AC 2012-4338: CHANGE IN ELEMENTARY STUDENT CONCEPTIONS OF ENGINEERING FOLLOWING AN INTERVENTION AS SEEN FROM THE DRAW-AN-ENGINEER TEST

Mr. Ronald L. Carr, Purdue University

Ronald Carr serves as the P-12 Engineering Education Research Fellow for the Institute for P-12 Engineering Research and Learning (INSPIRE) in Purdue University's School of Engineering Education. Carr is a doctoral student in the Learning Design and Technology program through the Purdue College of Education and holds a master's degree in educational studies/gifted and talented education and a bachelor's degree in elementary education from Purdue. In addition to curriculum design related to problem solving and cognitive strategies, Carr's research interests include assessment of engineering design and "soft skills," assessment of engineering impact through STEM initiatives, integration of engineering into all content areas, instructional design and assessment of teacher professional development via online and face-to-face programs, and promotion of engineering through standards-based curriculum reform.

Prof. Heidi A. Diefes-Dux, Purdue University, West Lafayette

Heidi A. Diefes-Dux is an Associate Professor in the School of Engineering Education at Purdue University. She received her B.S. and M.S. in food science from Cornell University and her Ph.D. in food process engineering from the Department of Agricultural and Biological Engineering at Purdue University. She is a member of Purdue's Teaching Academy. Since 1999, she has been a faculty member within the First-year Engineering program at Purdue, the gateway for all first-year students entering the College of Engineering. She has coordinated and taught in a required first-year engineering course that engages students in open-ended problem solving and design. Her research focuses on the development, implementation, and assessment of model-eliciting activities with realistic engineering contexts. She is currently the Director of Teacher Professional Development for the Institute for P-12 Engineering Research and Learning (INSPIRE).

Change in Elementary Student Conceptions of Engineering Following an Intervention as Seen from the Draw-an-Engineer Test

Abstract

Change in elementary students' conceptions of engineering has been studied using the Draw-an-Engineering Test (DAET) prior to and following a curriculum intervention. This instrument asks students to draw an engineer doing engineering work and then write about what the engineer is doing, typically in a sentence or two. Children in participating grade 2-4 classrooms completed the DAET in a pre-post fashion during academic year 2010-2011. Classrooms were chosen based upon teacher participation in professional development in elementary engineering in a summer week-long academy in 2009 and three additional days in 2010. This study found the drawings at the beginning of the school year consistent with previous studies in which student conceptions rested heavily on manual labor occupations such as mechanics, builders and drivers. The results of the coding of the year-end drawings revealed over half of the participants' conceptions were design related and almost as many had moved away from the manual labor conception.

Introduction

Students' conceptions of engineering, and particularly elementary students, have been studied using the Draw-an-Engineer Test (DAET).[1–5] This instrument asks students to draw an engineer doing engineering work and then write about what the engineer is doing, typically in a sentence or two. Researchers have found that students associate engineering with fixing, building, and working on things; buildings and vehicles were the dominant artifacts in students' drawings.[6–8] In one study conducted at the start of a school year, prior to any engineering lessons, the DAET was used in conjunction with interviews to study elementary students' conceptions of engineering .[4]

The purpose of this study was to further analyze the effectiveness of teacher professional development and teacher practices through a simplified analysis of student drawings. The primary research question guiding this study was: How do students' conceptions of engineering change following an engineering curriculum intervention?

Draw an Engineer Test

The DAET emerged from the efforts of Mead and Metraux's 1957 study that identified children's' perceptions of scientists through questionnaires[9] as well as the Draw-a-Scientist-Test (DAST) study of 1966-1977[10]. The DAST and subsequent validation scales retain relevance as the line of study has found consistent results that have shown it as a valid instrument when triangulated with questionnaires, surveys, interviews and other measures (see Finson, 2002 for a comprehensive look at the history and validation of the DAST). Of particular importance to engineering educators are the results revealed through the DAST that have shown: 1) stereotypes were formed through media exposure[11]; 2) stereotypes are less present at the kindergarten and first grade ages[10]; 3) interventions were successful at changing student views of scientists[12] and 4) interventions positively affected self-efficacy and interest in science[9].

Knight and Cunningham[1] modified the DAST when developing the DAET and included four questions for students to answer in writing and one that prompted them to draw a picture of an engineer working. The results of the written and drawn parts of the test were similar to the DAST studies as they depicted common misperceptions of engineers, who were primarily depicted as building houses and bridges or fixing cars. In the study limitations, the researchers noted that the DAST and DAET capture a student's conception at only one moment in time. A follow-up study provided sixteen images of people working from which students could choose representations of engineers.[6] Supporting the existing DAET results, the researchers found: "When asked to choose what kinds of work engineers do, over half of the students indicated that they thought engineers repair cars (78.4%), install wiring (75.2%), drive machines (70.7%), construct buildings (69.7%), set up factories (67.1%), and improve machines (63.5%)." [6, p.4]

A DAET study of gifted children participating in a summer enrichment program that included science and engineering courses found that results from student drawings were supported by interview data.[5] While some children in this small sample thought engineers design, fix, build, test and invent things, physical labor was the highest occurring conception, even though 55% of the children reported knowing an engineer. Another study of middle school participants supported previous DAST and DAET findings that children conceive of engineers as males performing lower-level mental tasks or manual labor in the outdoors.[2]

An in-depth coding system currently being developed provides a nearly complete representation of engineering drawings; the system includes human descriptives, technology awareness, systems knowledge, engineering fields, and understanding of engineering tasks.[8] Recent results from triangulation of the coding system with drawings and interviews adds to the validity of drawings serving as reliable representations of basic student conceptions of engineering.[3,8]

Methods

In this study, engineering is being integrated into grades 2 to 4 in elementary schools in a single large district in south central United States. Teachers were provided with professional development in elementary engineering in a summer week-long academy in 2009 and three additional days in 2010. Children in participating classrooms completed the DAET in a pre-post fashion during academic year 2010-2011 with pre-data collection in August 2010 and post-data collection in May 2011. Data for this paper is drawn from this collection. Coding was done on 346 drawings from 173 students from 19 classrooms. Student drawings were not used in this study if students were without consent and assent, if either a pre or post drawings were missing due to student absence or relocation, or if the student had been tracked in a previous year.

In the professional development, the teachers participated in classroom-ready activities designed to increase technological literacy and knowledge of the roles and types of engineers. Teachers were engaged in mathematical modeling activities and engineering challenges to encourage the integration of math and science. The Model Design Process was presented in detail and teachers worked in teams to solve open-ended problems, or Model Eliciting Activities.[13] *Engineering is Elementary* (EIE) units from the Museum of Science, Boston[14] and a modified version of the EIE engineering design process were used across grade levels to provide consistent engineering curricula. Additional engineering design challenges and technology knowledge activities added to the problem solving emphasis.[15] Teachers were then asked to utilize a minimum of one engineering design activity and one EIE unit during the year in their classrooms.

In the study preceding this one[16], qualitative analysis of drawings identified four distinct categories of characteristics students assigned to an engineer based on the actions performed by the engineer and artifacts used by the engineer. These categories were laborer, mechanic, technician, and designer. Conceptions of engineering results using this coding scheme have not been reported for DAET drawings collected before and after an elementary classroom engineering intervention. Modifications of that coding scheme were necessary as a wider variety of designer drawings were identified in this data collection. Such things as teams, steps in an engineering design process, science concepts, and school and industry contexts began to appear in the post drawings.[16]

The primary coding sought to classify the type of activity that the student conceived engineers are involved in. The previous coding considered laborer, mechanic, technician and designer. The updated list of categories used in this coding are:

- Designer – Designing or improving objects or processes, usually portrayed by drawing plans or performing specific parts of the engineering design process, an implied client or public use is intended.
- Technician – Computer or electronic technician portrayed by a person fixing something electronic.
- Design/Create Single – Hobbies, crafts, and designs for personal use or making one object for a specific person.
- Tradesman – Carpenters, plumbers, welders, etc. where a person is fixing something that is not mechanical.
- Mechanic – Fixing a vehicle, engine, machine or something else that is mechanical.
- Laborer/Builder – Building houses, roads or buildings through physical labor and other forms of manual labor not covered in other categories.

- Driver – Drives or operates any type of vehicle including, but not limited to, cars, trains, trucks and airplanes.
- Object/Engine – A person is not drawn and an object is intended as the "engineer".
- Factory/Make quantity – Factory workers or individuals making a quantity of an item without the notion of design or process indicated.
- Other Professions – Teachers, lawyers, doctors, policemen, scientists and other professions.
- Other/None – Student was off-task or drawing is not discernable.

The drawings were also coded for instances of: Drawings or Blueprints, referring to the Engineering Design Process, and mentioning or drawing Class Activities. Drawings or Blueprints also included lists of supplies, and in one case, a computer illustration. Engineering Design Process included written references to the design process, words written in the drawings, and, in many cases, posters drawn on walls of the Engineering Design Process from EIE that would be found in participant classrooms. Class activities included teacher reported design challenges and activities from EIE units.

Data analysis was conducted using Nvivo qualitative data analysis software in which sections of each DAET could be highlighted and coded for multiple codes. Initial open-ended coding of 93 drawings from previous years' data was found to have 88% overall agreement between three coders using a traditional calculation based on percent agreement (Agreement % = Agreements/Total Codes). Final coding by two coders yielded a percent agreement of 97.63% (κ = 0.860). A third coder was used for comparison with both coders on 30 drawings for 98.6% agreement (κ = 0.923). A Kappa value (κ) above 0.80 shows near perfect agreement when accounting for chance agreement.[17]

Results & Discussion

Table 1 illustrates the movement of grades 2-4 participants' conceptions from pre to post. The total column to the far right represents the number of drawings that were coded in each conception category at the beginning of the school year. The total row at the bottom of the table represents the number of conceptions coded at the end of the year. Specific movement can be seen by comparing pre conceptions in the left column with post conceptions in the top row. As an example, the matrix shows the most frequent move - 24 students (circled) that began with the conception of an engineer as a Mechanic moved to the conception of Designer in the post drawings (See Appendix A, Sample 1 for an example). The second most frequently identified movement is 20 students that moved from Laborer/Builder to Designer (See Appendix A, Sample 2 for an example).

Table 1. DAET conception of engineer for grades 2-4, 2010-2011 (pre-post).

		POST CONCEPTION										
	Post Conception → *Pre Conception ↓*	**Other**	**Other Prof.**	**Factory / Qty**	**Driver**	**Labor/Build**	**Mechanic**	**Trade**	**Design Create Single**	**Tech**	**Designer**	*Pre-Total*
PRE CONCEPTION	*Other*	3				1	2	1	3		2	*12*
	Other Prof.	1	2	3	1	3	1		1	2	8	*22*
	Factory/ Make Quantity										2	*2*
	Object						1					*1*
	Driver		1		1	3	3		4		8	*20*
	Laborer/ Builder		4			5	1		3	1	20	*34*
	Mechanic	1	4	2	2	7	11	2	6		24	*59*
	Tradesman							1	1		4	*6*
	Design/Create Single		1			1			2		4	*8*
	Technician										4	*4*
	Designer								1		4	*5*
	Post- Total	**5**	**12**	**5**	**4**	**20**	**19**	**4**	**21**	**3**	**80**	173

From pre to post intervention, there were changes in each category. The number of Designers increased by 75 from 5 in pre to 80 in post. Fewer Mechanics (-40) appear among the post drawings, 59 in pre and 19 in post. . Following Mechanic, the greatest decreases were found for Driver (-16), 20 in pre and 4 in post, and Laborer/Builder (-14), 34 in pre and 20 in post (See Appendix A, Sample 3 for an example).

Looking across grade levels (Table 2), from pre to post, there is a migration to Design/Create Single in second and fourth grades rather than a jump to a designer conception. This may suggest an incomplete learning progression since students indicated an understanding that engineers design yet fell short in indicating a specific application of design. The results also show higher than expected numbers for Laborer/Builder (20) and Mechanic (19) in the post drawings.

Table 2. Conception of engineer by grade level 2-4, 2010-2011 (pre-post)

Conception	**Pre 2nd**	**Post 2nd**	**Pre 3rd**	**Post 3rd**	**Pre 4th**	**Post 4th**	**Pre Total**	**Post Total**
Other Prof.	7	3	5	3	10	6	22	12
Driver	7	1	3	2	10	1	20	4
Laborer/Builder	15	5	2	2	17	13	34	20
Mechanic	13	5	9	5	37	9	59	19
Design/Create Single	0	5	1	1	7	15	8	21
Designer	1	30	0	7	4	43	5	80

Table 3 shows the presence of engineering related aspects coded in the DAETs. Of the 102 instances, 98 were found in the post drawings. The inclusion of drawings and blueprints (4 in pre and 35 in post) were all found in DAETs coded Designer (35), Laborer/Builder (3) and Design/Create Single (1) show evidence of planning being involved in these activities.

The ability to transfer engineering design concepts beyond classroom activities is evidenced by 58 of the 80 drawings that were coded as Designer referred to design activities that were not done as in-class activities. For example, rather than drawing an engineer designing a windmill, which is one of the classroom activities, those students drew engineers designing other things such as a bicycle with a built-on-piano, a new clock, rat poison, or a safer playground.

Table 3. Engineering related aspects found in DAET in grades 2-4, 2010-2011 (pre-post).

	Class Activities	Engineering Design Process	Drawings or Blueprints
Pre	0	0	4
Post	32	31	35

Conclusion

The simplified coding process used to determine the primary conceptions showed findings in the pre-intervention drawings similar to what has been found in the previous research.[1-8, 16, 18] This lends credibility to the overall results. The primary goal of this work was to continue to find ways to use the DAET that are meaningful but manageable for measuring the impact of engineering integration in elementary classrooms. This instrument is age-appropriate and provides rich data but the data can be difficult to analyze. This modified coding scheme provides a simple way to measure the impact of a classroom engineering intervention. This coding scheme will be further tested with a larger data set. Those results will then be compared with the results of the in-depth coding system[8] on the same large data set for validation and correlation.

The results from the study show evidence of effectiveness of the teacher professional development and the curriculum integration by the teachers in terms of changing student conceptions of engineering. Not only can this coding lend to the evaluation of current teacher professional development, but can also contribute to future program and curricula development. Since teachers involved in early engineering teaching efforts in Massachusetts were found to have similar misconceptions to those with student populations[18], meaningful experiences in engineering, such as is involved in this program through engineering design and mathematical modeling, can help both teachers and students overcome misconceptions or incomplete conceptions[19].

Curriculum can be designed to build a conception of an engineer that is creative, works in teams, solves problems, and designs technology using science and mathematics [4]. Standards from the

National Research Council and the International Society for Technology in Education call for experiences such as are provided through this project to build technology understanding and to increase design understanding [4]. Furthermore, the need for curriculum design and teacher preparation in pre-college engineering are at a premium as engineering gains its place in state standards, probable national core science standards and in national testing.[20]

To encourage acceptance of engineering into curriculum design and classroom practices, programs such as this engineering teacher professional development need to have empirical data from assessments to measure their effectiveness.[21] Teacher and administrative resistance can be overcome once engineering has its place in standards and effective results can be demonstrated.[22] While evidence continues to support the validity of the DAET and DAST as stand-alone measures of student conceptual understanding[1-3, 5, 6, 8-12], a simpler coding such as this study's coding system, can make the DAET a more viable option for assessment of the most basic, yet essential engineering education construct: What does an Engineer do?

Acknowledgement

This work was made possible by a grant from the National Science Foundation (DLR 0822261). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Bibliography

1. Knight, M., & Cunningham, C. M. (2004). Draw an Engineer Test (DAET): Development of a tool to investigate students' ideas about engineers and engineering. *Proceedings of the 2004 American Society for Engineering Education Conference & Exposition, Salt Lake City, UT.*
2. Fralick, B., Kearn, J., Thompson, S. & Lyons, J. (2009). How middle schoolers draw engineers and scientists," *Journal of Science Education and Technology*, 18(1), 60-73.
3. Dyehouse, M. Weber, N., Kharchenko, O., Duncan, D., Strobel, J., & Diefes-Dux, H. (2011). Measuring students' perceptions of engineers: Validation of the draw-an-engineer (DAET) coding system with Interview Triangulation. In W. Hernandez (Ed.), *2011 Research in Engineering Education Symposium: Book of Proceedings* (pp. 622-635), Madrid, Spain: Universidad Politécnica de Madrid. ISBN 978-84-695-2615-6
4. Capobianco, B., Diefes-Dux, H.A., Mena, I., and Weller, J. (2011). What is an engineer? Implications of elementary school student conceptions for engineering education, *Journal of Engineering Education*, *100*(2), 304-328.
5. Oware, E., Capobianco, B., and Diefes-Dux, H.A. (2007). Gifted students' perceptions of engineers – A study of students in a summer outreach program. *Proceedings of the 2007 American Society for Engineering Education Conference & Exposition, Honolulu, HI.*
6. Cunningham, C. M., Lachapelle, C. P., & Lindgren-Streicher, A. (2005). Assessing elementary school students' conceptions of engineering and technology. *Proceedings of the 2005 American Society for Engineering Education Conference & Exposition, Portland, OR.*
7. Capobianco, B., Mena, I. & Diefes-Dux, H.A. (2009). Significant cases of elementary student development of engineering perceptions. *Proceedings of the 2009 American Society for Engineering Education Conference & Exposition, Austin, TX.*

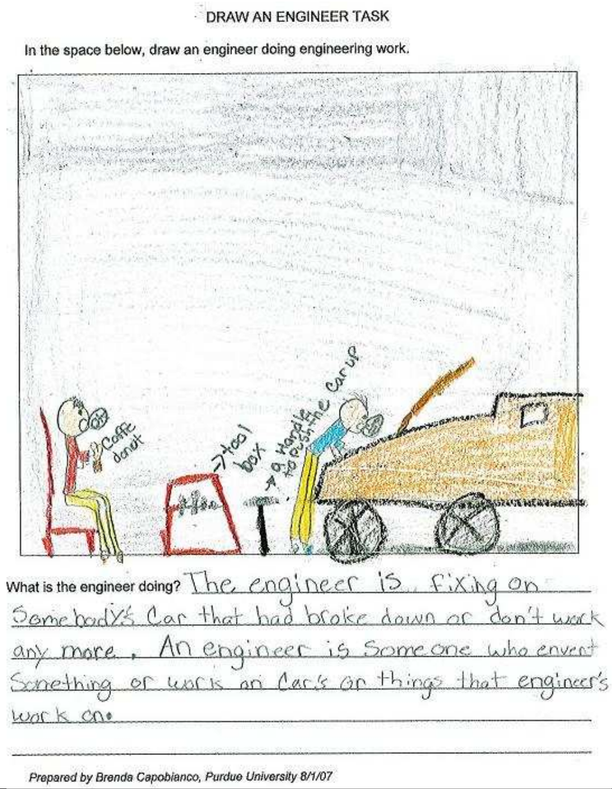
8. Weber, N., Duncan, D., Dyehouse, M., Strobel, J., & Diefes-Dux, H.A. (2011). The development of a systematic coding system for elementary students' drawings of engineers. *Journal of Pre-College Engineering Education Research (J-PEER)*, *1*(1), Article 6. Available at: http://docs.lib.purdue.edu/jpeer/vol1/iss1/6
9. Finson, K. D. (2002). Drawing a Scientist: What we do and do not know after fifty years of drawings. *School Science and Mathematics*, *102*(7), 335-345.
10. Chambers, D.W. (1983).Stereotypic images of scientists: The Draw-a-Scientist test. *Science Education*, 67(2), 255-265.
11. Schibeci, R. A. (1986). Images of science and scientists and science education. *Science Education*, *70*, 139-149.
12. Thomas, J. A., Pedersen, J.E., and Finson, K. (2001). Validating the Draw-A-Science-Teacher-Test Checklist (DASTT-C): Exploring mental models and teacher beliefs. *Journal of Science Teacher Education*, *12*(3), 295-310.
13. Zawojewski, J. S., Diefes-Dux, H., & Bowman, K. (Eds.) (2008). *Models and modeling in Engineering Education: Designing experiences for all students.* Rotterdam, the Netherlands: Sense Publishers.
14. Lachapelle, C. P., & Cunningham, C. M. (2007). Engineering is Elementary: Children's Changing Understandings of Science and Engineering. *Proceedings of the 2007 American Society for Engineering Education Conference & Exposition, Honolulu, HI.*
15. Carr, R.L. & Strobel, J. (2011). Integrating engineering into secondary math and science curriculum: Preparing teachers. *Proceedings of the Integrated STEM Education Conference 2011 (IEEE-ISEC 2011), Ewing, NJ.*
16. Diefes-Dux, H.A. & Capobianco, B.M. (2011). WIP: Interpreting Elementary Students' Advanced Conceptions of Engineering from the Draw-An-Engineer Test. *Proceedings of the 41st Annual Frontiers in Education Conference, Rapid City, SD.*
17. Viera, A. J. & Garrett, J. M. (2005). Understanding interobserver agreement: the kappa statistic. *Family Medicine*, *37*(5), 360-363.
18. Cunningham, C. M., Lachapelle, C. P., & Lindgren-Streicher, A. (2006). Elementary teachers' understandings of engineering and technology. *Proceedings of the 2006 American Society for Engineering Education Annual Conference & Exposition,* Chicago, IL.
19. English, L. D. & Mousoulides, N. G. (2009) Integrating engineering education within the elementary and middle school mathematics curriculum. *Proceedings of the 6th Conference of the European Research in Mathematics Education, Université Claude Bernard Lyon 1, Lyon, France.*
20. Strobel, J., Carr, R.L., Martinez-Lopez, N.E. & Bravo, J.D. (2011). National survey of states' P-12 engineering standards. *Proceedings of the 2011 American Society for Engineering Education Annual Conference & Exposition, Vancouver, BC, Canada.*
21. National Research Council. (2010). *Standards for K-12 Engineering Education?*. Washington, DC: The National Academies Press.
22. Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education*, *97*(3), 369-387.

Appendix A

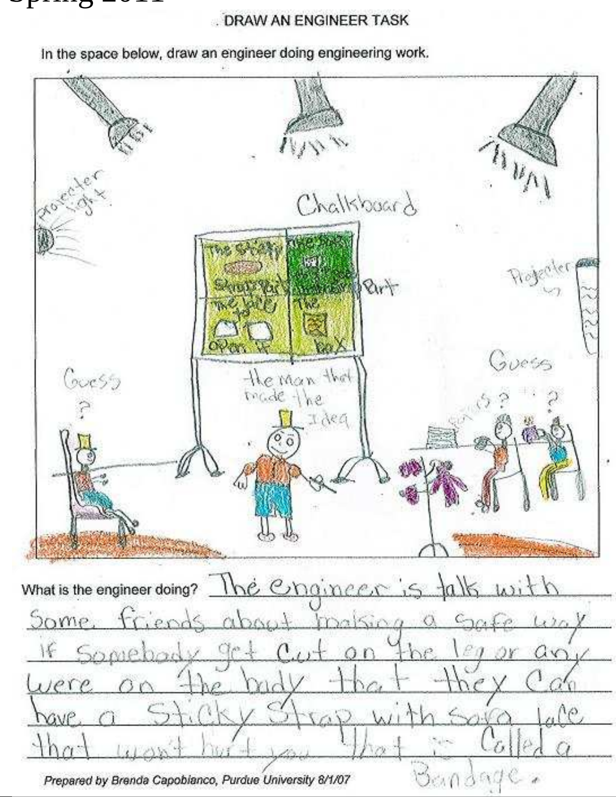
Student DAET Examples Grades 2-4, 2010-2011

Sample 1

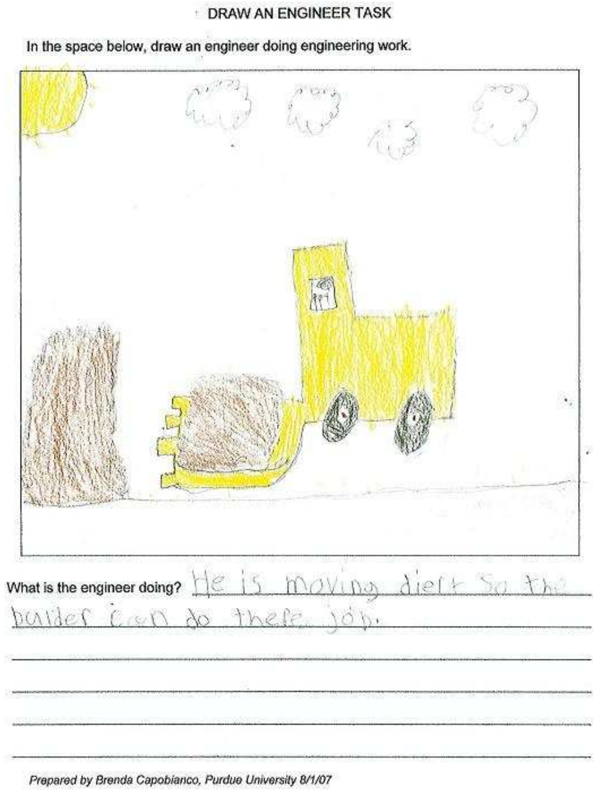
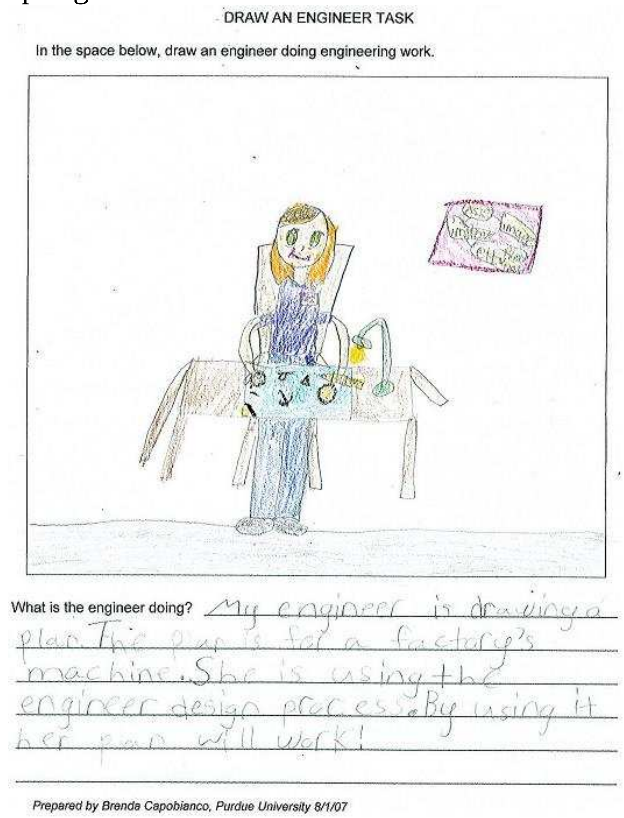
Fall 2010

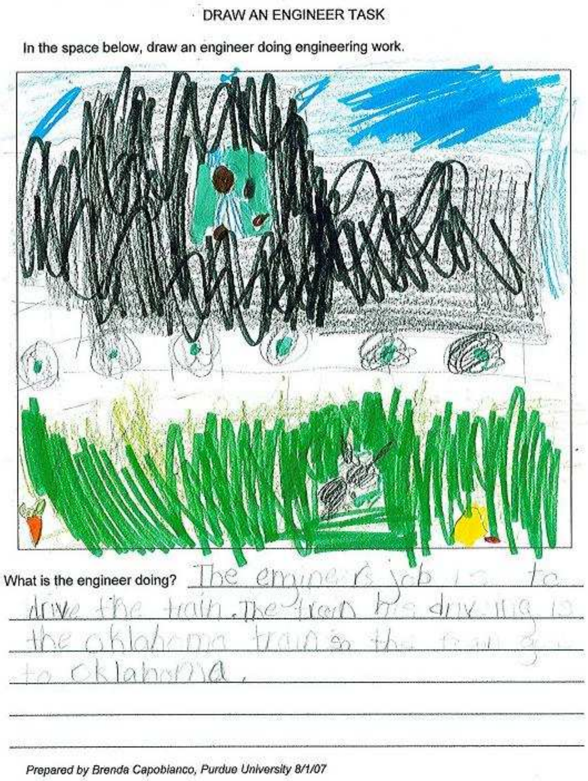
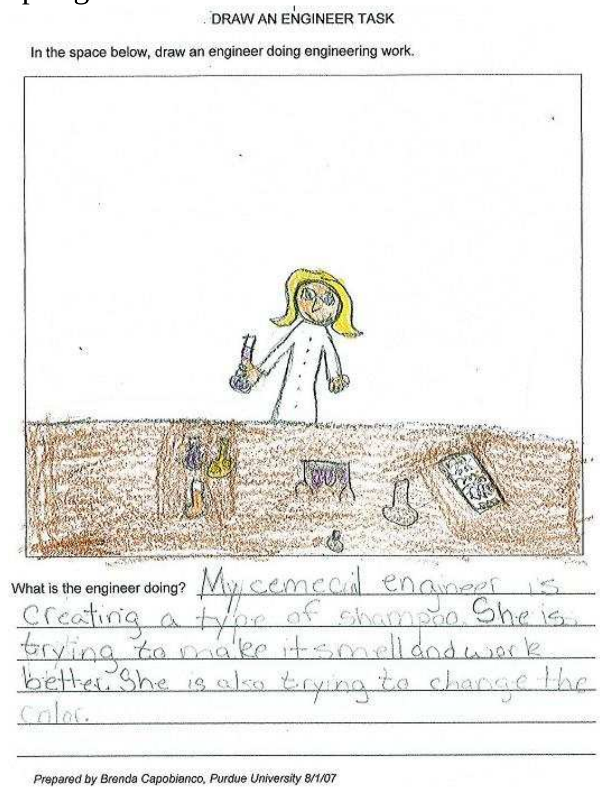


Spring 2011



Grade Four, Boy moved from **Mechanic to Designer** (pre-post). In Fall 2010 drawing, he wrote "The engineer is fixing on somebody's car that had broke down or don't work any more. An engineer is someone who envent something or work on cars or things that engineer's work on." In Spring 2011 drawing, he wrote "The engineer is talk with some friends about making a safe way if somebody get cut on the leg or any were on the body that they can have a sticky strap with sovo lace that won't hurt you that is called a Bandage."

<table>
<tr><td colspan="2">Sample 2</td></tr>
<tr><td>Fall 2010

</td><td>Spring 2011

</td></tr>
<tr><td colspan="2">Grade Three, Girl moved from Laborer/Builder to Designer (pre-post). In Fall 2010 drawing, she wrote “He is moving dirt so the builder can do their job.” In Spring 2011 drawing, she wrote, “My engineer is drawing a plan. The plan is for a factory’s machine. She is using the engineer design process. By using it her plan will work!” Notice that she has an EDP poster on the wall and a Drawing/Blueprint is present in the DAET.</td></tr>
</table>

<table>
<tr><td colspan="2">Sample 3</td></tr>
<tr><td>Fall 2010

</td><td>Spring 201


1</td></tr>
<tr><td colspan="2">Grade Two, Girl moved from Driver to Designer. In Fall 2010 drawing, she wrote “The engineer’s job is to drive the train. The train he’s driving is the Oklahoma train so this train going to Oklahoma.” In Spring 2011 drawing, she wrote “My chemical engineer is creating a type of shampoo. She is trying to make it smell and work better. She is also trying to change the color.”</td></tr>
</table>