounter, what would have made this exercise simpler, what made this process more difficult, how you would change the way you approach the activity the next time you complete it? How does this Level compare with Level 1?

- ☐ Level 3

  You can now design your structure on MLCAD. Make sure to insert the necessary steps so that you do not add too many bricks at one time. After you have finished designing your structure, save your file and save the picture of each step. Insert the steps into a word document and print your instructions. Trade instructions with another student that has not previously worked with you on your structure and have them check your drawings.

  Once someone has successfully replicated your structure you need to write a reflection over the process designing visual instructions. Compare the results and success to that of giving verbal instructions (as in Level 1) and written instructions (as in Level 2). What roadblocks did you encounter, what could have made this exercise simpler, what made your current project more difficult, how you could change the way you approach the activity the next time you complete it? How does this Level compare with Level 1 and Level 2?

Lego™ Proportion

Using a millimeter ruler you must move through each station and measure the two objects at each station and find the proportion between the two objects. Decide if the objects are similar or not similar.

Object One | Object Two

- ☐ Station 1
  - ☐ Similar
  - ☐ Not similar
  - ☐ Reason?
- ☐ Station 2
  - ☐ Similar
  - ☐ Not similar
  - ☐ Reason?
- ☐ Station 3
  - ☐ Similar
  - ☐ Not similar
  - ☐ Reason?
- ☐ Station 4
  - ☐ Similar
  - ☐ Not similar
  - ☐ Reason?
- ☐ Station 5
  - ☐ Similar
  - ☐ Not similar
  - ☐ Reason?
- ☐ Station 6
  - ☐ Similar
  - ☐ Not similar
  - ☐ Reason?

Write a reflection on what you discovered after comparing several different sizes of bricks. Can you draw any conclusions from your discoveries? What are the challenges you encountered in your measurement? What are the challenges you encountered in your calculations? Do you have any tips for students who would complete this activity at another time?

Lego™ Scaling

- ☐ Level 1
  - ∇ Build a unique structure using the basic 26 pieces in a set
  - ∇ Record the measurements of your structure to the nearest millimeter, include:
    - o Length of entire structure
    - o Width of entire structure
    - o Height of entire structure
    - o Length of base
    - o Width of base

- ☐ Level 2
  - ∇ Use the scale factors you discovered in *Lego™ Proportions* to predict the dimensions of your structure in the other two standard sizes of Lego brick

Size____________ Size___________

Length of entire structure
- o Width of entire structure
- o Height of entire structure
- o Length of base
- o Width of base

- ☐ Level 3
  - ∇ Build two other student's structures using their model (record and initial on their sheet)
  - ∇ Record their measurements of your structure to the nearest millimeter

Size _________ Size ____________

- o Length of entire structure
- o Width of entire structure
- o Height of entire structure
- o Length of base
- o Width of base

- ☐ Level 4
  - ∇ Write a reflection on what you learned, including:
    - o Challenges in measuring? How could you have been more exact?
    - o Were your predictions close to the actual measurements?
    - o What would you change? Or keep the same?

Write a reflection on what you learned, including the challenges in measuring, how could you have been more exact, were your predictions close to the actual measurements, what would you change, and what would you keep the same?

Lego™ Final Project

- ☐ Level 1
  - ∇ Design a unique structure on MLCAD using the basic 26 pieces in each set
  - ∇ Rotate at least six bricks to create a structure that is more than two studs wide
  - ∇ Insert steps where appropriate
  - ∇ Insert the steps into a word document to create instructions.
  - ∇ Print three perspective drawings with scale factors
  - ∇ Label the three perspective drawings with the actual measurements from the three standard sizes of Lego bricks.

- Level 2
  - Build three other student's structures from their directions
  - Measure each structure and compare with the drawing specifications
  - Submit a review of each design with a critique including:
    - Positives and negatives in instructions
    - Accuracy of projected dimensions
    - Accuracy of scaling factor
    - Overall ease of design completion

- Level 3
  - Review critiques from other builders
  - Revise specifications as needed
  - Write a one page reflection on the entire project, including:
    - Personal challenges and successes from the different levels
    - What you learned from the reviews of your design
    - What you learned in critiquing other students designs
    - What would you change? Or keep the same?
  - Submit Project Cover Sheet, primary drawings and specs, amended drawings, if needed, and reflections

All projects will be graded on their instruction design, build-ability, accuracy of specifications, accuracy of scale factors, & quality of your critiques for three of your peers.

Sample Questions from district proportional reasoning assessments

12.5% of 40 is what number?

What percent of 4500 is 54?

Sydney and Sara bought a disco ball for their end-of-year party. At Electronic Boutique, they found one on sale marked $21 off the original price of $70. What is the percent of discount?

Old Navy is having a sale this weekend. Everything is discounted 20%. The Early Bird Special, if you shop between 7 am and 10 am on Saturday, is another 25% off the sale price. Find the regular price of a dress that costs $33 during the Early Bird Special.

What is the probability that a month will begin with the letter J?

At the same time of day two trees cast shadows of 18 feet and 36 feet, if the tallest tree is 54 feet, how tall is the second tree? **SHOW YOUR WORK!**

Yesterday, Chelsea brought a 16 inch Laffy Taffy rope to school. Every hour she took off three inches of taffy, she gave one inch to herself, and one inch each to two different friends. **How many friends got taffy from Chelsea yesterday**?

Change each of the following to a fraction in simplest form:

.65 56%

Solve each of the following proportions. Show your work.

$$\frac{2}{7} = \frac{x}{21}$$

$$\frac{3}{x} = \frac{4}{9}$$

Which of the following statements are true?

yes no ¼ = 25% = .25
yes no 1/8 = 87.5% = .875
yes no 2/3 = 66 2/3 % = .66
yes no 80/80 = 800% = .800

Mrs. Jones wants to enlarge this picture of her sons. If the **dimensions** will be four times larger than shown, how many times larger will the **area** of the picture be? (See Figure 4)

2 in

1.5 in.

Figure 4. *Picture of Mrs. Jones sons for test question*

Nicholas's great-papa buys a new sailboat for $18,750 including tax. He only makes a 25% down payment on the boat and finances the remaining amount for 18 months at 0% interest.
Use the information given to answer the following questions. Then explain how you found your answers. **<u>Show all work</u>**, including mental math and work done on a calculator.

a. How much was his down payment?
b. How much is his monthly payment? (Round to the nearest penny.)

Sample Student Work

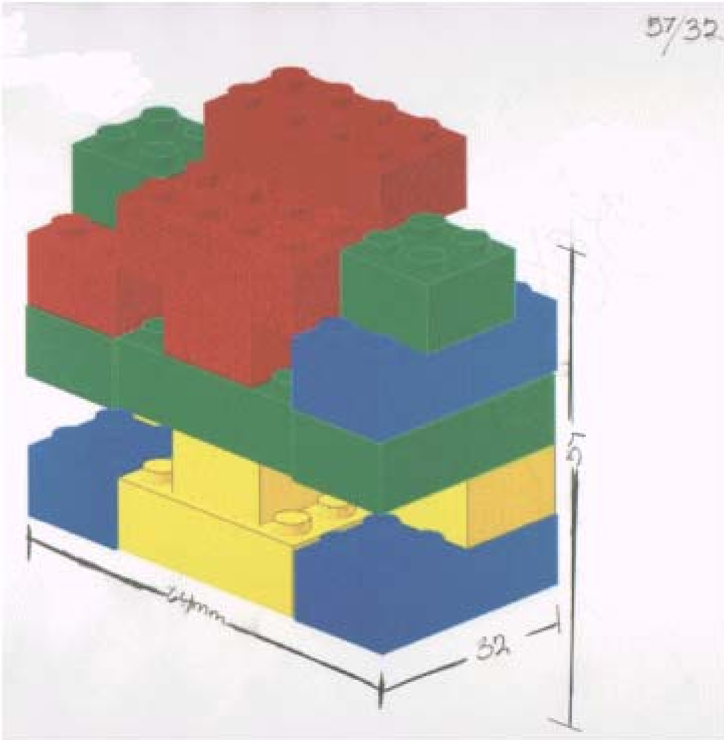

Figure 5. *One final project perspective of student K – missing some measurement labels, and the size of brick*

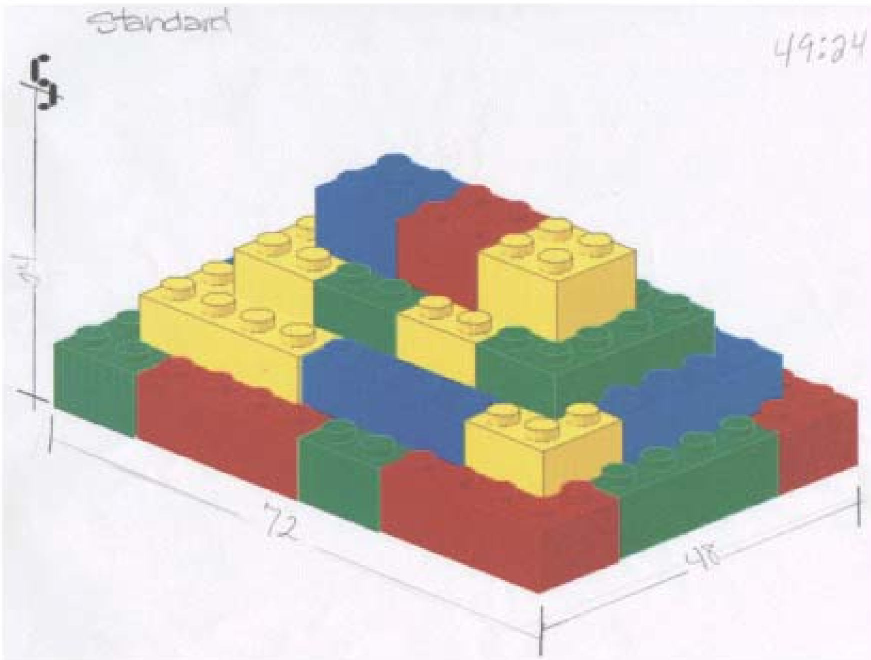

Figure 6. *One rough draft project perspective of student G –incorrect measurements & missing measurement labels*

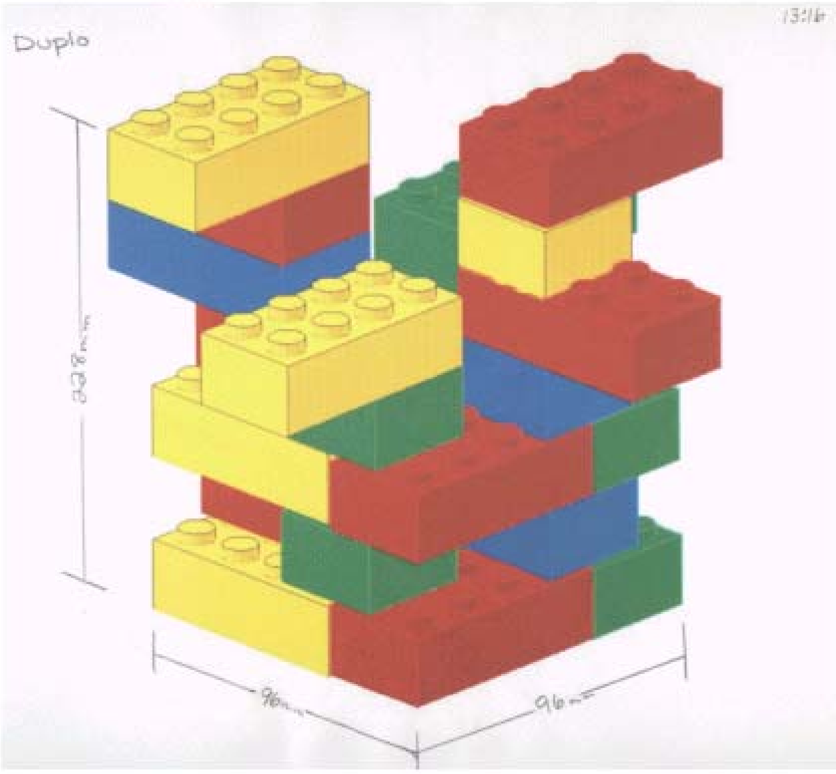

Figure 7. *One final project perspective of student F – all elements present and correct*