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Longitudinal Profiles of Children's Conceptions of an Engineer*

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This study examines elementary school (grades 1–5) children's conceptions of an engineer as they progress from one year to the next over a three-year period. Data were gathered from three distinct cohorts of students progressing from grades 1 through 3, 2 through 4, and 3 through 5. Using the Draw-An-Engineer Test and semi-structured interviews, we explore children's conceptions before and after they engaged in engineering design-based lessons and furthermore, demonstrate how conceptual change occurred among distinct cohorts of children. Data were analyzed using grounded theory. Results indicated that children were more likely to invoke more fragmented conceptions at younger ages (grades 1 and 2) and more diverse and accurate conceptions as they progressed from grades 3 to 4 to 5. Retention of more accurate conceptions occurred among children at an older age. Consideration must be given to the development of high quality engineering design-based instructional materials and curricular resources that can capture children's naive ideas and furthermore, promote students' abilities to develop more meaningful, accurate understandings over time.

Keywords: engineering; elementary; conceptions; case study

1. Introduction

Exploring students' conceptions of an engineer has become increasingly popular and important in the fields of science, technology, and engineering education [1–5]. To capture students' conceptions, researchers have used a widely accepted tool called the Draw-An-Engineer-Test (DAET) [1, 3, 6]. Previous research indicates that students harbor misconceptions of engineers performing tasks such as planning or performing physical labor [1]. Common images include tools, cars and computers [4]. Missing from this valuable work is a longitudinal examination of students' conceptions. Considering children's cognitive development is both formative and malleable through pre-adolescent years, attention must be given to examining critically if and how students' conceptions may transform over time.

In this study we use the DAET accompanied by individual student interviews to learn more about what children's conceptions of an engineer are before and after they engage in engineering design-based lessons. Additionally, we explore if and how children's conceptions change over time. In this manner, we follow several cohorts of children as they progress from one grade to the next over three consecutive years and explore the construction and re-construction of their conceptions as they develop new and different conceptual understandings of an engineer in the elementary classroom.

2. Research questions

This study is guided by the following research questions: (a) what are children's conceptions of an engineer prior to and after [engineering design-based] instruction? (b) what are children's conceptions as they progress from one grade to the next? (c) do children's conceptions become more accurate, that is, more in accord with engineering educators' views of an engineer, and if so, how?

3. Theoretical framework

For the purpose of this study we draw from the literature on conceptual change in science education. Conceptual change is often used to explain the cognitive processes by which students learn [7, 8]. Conceptual change occurs effectively when students construct their own knowledge to achieve conceptual change through modification of their conceptual frameworks [9–12]. The framework is comprised of what are called mental models, which are transformed representations of real-world systems and phenomena called modeled target systems or phenomena [13]. As such, mental models are defined as simplified, conceptual representations that are personalized interpretations of modeled target systems or phenomena in the world around us [13]. Thus, the transformed modeled target systems or phenomena become the mental

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models which are more visible or comprehensible to an individual [14]. Useful mental models allow us to understand, explain, and predict behavior of systems and phenomena, whereas faulty mental models, which lead to misconceptions, cannot. After revealing and characterizing students' misconceptions, scientific inquiry- and/or engineering design-based activities, for example, can be designed to displace them by processes such as "cognitive dissonance" which use discrepant events and by "analogical reasoning" in which abstract concepts bridge to individual understanding through explanation with concrete, real-world analogies [15]. For an individual learner to want to adopt a new concept, it should also be intelligible, plausible, and fruitful [16, 17]. The conditions for intelligibility, plausibility, and fruitfulness contribute to the status of an idea. During conceptual change the status of different ideas within a person's cognitive ecology (the range of ideas they hold) changes [18, 19]. In this study, we explore the different conceptions students hold with regard to what an engineer does and furthermore, explore how enduring students' conceptions are over time.

4. Methodology

We carried out an exploratory, descriptive case study of a finite number of students [20]. Each case was comprised of individual cohorts of students who progressed from one grade to the next. Cohort I included three student participants who progressed from grades 1 to 2 to 3. Cohort II included four student participants who progressed from grades 2 to 3 to 4. Cohort III included five student participants who progressed from grades 3 to 4 to 5. By establishing three distinct cohorts across grades 1 through 5, we attempted to capture a comprehensive longitudinal perspective and furthermore, compare and contrast these perspectives accordingly.

Within our case study approach, we utilized qualitative evidence [21]. A mixed-evidence case study approach was chosen for several reasons. First, the phenomenon of interest, students' conceptions of an engineer within and across a specific grade level, is best explored via multiple sources of evidence, and this is a hallmark of case study methodology. Second, the phenomenon was naturally "bounded" and thus appropriately explored through case study research [20]. Indications of the "boundedness" of the phenomenon were the finite number of students that could be sampled (the twelve consenting students) and the fixed duration of the instruction (one engineering design-based unit each year over three years). Third, case study methods are particularly suitable for capturing process and development over time [21], and our research questions called for attending to changes in students' conceptions of an engineer over time. Quantifying some of the qualitative data, such as drawings, helped to characterize major patterns of change as well as identify students for in-depth descriptions of learning. Qualitative evidence, such as interview transcripts, highlighted the differences among individual students' learning using their own accounts.

4.1 Setting and participants

This study is part of a larger, multi-year project that examines elementary school students' perceptions, aspirations, and identity development in engineering [22]. The study population within the larger project included 274 elementary school students (defined as grades 1–5) purposefully selected [23] from Mayflower Elementary School (pseudonym), an urban elementary school in the central Midwest. The primary sampling criterion for participants in this larger project included the school's strong interest in integrating engineering-based curriculum for the first time. This allowed the research team to learn first-hand how students approach, experience and interact with engineering activities and how students' learning informs students' conceptions of engineers. The demographic profile of the students at Mayflower Elementary School was: females (138); males (137); White/Caucasian (181) 66%; African-American (75) 27%; Hispanic (37) 16%; Free-reduced lunch: (240) 88%.

For the purpose of the study reported in this article, we opted for a sample size (n = 12) that would provide a range of students from grades 1 through 5 so as to document the similarity, diversity, and/or variation in their conceptions of an engineer across grades and over a three-year time period. All student responses reported in this study were retrieved prior to and immediately after engaging in engineering design-based activities. The selection criteria for this sample included the following: 1) each student completed both measures (DAET and interview) at the beginning and end of each year of the study and 2) each student was verbal and descriptive in his/her responses. As previously stated, the students were clustered into three distinct cohorts: 1) Cohort I (grade 1 to 2 to 3); Cohort II (grade 2 to 3 to 4); and Cohort III (3 to 4 to 5).

Teacher participants in the larger study attended an intense three-day, hands-on workshop in the summer and a two-hour follow-up professional development session in the fall. During this time, the teachers learned about wind and the ways engineers design machines to capture wind energy; examined ways to clean water; and developed a series of standards-based science lessons that inte-

Table 1. Overview of grade level engineering design units

Grade	Science Concept	Science Process Skills & Objectives Related to Engineering Design	Design Task*
1	States of Matter—solids, liquids, & gases.	Observation; Generate questions; Plan and conduct investigations; Analyze and reflect on investigation results. Identify and sort objects by observable attributes. Know and identify the three states of matter and their properties. Use the engineering design process and data from investigations to demonstrate how matter can be changed.	*Engineering a better play dough.* Task: Using an existing procedure, can you re-design and improve upon this procedure to make better play dough?. Client: Kindergarteners who wanted new colors and scented play dough.
3	Force—Force is any push or pull. Simple machines	Relate a change in motion of an object to the force that caused the change of motion. Identify different types of simple machines. Give examples of simple machines. Use Lego simple and motorized machines.	*Birds busting a beat.* Task: Can you create a pair of Lego dancing birds that can rotate and sing? Use and apply knowledge of structures and forces, levers, wheels, axles, gears, and pulleys. Client: Toddlers in need of toys.
5	Forces affect the motion and speed of an object.	Distinguish between contact and noncontact forces. Use the engineering design process to design, construct, test, and optimize a model of a crawler. Correctly program the "Mindstorm" brick to move the crawler on the intended path with success.	*Crawler creations.* Task: Can your team construct a Lego crawler that can support and move a model of your rocket to a pre-determined launch area?. Client: Aeronautical engineers.

* All of the tasks included the use of an "engineering notebook," "design journal," or "mission log" that served as a way of chronicling students' engagement in the engineering design process.

grated the engineering design process. Once the teachers completed the summer workshop, they developed a six-week unit that included grade appropriate, standards-based engineering learning modules they would instruct during the school year (Table 1). In Table 1 we provide brief examples of an early, mid-, and late-elementary engineering design-based unit of study.

4.2 Data collection

The primary methods for collecting data included the Draw-An-Engineer-Test (DAET) and semi-structured interviews. What follows is a brief description of each data source.

4.3 Draw-An-Engineer-Test (DAET)

For the purpose of our study, the Draw-An-Engineer-Test (DAET) was intended as an idea-eliciting task. The task itself is an adaptation of a data collection technique first introduced by Chambers [24], who examined school children's stereotypic views of scientists through drawings— the Draw a Scientist Test (DAST). Chambers argued that a drawing of a scientist made by a child on a blank sheet of paper could be examined to identify specific attributes about the drawing, and, therefore, the child's mental image of a scientist. Finson [25] suggests that many children's drawings, taken together, could reveal a certain set of attributes students assign to scientists or what Chambers called "stereotypical images." It became evident, from a psychological perspective, that drawings could certainly reveal significant information about a student's (child's) deeply embedded ideas or mental images [25, 26] without constraining the student to predetermined responses [27].

The DAET we used in this study was presented on an $8\frac{1}{2}$ inches $\times$ 11 inches piece of paper. At the top of the paper, students were given the following instructions: "In the space below, draw an engineer doing engineering work." The space consisted of an empty box (7 inches $\times$ 7 inches) for the child to draw his or her image of an engineer. Students were then encouraged to use the space below the box to write their response to the following question: "What is your engineer doing?" In order to ensure a level of quality in all the drawings, teachers gave students approximately 30 minutes to complete their drawings and encouraged them to provide any details, labels, or notes in their drawings. Each student participant completed the DAET on two separate occasions—before and after the engineering design-based unit (2 DAETs/year; total = 6 DAETs per student participant).

4.4 Interviews

Student participants in this study were interviewed as a means of examining critically what students drew and how they represented their ideas, thoughts, and conceptions [28]. Each student participant was interviewed individually for approximately 30 minutes on two separate occasions—

before and after the engineering design-based unit (2 interviews/year; total = 6 interviews per student participant). Each interview began with the interviewer asking the student to look at his or her drawing and talk aloud about what he/she drew. Examples of interview questions included the following: "Tell me about your drawing." "Is your engineer a boy or a girl?" "What is the engineer doing? What can you tell me about this person?" "Can you complete the following sentence starter for me? An engineer is someone who. . ." The interviews were audio-taped and transcribed by members of the research team. Short notes about what had happened were recorded both during and immediately after the interviews.

4.5 Data analysis

Analysis and interpretation of student interviews and DAETs involved the use of grounded theory [29]. This entailed the reading and re-reading of all transcript data, assigning descriptive and interpretative codes to emerging ideas [23], and further exploring these codes for essential relationships and patterns [30]. Recurring codes formed the basis for thematic units that were then translated into theoretical memos. Matrices and network displays were created to facilitate the analyses [23]. Triangulation of both data sources was employed to ensure confirmation and validity of emerging findings as well as provide a holistic understanding of the students' engagement in and understanding of engineering [23].

The final product presented in this study is a series of profiles of three focal student participants, one from each cohort. Each case includes data from the student's DAET and interview over the course of three years. Collectively, the data presented in this study provide a longitudinal examination of students' conceptions of an engineer over a three-year period.

5. Results

Findings from this study are presented in three sections. In the first section, we present results from students in Cohort I, in the second section, results from students in Cohort II, and in the third section, results from students in Cohort III. The results include trends found in the students' DAETs and supporting interviews. Embedded in each section is a profile of one student from each cohort to illustrate his/her conceptions over time. In this manner, we used individual pseudonyms to protect the anonymity of the participants. Each student profile represents recurring characteristics revealed by the members of his/her respective cohort.

5.1 Students' conceptions of an engineer

The DAET and interview data revealed that students' descriptions of engineers could be categorized into one of four conceptions. As described by Capobianco, Diefes-Dux, Mena, and Weller [6], these conceptions are:

- *Conception 1*—An engineer is a mechanic: The engineer is someone who fixes, drives, and/or works with vehicles.
- *Conception 2*—An engineer is a laborer: The engineer is someone who fixes, builds, and/or makes structures, such as buildings and roads, or artifacts, such as chairs and wagons. The engineer as laborer could also work on plumbing tasks, such as fixing a toilet.
- *Conception 3*—An engineer is a technician: The engineer fixes and/or works with electronics, computers, or electricity.
- *Conception 4*—An engineer is a designer: The engineer designs, invents, and/or improves.

Some students provided descriptions of engineers that did not fall under any of these conceptions. These descriptions were categorized as "Other." Examples of descriptions of engineers that were placed in this category were: engineers pick up litter, engineers are elementary school teachers, and engineers are fashion designers, among others.

5.2 Cohort I—grades 1 to 2 to 3

The results from Cohort I are presented in Figure 1. When the students were in grade 1, students described an engineer as a mechanic, laborer, or "Other." At the end of the year, all three students' conceptions were coded as "Other." At the beginning and end of grade 2, the three Cohort I students described an engineer as a laborer or "Other." In grade 3, the students again described an engineer as a laborer, mechanic, or "Other." At the end of grade 3, students characterized engineers as a mechanic, designer, or "Other." This is the first and only time we observed a Cohort I student conceptualizing an engineer as a "designer."

Akeem is a male student from Cohort I. He is an example of a student who demonstrated the cohort characteristics. His grade 1 pre-DAET (Fig. 2) illustrates an engineer next to a train. According to Akeem, "He [the engineer] is getting in the train because . . . [he] puts coal in a train to make it go." Because Akeem did not specifically say the engineer was driving or fixing the train, but rather that the engineer was putting coal in the train, this was coded as "Other," and not as mechanic. Akeem drew two engineers in his post DAET (Fig. 3). These engineers were making some play dough, because according

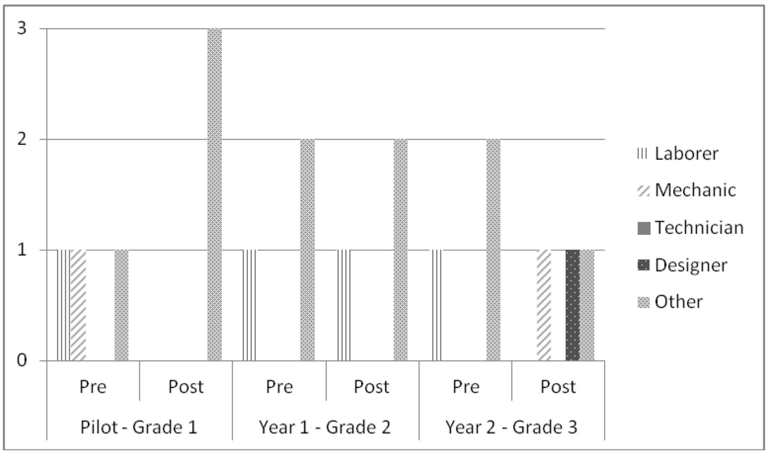

Fig. 1. Cohort I (n = 3) Conceptions of Engineers by Year.

to Akeem, engineers "make stuff." This was coded as "Other."

In grade 2, Akeem returns to his original conception that engineers work on trains. He drew an engineer standing next to a train (Fig. 4), and said that "the engineer is calling the train to pick up people." He did not describe the engineer as driving or fixing the train, but rather as someone who provides passengers with information. At the end of grade 2, Akeem again drew an engineer who worked on a train (Fig. 5). This engineer took coal out of the train and "calls the trains to pick up

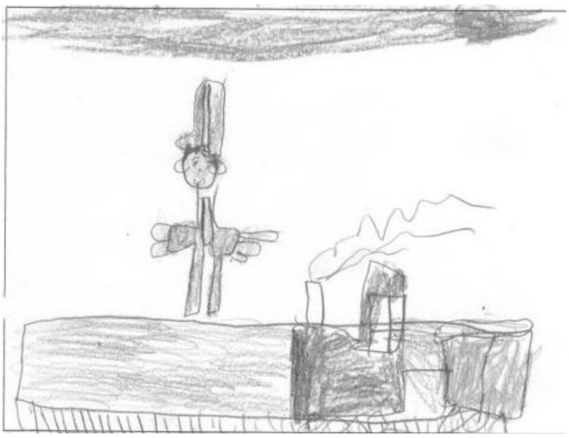

Fig. 2. Akeem—Grade 1—Pre DAET.

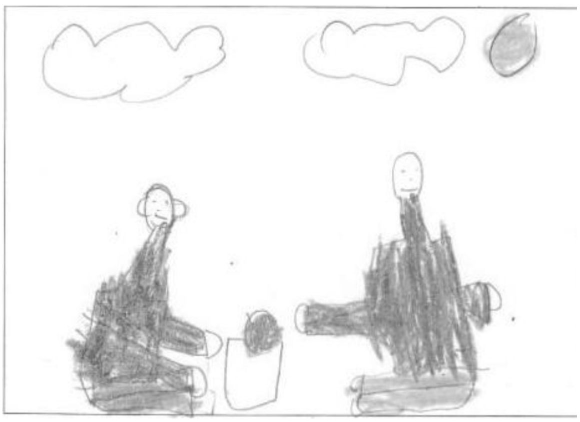

Fig. 3. Akeem—Grade 1—Post DAET.

Fig. 4. Akeem—Grade 2—Pre DAET.

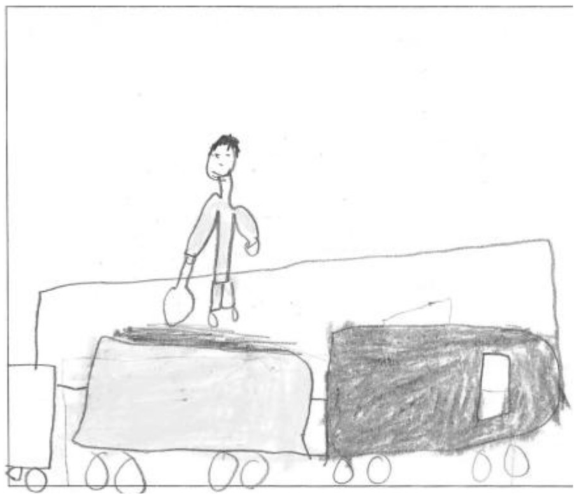

Fig. 5. Akeem—Grade 2—Post DAET.

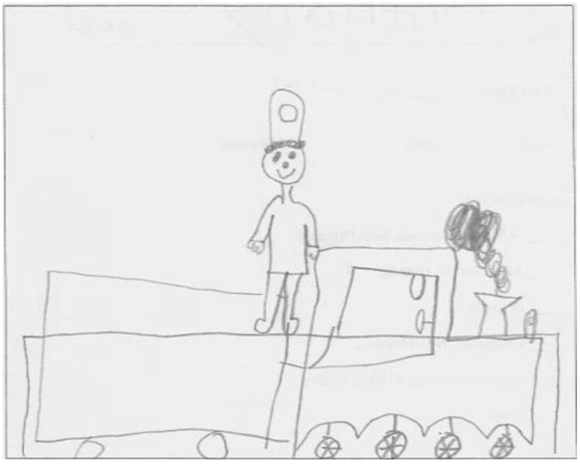

Fig. 6. Akeem—Grade 3—Pre DAET.

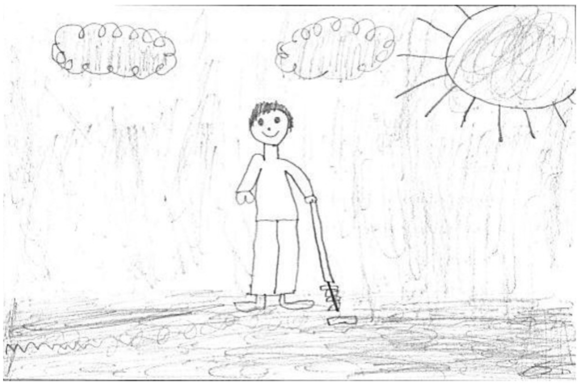

Fig. 7. Akeem—Grade 3—Post DAET.

passengers." According to Akeem, an engineer "does stuff with trains." This was coded as "Other."

In grade 3, Akeem drew the engineer as a "train worker" who waits "for passengers so he can lead them to the door of the. . .station...he stands outside and waits for the train people" (Fig. 6). This was coded as "Other." By the end of grade 3, Akeem no longer thought engineers worked in trains but collected litter (Fig. 7). This was coded as "Other."

5.3 Cohort II—grades 2 to 3 to 4

The results from Cohort II are below (Fig. 8). In grade 2, all four students described an engineer as a mechanic. At the end of the year, one of the four students described an engineer as a designer, while the remaining three maintained their original conceptions. In grade 3, three students described an engineer as a mechanic and one student as "Other". At the end of grade 3, the students described an engineer as a mechanic, a technician, and "Other." In grade 4, students' conceptions fell into the categories of mechanics, technicians, and "Other." At the end of grade 4, half the students described engineers as mechanics, while the other half described engineers as designers. These results indicate that students' conceptions of an engineer focus primarily on Conception 1—mechanic. It is not until the end of grade 3 and beginning of grade 4 that students' conceptions begin to diversify.

Malachi is a male student representative from Cohort II. In grade 2, his pre and post conceptions of an engineer were characterized as the engineer is a mechanic (Fig. 9). He drew an engineer fixing a truck: "he got the bucket of tools and then he went to the truck to fix the wheels. . .my engineer is fixing the car and pump up the wheels." His post DAET (Fig. 10) was very similar: the engineer is standing next to a car, and he is "fixing the brake because it is not working." Again, Malachi characterized the engineer as a mechanic.

In grade 3, Malachi's pre DAET (Fig. 11) consisted of an engineer extinguishing a fire. This was coded as "Other." This is how Malachi described his post DAET (Fig. 12): "It's a dealer shop and there's two cars that's on a stand to show the new cars." The man in the drawing is the engineer, "he makes cars." This was coded as mechanic.

In grade 4, Malachi described an engineer as: ". . . putting mail inside of a mailbox" (Fig. 13). This was coded as "Other." Malachi's grade 4 post

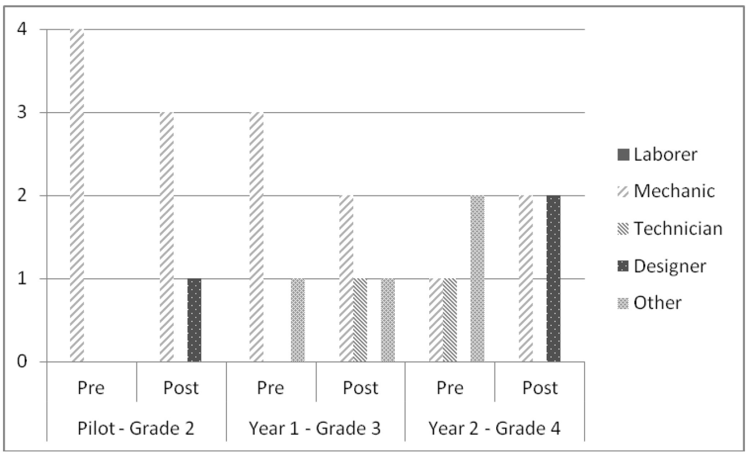

Fig. 8. Cohort II (n = 4) Conceptions of Engineers by Year.

Fig. 9. Malachi—Grade 2—Pre DAET.

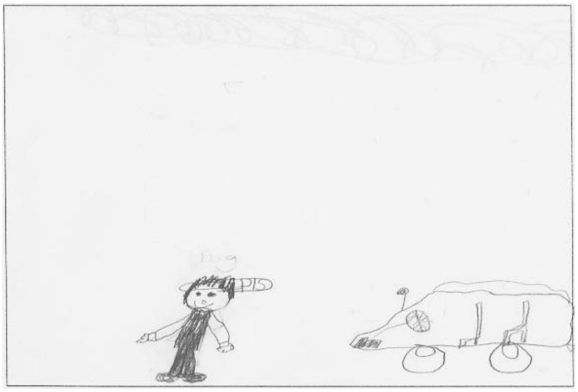

Fig. 10. Malachi—Grade 2—Post DAET.

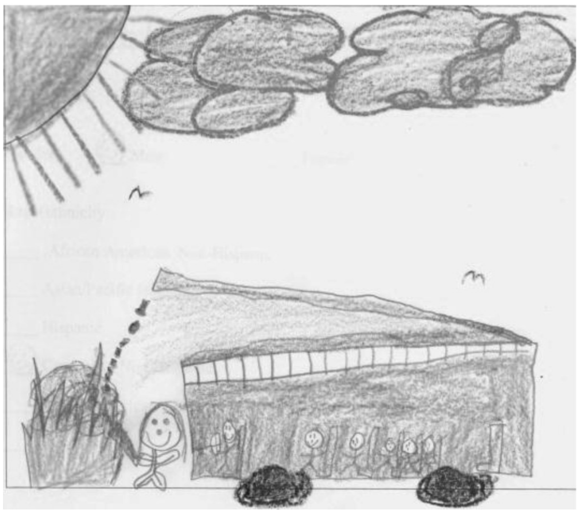

Fig. 11. Malachi—Grade 3—Pre DAET.

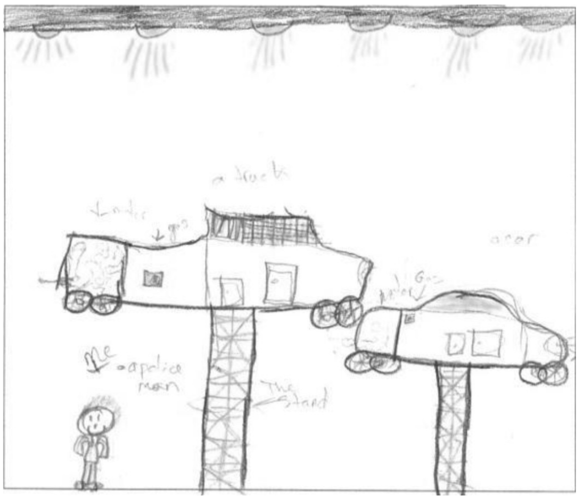

Fig. 12. Malachi—Grade 3—Post DAET.

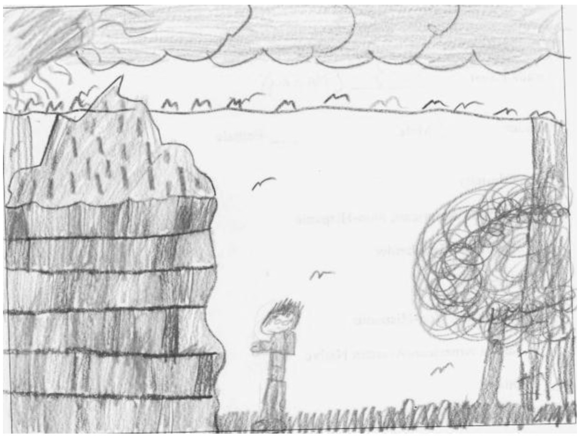

Fig. 13. Malachi—Grade 4—Pre DAET.

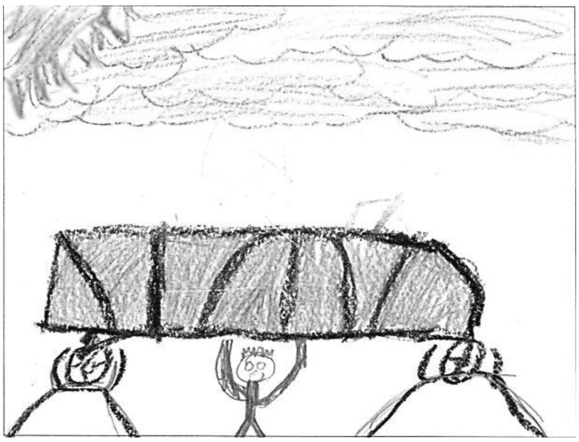

Fig. 14. Malachi—Grade 4—Post DAET.

DAET consisted of an engineer fixing an airplane (Fig. 14). This was coded as mechanic.

5.4 Cohort III—grades 3 to 4 to 5

In grade 3, students described an engineer as a mechanic or a technician (Fig. 15). At the end of the year, one student described an engineer as a laborer, while the remaining Cohort III students described an engineer as a designer. At the beginning of grade 4, two students described an engineer

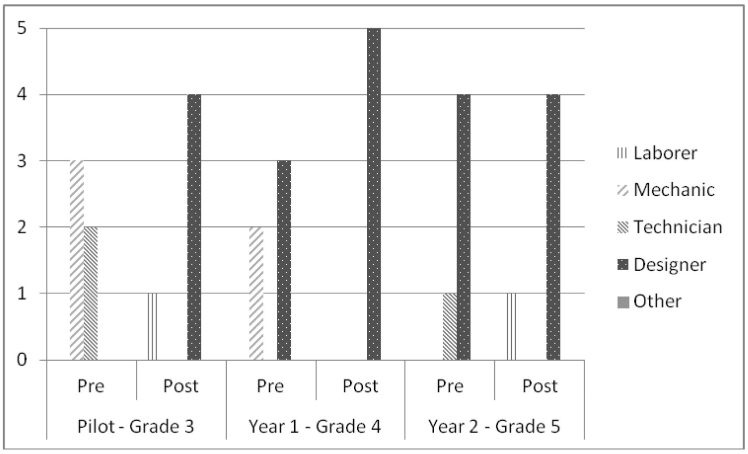

Fig. 15. Cohort III (n = 5) Conceptions of Engineers by Year.

as a mechanic or a designer, and at the end of the year, all four students described an engineer as a designer. In grade 5, four of the five students described an engineer as a designer at the beginning and end of the school year. Only one student harbored the misconception that an engineer was either a technician or "Other."

Heather is a female student representative from Cohort III. In grade 3, she described her initial drawing in the following manner (Fig. 16):

> It's an engineer trying to fix a train 'cause there's something that stopped the train. He found a paper and a stick under the train. The engineer wanted to see what was wrong, he didn't know, but then he saw that there was a paper under the train . . . He's looking all around the train and trying to see what's wrong.

She described the engineer as a mechanic. Heather's grade 3 post DAET (Fig. 17) is different. In her interview she stated: "My engineer is inventing something that never has been invented and he's using all types of simple machines, like a wheel and axle." At this point, Heather is beginning to describe engineers as designers.

In grade 4, Heather continued to describe an engineer as a designer (Fig. 18). In her interview, Heather stated "Well it's an engineer. . .something that [has never] been made . . . cool invention that never been made . . . he's trying to make something that's like, once you step into it, it's going to zap you somewhere different." At the end of grade 4, Heather conveyed the same conception (Fig. 19). In her interview she stated:

> Well it's an engineer trying to make . . . a flying car . . . so like instead of just driving, it would go by itself to help people. . .all you have to do is just talk and it's gonna make it go . . . Well he's trying to improve it right now, he's trying to make it look cool 'cause . . . you can mostly see everything that he did in it so he's trying to like cover most of everything so that it looks cooler and people would want to buy it."

By grade 5 Heather maintained her conception of an engineer as a designer (Fig. 20). Rather than focus-

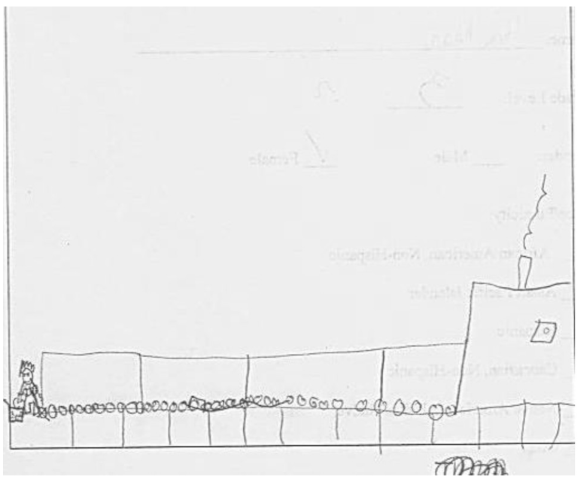

Fig. 16. Heather—Grade 3—Pre DAET.

Fig. 17. Heather—Grade 3—Post DAET.

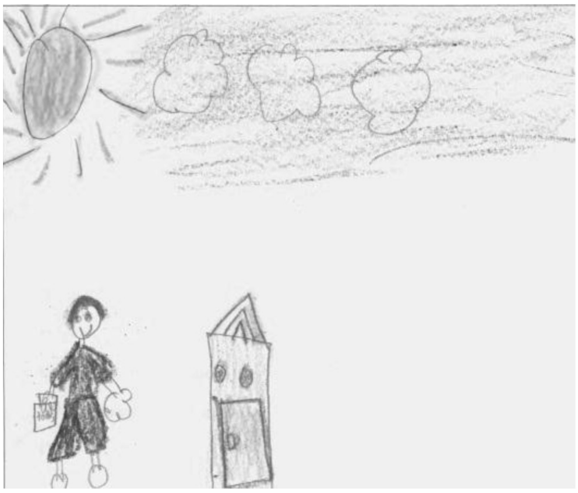

Fig. 18. Heather—Grade 4—Pre DAET.

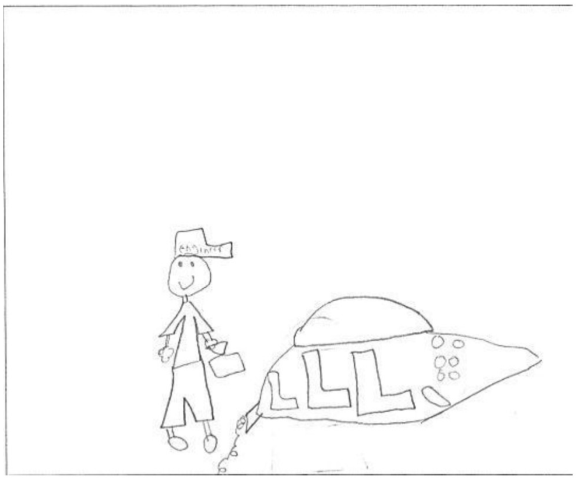

Fig. 19. Heather—Grade 4—Post DAET.

ing on "creating" and "inventing," Heather focused on "improving" the artifact or prototype (e.g., car). In her interview she stated:

> It's an engineer that trying to improve a car, so it can fly, go underwater, and drive . . . [the engineer is] trying to improve a car for the future . . . Instead of driving itself, it's going to be driving, but it's like electrical so it can zap you somewhere, it can also fly and go underwater.

By the end of grade 5, Heather expressed the same conception of an engineer as a designer improving the artifact (Fig. 21): "This engineer's improving this car. It's a regular car and he wants to make it better for the future, trying to experiment with it. Trying to see what he can add on or take away."

6. Discussion

Results from students' responses to both drawings and interviews indicate that students in this study harbor a variety of misconceptions related to what

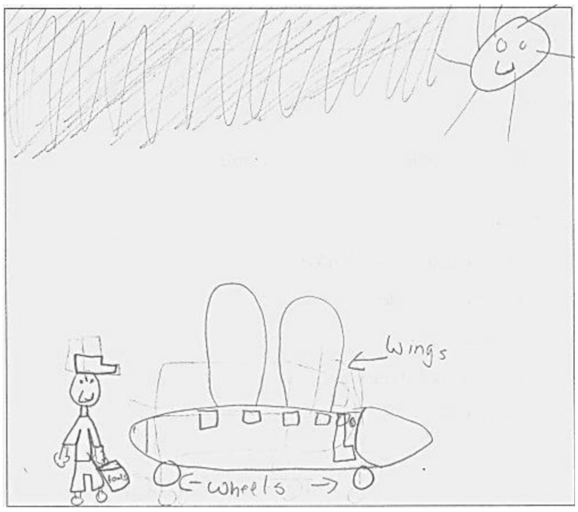

Fig. 20. Heather—Grade 5—Pre DAET.

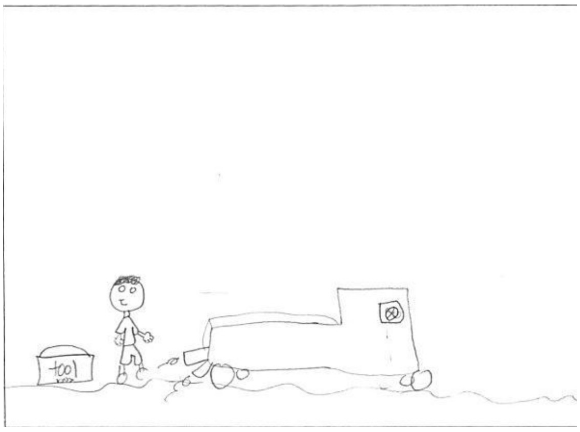

Fig. 21. Heather—Grade 5—Post DAET.

an engineer is and the work of an engineer. Furthermore, there is a trend that indicates that late elementary school children (grades 4 and 5) develop more informed, diverse, and accurate conceptions of an engineer than early elementary school children (grades 1, 2 and 3). Findings from Cohort I (student participants who progressed from grades 1 to 2 to 3) indicate that younger children associate an engineer as either a mechanic or laborer. Moreover, this data highlight younger children's literal interpretation of the work of engineers. Students at this age associate engineer with simple and literal meanings of the word engineer, "engine." We asked children to 'draw an engineer doing engineering work.' The words 'engineer' and 'engineering work' have socially constructed meanings that are abstract in nature simply because language is a common property of all individuals [31]. Because of this, children in Cohort I interpret the words 'engineer' and 'engineering work' by means of their own systems of personal mental images [31, p. 380]. Hence we argue that the children's drawings are models that show students' own personal conceptions or perhaps misconceptions of 'engineers doing engineering work.'

Findings from Cohort II (student participants who progressed from grades 2 to 3 to 4) demonstrate that students at this grade level characterize an engineer as either a mechanic or technician. Responses from Cohort II students emphasized the practical skills of a person who works directly with electronics and electricity (e.g., computers, software, telephones, or televisions). This conception implies the notion of the person having or using technical skills to do their job and/or working with particular artifacts, such as discrete tools (e.g., wrench, measuring tape, or screwdriver) and supplies (e.g., wire, software, or cords). Interestingly, conceptions reported by Cohort II students begin to change from mechanic and technician to designer as early as Grade 2 and more so by Grade 4. However, it is not until late in Grade 4 that the conception of a designer is more pronounced and accurately represented. This is the first indication that students can develop and express more accurate conceptions of an engineer.

Findings from Cohort III (student participants who progressed from grades 3 to 4 to 5) indicate a clear trend toward students' conceptions becoming more informed and accurate. Students in this cohort described an engineer as one who "designs," "creates," and/or "improves" on his or her designs. In short, students are using the discourse they developed as a result of participating in discrete engineering design-based learning activities. In other words, students are using terms, vocabulary, and expressions they have been introduced to while engaging in an engineering design task and as a result, transfer their own learning of these respective terms to describe their drawings and conceptions of an engineer. In summary, students' original abstract conceptions have become more formalized by their representations of real-world images and the terminology affiliated with these images.

7. Conclusion

The purpose of this study was to examine elementary school children's conceptions of an engineer over the course of three years. Results from this study are consistent with prior work in the field, which suggested that elementary school students were most likely to characterize an engineer as a mechanic, laborer or technician. The students in our study; however, were more likely to invoke more fragmented and less accurate conceptions at younger ages (grades 1 and 2) and more diverse and accurate conceptions as they progressed from grades 3 to 4 to 5. They also indicated retention of more accurate conceptions at an older age. By grade 3 students were beginning to understand that engineers are involved in the actions of designing, testing, and improving artifacts and moreover, were able to retain this understanding from one grade to the next.

The conceptions of an engineer and the tendency for these conceptions to be altered suggest that learning about the work of an engineer is an active, dynamic process. Almost half of the students' drawings, more specifically post-DAETs, represented improved and more accurate conceptions of an engineer which suggests that the engineering design-based learning activities implemented in the classroom were seen as having a positive effect on students' conceptions. Equally important was the fact that grades 4 and 5 students tended to retain their accurate conceptions of an engineer from the beginning to the end of a school year. This suggests that prolonged or subsequent engagement in the engineering design-based learning activities has a positive longitudinal effect on students' conceptions.

This study suggests that stakeholders, such as elementary school science teachers, curriculum developers, and engineering and science educators, must take into consideration the preconceptions students bring to the classroom and their respective instructional materials. Attention must be given to the unyielding conceptions young children harbor and the role that productive, developmentally appropriate, engineering design-based learning activities can play on challenging and transforming these conceptions as children mature cognitively and physically. In sum, instructional materials and curricular resources devised purposefully to engage children in elementary engineering education should incorporate ways to capture children's naive ideas and furthermore, scaffold students' learning such that they can develop more meaningful, accurate understandings over time.

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