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From mechanic to designer: Evolving perceptions of elementary students over three years of engineering instruction

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By Anastasia Marie Rynearson

Entitled
From Mechanic to Designer: Evolving Perceptions of Elementary Students over Three Years of Engineering Instruction

For the degree of Doctor of Philosophy

Is approved by the final examining committee:

Heidi Diefes-Dux
Brenda Capobianco
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Kerrie Douglas
Allison Godwin

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Approved by Major Professor(s): Heidi Diefes-Dux, Brenda Capobianco

Approved by: David Radcliffe 7/4/2016

Head of the Departmental Graduate Program Date
FROM MECHANIC TO DESIGNER: EVOLVING PERCEPTIONS OF ELEMENTARY STUDENTS OVER THREE YEARS OF ENGINEERING INSTRUCTION

A Dissertation
Submitted to the Faculty of Purdue University by Anastasia M Rynearson

In Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

August 2016
Purdue University
West Lafayette, Indiana
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>x</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>xv</td>
</tr>
<tr>
<td>CHAPTER 1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Background</td>
<td>1</td>
</tr>
<tr>
<td>1.1.1 Case Studies in Educational Research</td>
<td>2</td>
</tr>
<tr>
<td>1.1.2 Elementary Engineering Education Research</td>
<td>3</td>
</tr>
<tr>
<td>1.2 Statement of the Problem</td>
<td>5</td>
</tr>
<tr>
<td>1.3 Purpose of the Study</td>
<td>6</td>
</tr>
<tr>
<td>1.3.1 Research Question</td>
<td>6</td>
</tr>
<tr>
<td>1.3.2 Personal Motivation</td>
<td>6</td>
</tr>
<tr>
<td>1.4 Significance of the Study</td>
<td>7</td>
</tr>
<tr>
<td>1.5 Organization</td>
<td>8</td>
</tr>
<tr>
<td>CHAPTER 2. LITERATURE REVIEW</td>
<td>9</td>
</tr>
<tr>
<td>2.1 Introduction</td>
<td>9</td>
</tr>
<tr>
<td>2.2 Engineering Perceptions</td>
<td>9</td>
</tr>
<tr>
<td>2.3 Student Learning</td>
<td>12</td>
</tr>
<tr>
<td>2.4 Overview Literature Review: Full Data Set</td>
<td>14</td>
</tr>
<tr>
<td>3.2.4.1.3</td>
<td>Second Grade Unit: <em>A Work in Process: Improving a Play Dough</em></td>
</tr>
<tr>
<td>3.2.4.1.4</td>
<td>Third Grade Unit: <em>Marvelous Machines: Making Work Easier</em></td>
</tr>
<tr>
<td>3.2.4.1.5</td>
<td>Fourth Grade Unit: <em>A Stick in the Mud: Evaluating a Landscape</em></td>
</tr>
<tr>
<td>3.2.4.2</td>
<td>Additional Engineering Lessons</td>
</tr>
<tr>
<td>3.2.4.2.1</td>
<td>Bat Puzzles</td>
</tr>
<tr>
<td>3.2.4.2.2</td>
<td>Gumdrop People and Chairs</td>
</tr>
<tr>
<td>3.2.4.2.3</td>
<td>Tower Power</td>
</tr>
<tr>
<td>3.2.4.2.4</td>
<td>Paper Table</td>
</tr>
<tr>
<td>3.2.4.2.5</td>
<td>Pop-Up Cards</td>
</tr>
<tr>
<td>3.2.4.2.6</td>
<td>GT Pyramids</td>
</tr>
<tr>
<td>3.2.4.2.7</td>
<td>Model Eliciting Activity: Stickers</td>
</tr>
<tr>
<td>3.2.4.2.8</td>
<td>Model Eliciting Activity: Paper Airplanes</td>
</tr>
<tr>
<td>3.2.4.2.9</td>
<td>Sally Ride Science Books</td>
</tr>
<tr>
<td>3.2.4.2.10</td>
<td>PBS Design Squad Videos</td>
</tr>
<tr>
<td>3.3</td>
<td>Instruments</td>
</tr>
<tr>
<td>3.3.1</td>
<td>The Draw an Engineer Task (DAET)</td>
</tr>
<tr>
<td>3.3.2</td>
<td>Engineering Identity Development Scale (EIDS)</td>
</tr>
<tr>
<td>3.3.3</td>
<td>Student Knowledge Test (SKT)</td>
</tr>
<tr>
<td>3.3.4</td>
<td>Teacher Debrief Survey</td>
</tr>
<tr>
<td>3.3.5</td>
<td>Student Interview Protocol</td>
</tr>
<tr>
<td>3.3.6</td>
<td>Teacher Interview Protocol</td>
</tr>
<tr>
<td>3.4</td>
<td>Analysis</td>
</tr>
</tbody>
</table>
3.4.1 Individual Case Studies .......................................................... 42
3.4.2 Cross-Case Analysis ............................................................... 45
3.5 Chapter Summary ....................................................................... 45

CHAPTER 4. INDIVIDUAL CASE STUDIES ............................................ 46
4.1 Introduction ................................................................................ 46
4.2 Ashleigh ..................................................................................... 46
  4.2.1 Overall .................................................................................. 47
  4.2.2 Year One: Second Grade ....................................................... 48
    4.2.2.1 Initial Data Collection ...................................................... 49
    4.2.2.2 Final Data Collection ....................................................... 51
  4.2.3 Year Two: Third Grade .......................................................... 54
    4.2.3.1 Initial Data Collection ...................................................... 56
    4.2.3.2 Final Data Collection ....................................................... 59
  4.2.4 Year Three: Fourth Grade..................................................... 62
    4.2.4.1 Initial Data Collection ...................................................... 63
    4.2.4.2 Final Data Collection ....................................................... 66
4.3 Sofia ............................................................................................ 69
  4.3.1 Overall .................................................................................. 69
  4.3.2 Year One: Second Grade ....................................................... 70
    4.3.2.1 Initial Data Collection ...................................................... 70
    4.3.2.2 Final Data Collection ....................................................... 74
  4.3.3 Year Two: Third Grade .......................................................... 77
    4.3.3.1 Initial Data Collection ...................................................... 79
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.3.3.2</td>
<td>Final Data Collection</td>
<td>82</td>
</tr>
<tr>
<td>4.3.4</td>
<td>Year Three: Fourth Grade</td>
<td>86</td>
</tr>
<tr>
<td>4.3.4.1</td>
<td>Initial Data Collection</td>
<td>87</td>
</tr>
<tr>
<td>4.3.4.2</td>
<td>Final Data Collection</td>
<td>91</td>
</tr>
<tr>
<td>4.4</td>
<td>Marcos</td>
<td>95</td>
</tr>
<tr>
<td>4.4.1</td>
<td>Overall</td>
<td>95</td>
</tr>
<tr>
<td>4.4.2</td>
<td>Year One: Second Grade</td>
<td>97</td>
</tr>
<tr>
<td>4.4.2.1</td>
<td>Initial Data Collection</td>
<td>97</td>
</tr>
<tr>
<td>4.4.2.2</td>
<td>Final Data Collection</td>
<td>99</td>
</tr>
<tr>
<td>4.4.3</td>
<td>Year Two: Third Grade</td>
<td>102</td>
</tr>
<tr>
<td>4.4.3.1</td>
<td>Initial Data Collection</td>
<td>103</td>
</tr>
<tr>
<td>4.4.3.2</td>
<td>Final Data Collection</td>
<td>106</td>
</tr>
<tr>
<td>4.4.4</td>
<td>Year Three: Fourth Grade</td>
<td>109</td>
</tr>
<tr>
<td>4.4.4.1</td>
<td>Initial Data Collection</td>
<td>112</td>
</tr>
<tr>
<td>4.4.4.2</td>
<td>Final Data Collection</td>
<td>116</td>
</tr>
<tr>
<td>4.5</td>
<td>Jake</td>
<td>120</td>
</tr>
<tr>
<td>4.5.1</td>
<td>Overall</td>
<td>121</td>
</tr>
<tr>
<td>4.5.2</td>
<td>Year One: Second Grade</td>
<td>122</td>
</tr>
<tr>
<td>4.5.2.1</td>
<td>Initial Data Collection</td>
<td>123</td>
</tr>
<tr>
<td>4.5.2.2</td>
<td>Final Data Collection</td>
<td>125</td>
</tr>
<tr>
<td>4.5.3</td>
<td>Year Two: Third Grade</td>
<td>128</td>
</tr>
<tr>
<td>4.5.3.1</td>
<td>Initial Data Collection</td>
<td>128</td>
</tr>
<tr>
<td>4.5.3.2</td>
<td>Final Data Collection</td>
<td>132</td>
</tr>
<tr>
<td>Section</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>4.5.4</td>
<td>Year Three: Fourth Grade</td>
<td>135</td>
</tr>
<tr>
<td>4.5.4.1</td>
<td>Initial Data Collection</td>
<td>136</td>
</tr>
<tr>
<td>4.5.4.2</td>
<td>Final Data Collection</td>
<td>139</td>
</tr>
<tr>
<td>4.6</td>
<td>Mike</td>
<td>142</td>
</tr>
<tr>
<td>4.6.1</td>
<td>Overall</td>
<td>143</td>
</tr>
<tr>
<td>4.6.2</td>
<td>Year One: Second Grade</td>
<td>145</td>
</tr>
<tr>
<td>4.6.2.1</td>
<td>Initial Data Collection</td>
<td>145</td>
</tr>
<tr>
<td>4.6.2.2</td>
<td>Final Data Collection</td>
<td>148</td>
</tr>
<tr>
<td>4.6.3</td>
<td>Year Two: Third Grade</td>
<td>150</td>
</tr>
<tr>
<td>4.6.3.1</td>
<td>Initial Data Collection</td>
<td>152</td>
</tr>
<tr>
<td>4.6.3.2</td>
<td>Final Data Collection</td>
<td>156</td>
</tr>
<tr>
<td>4.6.4</td>
<td>Year Three: Fourth Grade</td>
<td>159</td>
</tr>
<tr>
<td>4.6.4.1</td>
<td>Initial Data Collection</td>
<td>159</td>
</tr>
<tr>
<td>4.6.4.2</td>
<td>Final Data Collection</td>
<td>162</td>
</tr>
<tr>
<td>4.7</td>
<td>Beth</td>
<td>166</td>
</tr>
<tr>
<td>4.7.1</td>
<td>Overall</td>
<td>166</td>
</tr>
<tr>
<td>4.7.2</td>
<td>Year One: Second Grade</td>
<td>168</td>
</tr>
<tr>
<td>4.7.2.1</td>
<td>Initial Data Collection</td>
<td>168</td>
</tr>
<tr>
<td>4.7.2.2</td>
<td>Final Data Collection</td>
<td>170</td>
</tr>
<tr>
<td>4.7.3</td>
<td>Year Two: Third Grade</td>
<td>173</td>
</tr>
<tr>
<td>4.7.3.1</td>
<td>Initial Data Collection</td>
<td>174</td>
</tr>
<tr>
<td>4.7.3.2</td>
<td>Final Data Collection</td>
<td>177</td>
</tr>
<tr>
<td>4.7.4</td>
<td>Year Three: Fourth Grade</td>
<td>180</td>
</tr>
<tr>
<td>Page</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.7.4.1 Initial Data Collection</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>4.7.4.2 Final Data Collection</td>
<td>183</td>
<td></td>
</tr>
<tr>
<td>4.8 Elena</td>
<td>187</td>
<td></td>
</tr>
<tr>
<td>4.8.1 Overall</td>
<td>187</td>
<td></td>
</tr>
<tr>
<td>4.8.2 Year One: Second Grade</td>
<td>189</td>
<td></td>
</tr>
<tr>
<td>4.8.2.1 Initial Data Collection</td>
<td>189</td>
<td></td>
</tr>
<tr>
<td>4.8.2.2 Final Data Collection</td>
<td>191</td>
<td></td>
</tr>
<tr>
<td>4.8.3 Year Two: Third Grade</td>
<td>195</td>
<td></td>
</tr>
<tr>
<td>4.8.3.1 Initial Data Collection</td>
<td>196</td>
<td></td>
</tr>
<tr>
<td>4.8.3.2 Final Data Collection</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>4.8.4 Year Three: Fourth Grade</td>
<td>204</td>
<td></td>
</tr>
<tr>
<td>4.8.4.1 Initial Data Collection</td>
<td>204</td>
<td></td>
</tr>
<tr>
<td>4.8.4.2 Final Data Collection</td>
<td>209</td>
<td></td>
</tr>
</tbody>
</table>

CHAPTER 5. CROSS-CASE ANALYSIS | 213 |
| 5.1 Introduction | 213 |
| 5.2 Students’ Conceptions of Engineers | 214 |
| 5.3 Students’ Understanding of Technology | 217 |
| 5.4 Students’ Knowledge that Engineers Design Technology | 217 |
| 5.5 Students’ Attitudes toward Engineering | 235 |
| 5.6 Students’ Reported Experiences | 236 |
| 5.7 Teacher Professional Development | 241 |

CHAPTER 6. DISCUSSION | 242 |
| 6.1 A Developmental Perspective | 242 |
### Page

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.2 Students’ Understanding of Technology</td>
<td>245</td>
</tr>
<tr>
<td>6.3 Chapter Summary</td>
<td>247</td>
</tr>
<tr>
<td>CHAPTER 7. CONCLUSIONS</td>
<td>249</td>
</tr>
<tr>
<td>7.1 Implications of this Study</td>
<td>250</td>
</tr>
<tr>
<td>7.2 Future Research</td>
<td>251</td>
</tr>
<tr>
<td>7.3 Limitations</td>
<td>252</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>254</td>
</tr>
<tr>
<td>APPENDICES</td>
<td></td>
</tr>
<tr>
<td>Appendix A Draw an Engineer Task</td>
<td>267</td>
</tr>
<tr>
<td>Appendix B Engineering Identity Development Scale, 2nd Grade</td>
<td>268</td>
</tr>
<tr>
<td>Appendix C Engineering Identity Development Scale, 3rd and 4th Grade</td>
<td>272</td>
</tr>
<tr>
<td>Appendix D Student Knowledge Tests</td>
<td>273</td>
</tr>
<tr>
<td>Appendix E Student Interview Protocols</td>
<td>313</td>
</tr>
<tr>
<td>Appendix F Teacher Survey</td>
<td>335</td>
</tr>
<tr>
<td>Appendix G Teacher Interview Protocols</td>
<td>337</td>
</tr>
<tr>
<td>VITA</td>
<td>357</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 3.1 Participant Relationships</td>
<td>28</td>
</tr>
<tr>
<td>Table 3.2 INSPIRE Engineering Design Process definitions</td>
<td>31</td>
</tr>
<tr>
<td>Table 3.3 Draw an Engineer Task Category Descriptions (Carr, Diefes-Dux, et al., 2012)</td>
<td>43</td>
</tr>
<tr>
<td>Table 4.1 Ashleigh’s Conceptions of an Engineer</td>
<td>48</td>
</tr>
<tr>
<td>Table 4.2 Sofia’s Conceptions of an Engineer</td>
<td>69</td>
</tr>
<tr>
<td>Table 4.3 Marcos’ Conceptions of an Engineer</td>
<td>96</td>
</tr>
<tr>
<td>Table 4.4 Jake’s Conceptions of an Engineer</td>
<td>121</td>
</tr>
<tr>
<td>Table 4.5 Mike’s Conceptions of an Engineer</td>
<td>144</td>
</tr>
<tr>
<td>Table 4.6 Beth’s Conceptions of an Engineer</td>
<td>167</td>
</tr>
<tr>
<td>Table 4.7 Elena’s Conceptions of an Engineer</td>
<td>188</td>
</tr>
<tr>
<td>Table 5.1 Basic Conceptions of Engineers</td>
<td>216</td>
</tr>
<tr>
<td>Table 5.2 Student Responses to a Toothbrush as an Example of Technology</td>
<td>219</td>
</tr>
<tr>
<td>Table 5.3 Student Responses to a Flower as an Example of Technology</td>
<td>223</td>
</tr>
<tr>
<td>Table 5.4 Student Responses to a Pulley as an Example of Technology</td>
<td>225</td>
</tr>
<tr>
<td>Table 5.5 Student Responses to a Soil Core Sample as an Example of Technology</td>
<td>228</td>
</tr>
<tr>
<td>Table 5.6 Student Responses to a Cellular Telephone as an Example of Technology</td>
<td>230</td>
</tr>
<tr>
<td>Table 5.7 Interest in engineering across instruments</td>
<td>235</td>
</tr>
</tbody>
</table>
Table 5.8 Students’ Memorable Experiences ................................................................. 238

Table 6.1 Piaget’s Stages of Intellectual Development (reproduced from Salkind, 2004, p. 243) ........................................................................................................................................ 242
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 2.1 Change in students’ engineering career knowledge and aspirations (INSPIRE, 2013, p.6)</td>
<td>19</td>
</tr>
<tr>
<td>Figure 2.2 Change in students’ engineering knowledge grade (INSPIRE, 2013, p. 10)</td>
<td>20</td>
</tr>
<tr>
<td>Figure 2.3 Change in student conceptions of engineers (INSPIRE 2013, p. 8)</td>
<td>21</td>
</tr>
<tr>
<td>Figure 3.1 Engineering Design Process as presented at the INSPIRE Summer Academy</td>
<td>30</td>
</tr>
<tr>
<td>Figure 4.1 Student Demographics at School One</td>
<td>47</td>
</tr>
<tr>
<td>Figure 4.2 Ashleigh’s Year One pre-DAET</td>
<td>50</td>
</tr>
<tr>
<td>Figure 4.3 Ashleigh’s Year One post-DAET</td>
<td>53</td>
</tr>
<tr>
<td>Figure 4.4 Ashleigh’s Year Two pre-DAET</td>
<td>57</td>
</tr>
<tr>
<td>Figure 4.5 Ashleigh’s Year Two post-DAET</td>
<td>60</td>
</tr>
<tr>
<td>Figure 4.6 Ashleigh’s Year Three pre-DAET</td>
<td>64</td>
</tr>
<tr>
<td>Figure 4.7 Ashleigh’s Year Three post-DAET</td>
<td>67</td>
</tr>
<tr>
<td>Figure 4.8 Sofia’s Year One pre-DAET</td>
<td>72</td>
</tr>
<tr>
<td>Figure 4.9 Sofia’s Year One post-DAET</td>
<td>75</td>
</tr>
<tr>
<td>Figure 4.10 Sofia’s Year Two pre-DAET</td>
<td>80</td>
</tr>
<tr>
<td>Figure 4.11 Sofia’s Year Two post-DAET</td>
<td>83</td>
</tr>
<tr>
<td>Figure 4.12 Sofia’s Year Three pre-DAET</td>
<td>89</td>
</tr>
<tr>
<td>Figure 4.13 Sofia’s Year Three post-DAET</td>
<td>93</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>Figure 4.14</td>
<td>Marcos’ Year One pre-DAET</td>
</tr>
<tr>
<td>Figure 4.15</td>
<td>Marcos’ Year One post-DAET</td>
</tr>
<tr>
<td>Figure 4.16</td>
<td>Marcos’ Year Two pre-DAET</td>
</tr>
<tr>
<td>Figure 4.17</td>
<td>Marcos’ Year Two post-DAET</td>
</tr>
<tr>
<td>Figure 4.18</td>
<td>Marcos’ Year Three pre-DAET</td>
</tr>
<tr>
<td>Figure 4.19</td>
<td>Marcos’ Year Three post-DAET</td>
</tr>
<tr>
<td>Figure 4.20</td>
<td>Student Demographics at School Two</td>
</tr>
<tr>
<td>Figure 4.21</td>
<td>Jake’s Year One pre-DAET</td>
</tr>
<tr>
<td>Figure 4.22</td>
<td>Jake’s Year One post-DAET</td>
</tr>
<tr>
<td>Figure 4.23</td>
<td>Jake’s Year Two pre-DAET</td>
</tr>
<tr>
<td>Figure 4.24</td>
<td>Jake’s Year Two post-DAET</td>
</tr>
<tr>
<td>Figure 4.25</td>
<td>Jake’s Year Three pre-DAET</td>
</tr>
<tr>
<td>Figure 4.26</td>
<td>Jake’s Year Three post-DAET</td>
</tr>
<tr>
<td>Figure 4.27</td>
<td>Student Demographics at School Three</td>
</tr>
<tr>
<td>Figure 4.28</td>
<td>Mike’s Year One pre-DAET</td>
</tr>
<tr>
<td>Figure 4.29</td>
<td>Mike’s Year One post-DAET</td>
</tr>
<tr>
<td>Figure 4.30</td>
<td>Mike’s Year Two pre-DAET</td>
</tr>
<tr>
<td>Figure 4.31</td>
<td>Mike’s Year Two post-DAET</td>
</tr>
<tr>
<td>Figure 4.32</td>
<td>Mike’s Year Three pre-DAET</td>
</tr>
<tr>
<td>Figure 4.33</td>
<td>Mike’s Year Three post-DAET</td>
</tr>
<tr>
<td>Figure 4.34</td>
<td>Beth’s Year One pre-DAET</td>
</tr>
<tr>
<td>Figure 4.35</td>
<td>Beth’s Year One post-DAET</td>
</tr>
<tr>
<td>Figure 4.36</td>
<td>Beth’s Year Two pre-DAET</td>
</tr>
<tr>
<td>Figure Description</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Figure 4.37 Beth’s Year Two post-DAET</td>
<td>178</td>
</tr>
<tr>
<td>Figure 4.38 Beth’s Year Three pre-DAET</td>
<td>181</td>
</tr>
<tr>
<td>Figure 4.39 Beth’s Year Three post-DAET</td>
<td>185</td>
</tr>
<tr>
<td>Figure 4.40 Elena’s Year One pre-DAET</td>
<td>190</td>
</tr>
<tr>
<td>Figure 4.41 Elena’s Year One post-DAET</td>
<td>193</td>
</tr>
<tr>
<td>Figure 4.42 Elena’s Year Two pre-DAET</td>
<td>198</td>
</tr>
<tr>
<td>Figure 4.43 Elena’s Year Two post-DAET</td>
<td>202</td>
</tr>
<tr>
<td>Figure 4.44 Elena’s Year Three pre-DAET</td>
<td>206</td>
</tr>
<tr>
<td>Figure 4.45 Elena’s Year Three post-DAET</td>
<td>210</td>
</tr>
<tr>
<td>Figure 5.1 Frequency of student responses to interest in engineering as a career during interviews and on the EIDS</td>
<td>236</td>
</tr>
</tbody>
</table>
ABSTRACT


Due in part to increasing state standards that require engineering in K-12 curricula and the Next Generation Science Standards’ incorporation of engineering outcomes, inclusion of engineering into elementary classrooms is on the rise. Teacher development and experiences in learning about and implementing engineering have been studied, but elementary students’ experiences when learning about engineering have not been explored.

The purpose of this study is to address the question: How do elementary students’ knowledge of, attitudes toward, and overall conceptions of engineering evolve over three years of engineering instruction?

This study follows seven elementary school students through three years of engineering instruction from second through fourth grade. During each year of the study, students took part in one complete Engineering is Elementary unit, preparatory engineering lessons discussing engineering and technology, and optional additional engineering design activities. Data was collected at the beginning and end of each school year, including a semi-structured interview, a Draw an Engineer Task, the Engineering
Identity Development Scale, and a Student Knowledge Test. This data was used to build descriptive case studies for each individual student, addressing the research question at the beginning and end of each school year. A cross-case analysis compares findings across all seven students to further explore the research question.

Through the engineering intervention, students were expected to learn that engineers design technology. For a complete understanding, students needed to know that technology is any object, process, or system that is man-made in order to solve a problem. They also needed to understand engineering as a technical design process where the outcome is the complete plan for a product or process, not necessarily the product or process itself. All of the students in the study described engineering as design and nearly all of the students correctly described technology as man-made, useful items at some point during the study. Three of the seven students described engineering as design of technology with a correct description of technology by their third year. Students had positive attitudes toward engineering, however many did not recognize some of the activities as engineering, attributing them to science instead. Overall, students were not interested in pursuing engineering as a primary career option though they enjoyed the in-class engineering activities. Students’ conceptions of engineers and engineering evolved from naïve representations including mechanics and laborers to designers during the study. The patterns and rates of change differed between students; some quickly understood engineering as design and retained this understanding, while others slowly or partially developed an understanding of engineering as design.

The findings of this study have implications for practice and future research. Educators need to be prepared for strongly-held misconceptions regarding engineering
and technology and be explicit when presenting engineering, especially when it is
presented in a science context. Elementary students are able to understand engineering as
design, however not all students fully grasped this concept. Future research is needed to
explore how students understand technology, how elementary students understand design
at their developmental level, and what long-term impact a foundation of engineering in
elementary grades provides.
CHAPTER 1. INTRODUCTION

1.1 Background

Nationally, there have been numerous calls for more graduates from increasingly diverse backgrounds in the fields of science, technology, engineering, and math (STEM) (e.g. Members of the 2005 “Rising Above the Gathering Storm” Committee, 2010; Office of the Press Secretary, 2012). In response to these calls, individual states have created standards for engineering and technology knowledge and practices, led by Massachusetts in 2001, leading up to the creation of the Next Generation Science standards, science standards incorporating engineering (Carr, Bennett IV, & Strobel, 2012). These areas will soon be a part of The Nation’s Report Card through the National Assessment of Educational Progress Technology and Engineering Literacy assessment (National Assessment Governing Board, 2013). With expanded offerings and a national assessment for students, more students are exposed to engineering and are expected to attain some level of engineering literacy. What these advances do not tell us is how students come to understand engineering or what they experience as they are introduced to engineering in ways that may conflict with common perceptions of engineers and engineering. A greater understanding of how P-12 students experience and understand engineering on an individual level, especially for underrepresented groups, is needed.
1.1.1 Case Studies in Educational Research

In educational settings, it is nearly impossible to divorce the context, the school environment, from the phenomenon of study. When considering fully the context of the phenomena of interest, especially in educational settings, this leads to an increasingly large number of variables, few of which can be controlled or studied in isolation. This leads to the use of case study research designs, as a case study is “An empirical inquiry in which the number of variables exceeds the number of data points” (Yin, 1993, p. 32). Case study research in educational settings can be for evaluation purposes, to gauge the success of programs or interventions, or for research purposes, to understand a phenomena within education through descriptive, exploratory, or explanatory methods (Yin, 2014).

Case study research has been employed to understand student’s daily school experiences (e.g. Grimes, 2012; White, 1987), cultural integration for children of immigrants (Valdés, 1996), and is commonly used in evaluations of schools and programs (e.g. Cambone, 1994; Epp & Epp, 2002; Soto, 1997). These studies allow for a complex understanding of the phenomenon of interest that strongly incorporates the context surrounding the phenomenon. According to Yin (1993), “Yet, case studies have frequently been the method of choice among experienced investigators in education for analyzing educational innovations” (p. 40). Engineering is new to many classrooms and is a perfect example of a not yet well-understood educational innovation that can benefit from context-bound case study research.
1.1.2 Elementary Engineering Education Research

In a review of P-12 engineering education research, few studies focus on elementary (primary) grade students and fewer than thirty papers met the criteria for engineering education research with student-focused studies in primary grades (Hynes, Mathis, Rynearson, Siverling, & Purzer, in press). The same study found that the number of publications in pre-college engineering yearly has been increasing, but there are a variety of journals that publish these studies ranging from engineering education journals like the Journal of Pre-College Engineering Education Research to science and technology education journals like the Journal of Research in Science Teaching. The most common areas of research are perceptions of, knowledge about, and attitudes towards engineering, but these areas are not commonly considered together and often focus on teachers so are as yet not well understood for students. Longitudinal studies are very uncommon and reflect a major gap in understanding students’ experiences with engineering. One research recommendation from the National Academy of Engineering and National Research Council is that research related to interest in STEM education should include longitudinal studies and address diversity, areas that have been lacking in research to date (National Academy of Engineering & National Research Council [NAE & NRC], 2014). This study addresses this gap by studying elementary students’ perceptions of, knowledge about, and attitudes toward engineering across three years of engineering instruction.

Few case studies have been completed in elementary education related to engineering. Engineering in elementary grades is commonly found in science or technology classrooms and is sometimes simply considered design. A search on the ERIC
educational database using the search terms “(design AND (science OR technology OR engineering)) OR engineering” and “case stud*” in the abstract, limited to the education levels “elementary education, grade 1, grade 2, grade 3, grade 4, preschool education, primary education” returned 169 results. Ninety-one of these results were journal articles, only three of which focused on elementary students involved in an engineering activity rather than teachers, classrooms, or schools as the unit of analysis. A similar search using the SCOPUS database ABS (case stud* AND (design AND (science OR technology OR engineering)) OR engineering) AND KEY (education AND (elementary OR primary OR precollege)) returned fifty-five documents, of which thirty-nine were journal articles and none of these articles focused on students as the unit of analysis.

The first of these articles focused on design fixation and cooperative learning in 3rd, 4th, and 5th grade elementary school students (Luo, 2015). Using an observational protocol with detailed field notes and student design journals and reflections, this case study examined design fixation of elementary school students engaging in cooperative learning in an engineering design context to find three major themes: fixation on common features, fixation on popular culture, and fixation on the first idea. Obstacles to cooperative learning at this age, including dominance and social loafing, and additional implications of the study were provided to inform practitioners in order to provide better cooperative learning experiences in elementary engineering.

The second case study focused on students’ experiences with engineering design in science classrooms (Roth, Tobin, & Ritchie, 2001). This extended series of case studies explored students’ developing science-like discourse in a classroom using and engineering or materials-centered approach for learning through engineering-based
design activities. The use of case study allowed the researcher to explore how students were engaging with and understanding the material and what process they follow, including what constraints and assumptions they bring, in order to provide recommendations for engineering integration in science classes.

The third study followed nine students as they learned about materials science during their third grade year (Wendell & Lee, 2010). This study combined classroom artifacts, engineering notebooks, with qualitative methods, two interviews, to study students’ conceptual change during a science-based engineering design unit. They found that students who completed their workbooks and were most engaged with the self-reflection tasks found the greatest gains in materials selection tasks completed as part of the interviews. These articles show the value of studying elementary engineering education at the individual level to understand student learning and experiences.

1.2 Statement of the Problem

Engineering is an increasing part of P-12 curricula across the United States (Moore, Tank, Glancy, & Kersten, 2015). Inclusion of engineering education in both formal and informal settings is often expected to increase students’ interest in engineering as a career path and to increase students’ engineering and technology literacy (Brophy, Klein, Portsmore, & Rogers, 2008; Ganesh & Schnittka, 2014; Lachapelle & Cunningham, 2014). Research on P-12 engineering education often focuses on broad impacts on students’ engagement or knowledge and few studies focus on elementary students (Hynes et al., in press). We do not understand how elementary school students’ perceptions of and attitudes toward engineering change over time on an individual level (NAE & NRC, 2014).
1.3 Purpose of the Study

The purpose of this study is to understand the individual experiences of elementary students as they are exposed to multiple years of engineering instruction as a part of their curriculum. In particular, students’ conceptions of engineers and engineering, their knowledge of engineering, and their attitudes toward engineering as a career and in their classroom activities will be investigated.

1.3.1 Research Question

The overall goal of this study is to understand individual student experiences and conceptions of engineering as they are exposed to engineering through classroom activities. From that overarching goal, the following research question will be explored through the course of this study: How do elementary students’ knowledge of, attitudes toward, and overall conceptions of engineering evolve over three years of engineering instruction?

1.3.2 Personal Motivation

One of my first tasks at Purdue University was coding Draw an Engineer Tests. One common theme in the drawings was the conception of an engineer as a mechanic, sometimes working on a car in a shop, and sometimes helping someone in a car on the side of the road. In nearly every case, the mechanic/engineer was male and if he was helping someone, that person was female. One drawing took me by surprise: It was the same scenario, but the gender roles were switched. I was then surprised at the fact that I was surprised by the gender role swapping seen in the image. As a female engineer, I would hope that I would be less surprised by nontraditional representations of gender in
engineering. That drawing stayed with me and caused me to consider what experiences
casted that student to have a different image of engineering as compared to common
stereotypes and the images presented by her peers. What caused that student, and others
like her, to have a different conception of engineers and engineering? What was her
story? How did she and other students understand engineering as elementary students?

1.4 Significance of the Study

This work provides an in-depth description of how elementary students from
diverse backgrounds understand engineering over three years of engineering instruction.
By looking at individual student narratives situated within their context, researchers,
educators, and others can understand how students personally experience and make
meaning of engineering during their elementary education. This can inform the design of
curriculum and presentation of engineering for younger students.

Hands-on engineering projects are often lauded for the benefits in student
motivation and engagement they bring to the classroom (Moore et al., 2014). Engineering
projects are open-ended, offering teachers an easy way to engage in student-focused
learning (Cunningham & Lachapelle, 2014). Many of the case studies found in the above
database searches focus on the teachers, seeking to explore how they came to understand
and integrate engineering in their elementary classrooms. While the teacher perspective
provides useful and necessary information, there are few studies exploring engineering in
elementary classrooms from the student perspective. Understanding student experiences
with engineering from their own perspective is of utmost importance to understanding
and best directing students’ ways of learning and knowing about engineering.
1.5 Organization

This dissertation contains six chapters. Chapter 1 provides the background and motivation for the study. Chapter 2 reviews the relevant literature contributing to the study. Chapter 3 details the methods used for data collection and analysis. Chapter 4 presents case study descriptions of each participant included in this study. Chapter 5 provides a cross-case analysis, comparing the individual case studies for common patterns. Chapter 6 concludes the dissertation with a discussion of the conclusions, implications, and future work.
CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

This chapter provides the theoretical background required to understand the assumptions behind and results of this dissertation. This work explores student conceptions of engineering and their understanding of engineers and technology. Research has been done in the area of elementary engineering perceptions, commonly studied using the Draw an Engineer Task, an instrument also used in this study. Research has also been done in the area of student learning, notably in conceptual change literature which is discussed here through situated knowledge. A discussion of research in the areas of engineering perceptions and situated knowledge as well as an overview of what has been learned from the larger data set used in this dissertation follows.

2.2 Engineering Perceptions

Engineers are commonly perceived as white males who work alone and have poor social skills (Yurtseven, 2002). This perception may be a deterrent to participation for females and people of color, underrepresented groups in engineering, as they do not see engineering as a career for people like themselves (Nauta & Kokaly, 2001; Zirkel, 2002). Increasing the number and diversity of engineers in part requires changing people’s perceptions of engineers and engineering (National Academy of Engineering Committee on Public Understanding of Engineering, 2008).
One common way to understand children’s perceptions of engineers and engineering is through responses to the Draw an Engineer Test/Task (DAET). This instrument was created based on the Draw a Scientist Test (DAST), which was developed as an easy way to understand students’ perceptions of scientists (Chambers, 1983). In this instrument, subjects are asked to draw a scientist, and a checklist, the DAST-C, is typically used to count the number of stereotypical features shown in the drawing (Finson, 1995). The original DAET included short-answer questions about engineers and engineering in addition to the drawing (Knight & Cunningham, 2004), as have many subsequent versions including the one used in this study (see Appendix A).

The DAST is commonly used to gauge stereotypical perceptions of scientists (Finson, 2002), while the DAET tends to be used to gauge stereotypical perceptions of engineering rather than the engineers doing the work. The DAET is typically analyzed in two main ways, as a way to understand students’ perceptions of engineers and as a way to gauge students’ disciplinary knowledge of what engineers do.

The initial publication presenting the Draw an Engineer Test did not use a predetermined rubric. Researchers analyzed the drawings for presence of male or female engineers, then inductively coded the drawings for common elements, grouping these elements into six main themes (Knight & Cunningham, 2004). These themes included images of Building/Fixing, Designing, Products of Engineering – Mechanical, Products of Engineering – Civil, Trains, and Laboratory Work (Knight & Cunningham, 2004, pp. 6-7). Capobianco and colleagues also inductively analyzed the DAET data, finding four main categories for conceptions of an engineer (Mechanic, Laborer, Technician, and Designer), five main actions performed by an engineer (Fixes, Builds (assembles), Makes
(creates), Works, and Designs), and five common types of artifacts (Vehicle, Engine, Building, Electrics, and Tools & supplies) (Capobianco, Diefes-Dux, Mena, & Weller, 2011). Carr and colleagues expanded the categories of engineering to eleven, adding Design/Create Single, Tradesman, Driver, Object/Engine, Factory/Make Quantity, Other Profession, and Other/None to categorize all drawings, even those that did not present an engineer (Carr, Diefes-Dux, & Horstman, 2012). Two rubrics have been published for the Draw an Engineer Test, the Checklist (Fralick, Kearn, Thompson, & Lyons, 2009) and the Systematic Coding System (Weber, Duncan, Dyehouse, Strobel, & Diefes-Dux, 2011). Both are more complex than the DAST-C, incorporating multiple aspects of engineering beyond common stereotypical factors.

The Checklist includes 61 checkboxes that pertain to potential imagery in the participants’ drawings. Seven main categories are used, including Species (Human, Non-Human, No Person), Skin Color (Brown, Peach, Yellow, Green, None, Other), Other Attributes (Crazy Hair, Glasses/Goggles, Lab Coat, Laborer’s Clothing, Other), Gender (Male, Female, Unknown), Location (Indoors, Outdoors, Space, Underground, Underwater, Can’t Tell), Inferences of Action (Making/Fixing/Working with Hands, Operating/Driving Machines & Vehicles, Designing/Inventing/Creating Products, Experimenting/Testing/Creating Knowledge, Explaining/Teaching, Observing, No Action Inferred, Other), and Objects (30 additional common objects including Robots, Computers, Tools, and others) (Fralick et al., 2009, p. 72). Unlike the DAST-C, this checklist is not something that can be easily scored and used to understand stereotypical perceptions held by students. Rather, it is a full diagnostic checklist that provides the researcher with a way to analyze multiple aspects of the participants’ drawings. When
used before an intervention, specific misconceptions can be quantified. After an intervention, this checklist can provide evidence of students’ new conceptions of engineering. When used in conjunction with a pre-test, comparisons can be made to understand what misconceptions are strong and what preconceptions the intervention has changed.

The Systematic Coding System allows for a more complete analysis of DAET data with eleven areas including 35 coded attributes and six write-in questions (Weber et al., 2011). Each of the 35 coded attributes is at a minimum a 1 (present) or 0 (absent). Two attributes, Objects and Clothing, are adapted directly from the Fralick, Kern, and Thompson Checklist. Some of the attributes have a large number of possible codes, including the Objects category with 34 potential codes. This system provides an extremely detailed list of all aspects of the DAET that had been studied previously or might be of interest. Some categories, like the engineering field shown, are difficult to code without the benefit of student interviews or written descriptions of their drawing.

Children may have meanings attached to their drawings that are not apparent when an outside observer considers their work. To ensure full understanding, Malchiodi (1998) recommends interviewing children about their drawings. In this study, both children’s drawings of engineers and interviews where they describe their drawing were used to enhance the understanding of participants’ perceptions of engineers and engineering.

2.3 Student Learning

One expected outcome of P-12 engineering education in the United States is an increase in the number of engineers (Lachapelle & Cunningham, 2014). To reach that
goal, P-12 students should learn what engineers do, moving beyond the common stereotypes of engineers as white males with minimal social skills (Yurtseven, 2002) or perceptions of engineers as mechanics and laborers (Capobianco et al., 2011).

Learning does not happen by filling up the blank slate of a child’s mind, rather, learning happens through refining existing mental structures through interaction (Bjorklund, 2005). As children interact with a phenomenon, whether directly or indirectly, they are presented with new information. Piaget (1952) described this broadly as assimilation and accommodation. New information can be assimilated when it can be made to fit with existing mental structures, while accommodation happens when the underlying mental structures, or schema, must change based on the input.

Chinn and Brewer (1993) provided additional responses to new information between assimilation and accommodation, focusing on anomalous information that conflicts with existing schemas. This new information can be ignored, accepted, explained using other knowledge, and/or used to change underlying theories or beliefs held by the individual, (Chinn & Brewer, 1993). As children interact with phenomena, schemas for these phenomena evolve. Each interaction has the potential to provoke conceptual change through accommodation, but it is also possible for reinterpretation of the data to something that fits within existing schema, peripheral change where the schema is partially modified to a partially correct understanding, or even outright rejection of the data or exclusion of the information from the schema (Chinn & Brewer, 1993). Conflicting information, such as that in the popular media about engineers and what they are learning in the classroom, may even create different schema for the same concept.
Concepts can be highly context-dependent, as noted by Marcia Linn in her 2002 presentation, “Objects in motion remain in motion in the classroom, but come to rest on the playground” (as cited by Perkins, 2010, p. 95). Students may have separate schemas for how they should answer in the classroom, “Objects in motion remain in motion,” and how they believe the world really works, “come to rest on the playground.” Students “play the school game” by responding as they know they should on an exam while holding alternate beliefs about the reality of the concept. Full accommodation only happens when all perceptions of a phenomenon align. Student learning is constructed through assimilation and accommodation.

2.4 Overview Literature Review: Full Data Set

This project uses data from a large-scale, five-year longitudinal study involving data from one school district, fifteen different schools, 168 teachers, and over four thousand individual students using a variety of instruments. The study is further described in Section 3.2 Context. This data set has been explored through numerous studies published in journals (e.g. Douglas, Rynearson, Yoon, & Diefes-Dux, 2015; Hsu, Purzer, & Cardella, 2011; Weber et al., 2011; Yoon, Dyehouse, Lucietto, Diefes-Dux, & Capobianco, 2014), conferences (e.g. Douglas, Wiles, Yoon, & Diefes-Dux, 2013; Dyehouse, Diefes-Dux, & Capobianco, 2011; Lee & Strobel, 2010; Rynearson, Diefes-Dux, & Douglas, 2014), and even book chapters (e.g. Diefes-Dux, Whittenberg, & McKee, 2013; Hsu, Cardella, & Purzer, 2014; Liu, Carr, & Strobel, 2012). The data have been explored in various ways but there are still unexplored avenues, particularly in the student interview data. To situate this case study in the broader study of which it is a part, an Overview Literature Review (Grant & Booth, 2009) is provided.
2.4.1 The Data Itself

The longitudinal study generated a large, complex data set that required methodical planning to collect and a large database to store and access the data. Due to its size and complexity, the creation and maintenance of the database itself has been the topic of one paper (Tafur, Diefes-Dux, & Douglas, 2014). In addition, there was one publication presenting the data set as a resource for other educational researchers (Diefes-Dux, 2015).

2.4.2 Methods

The longitudinal study used a variety of instruments administered to students and teachers. Data gathered during the early stages of the study were used for further refinement of the Design, Engineering, and Technology (DET) instrument (Hong, Purzer, & Cardella, 2011) and to further refine rubrics for the Draw an Engineer Task (DAET) (Carr, Diefes-Dux, et al., 2012; Weber, Duncan, Dyehouse, Strobel, & Diefes-Dux, 2011). The use of DAET was further explored through triangulating rubric-based drawing rating and student interviews to ensure that the use of rubrics is valid for DAET data (Dyehouse, Weber, et al., 2011). This study found that reliability between raters and comparing interview statements to the drawing was approximately 80% for the commonly scored items found on the initial stereotype checklist, but decreased to approximately 67% when rating more ambiguous aspects like whether the engineer was involved in the engineering design process.

In addition to reviewing methods on previously available instruments, some instruments were developed during the study. The Design Process Knowledge (DPK) test, a verbal protocol used for college students, was adapted for student use as part of the
interview protocol throughout the study (Hsu, Cardella, & Purzer, 2012). This protocol presents participants with a peer’s design process through a short scenario and asks them to discuss what about the process went well and what could be improved. It was also adapted for teachers, asking teachers to comment on a student’s design process, and piloted as a pre-/post-test during the teacher professional development provided during this study (Hsu, Cardella, & Purzer, 2010). The Doing Science Self-Efficacy (DSSE) instrument was developed and validated to understand how comfortable elementary school teachers are with science and scientific inquiry practices (Lee & Strobel, 2010).

Some studies have been published focusing on the logistics of the program, including video observations of classrooms and creating an online learning community for teachers. Considerations for collecting video data in classrooms and at professional development workshops and the handling of video data were explored through a conference paper (Strobel & Liu, 2010). The rationale for and addition of an online learning community to enhance teacher professional development throughout the longitudinal study was published (Liu, Carr, et al., 2012) while a discussion on how to cultivate a community of practice focusing on engineering education for elementary teachers was presented at a conference (Liu, Mellish, & Strobel, 2012).

2.4.3 Teachers

Engineering professional development was a large component of the longitudinal study. Data were collected as part of the professional development workshops and throughout the study to understand teachers’ classroom experiences and development. Standards for engineering in elementary grades were uncommon when the study began and many elementary-grade teachers had little or no prior experience with engineering
(Carr, Bennett, et al., 2012). Teachers’ views on teaching design, engineering, and technology (DET) have also been studied; finding that teachers tend to believe that teaching DET is important, but they are generally unfamiliar with the content (Hsu et al., 2011). Teachers also had differing motivations for why they should teach DET content that was strongly correlated with their ethnic background. An in-depth discussion of the Summer Academies, what teachers learned, barriers to implementing engineering, and recommendations for practitioners based on findings from this and other studies involving the Summer Academies, teacher development workshops presented by INSPIRE, are presented in a chapter of *Engineering in Pre-College Settings* (Diefes-Dux, 2014).

Additional studies explored teachers’ experiences beyond the professional development. Elementary teachers’ understanding of pedagogical content knowledge from professional development through implementation was found to be a continuum from knowing about engineering to knowing how to teach engineering to their students (Sun & Strobel, 2013). Many of the concepts learned during professional development were adapted when teachers were faced with students’ misconceptions and engineering-related learning difficulties. A case study was undertaken to understand the differences between schools that continued to sustain engineering integration and those that did not (Douglas et al., 2015). This study found that schools with teachers who believed the engineering supported required state standards were more likely to continue to implement engineering.
2.4.4 Students

Students’ engineering perceptions, knowledge, and identity development as well as design process knowledge have been explored through the available data. Beyond rubrics for the DAET described in the earlier section, studies on student perceptions found that after the intervention, overall student perceptions of engineers moved from common naïve understandings of laborers and mechanics toward design-focused activities (Carr, Diefes-Dux, et al., 2012). Even in the early years of the longitudinal study, students at higher grade levels described more aspects of the Engineering Design Process during the Design Process Knowledge interview, without having prior years of engineering (Hsu et al., 2010). There may be developmental aspects about engineering design that allow more mature students to attain a greater understanding of the Engineering Design Process. Student knowledge testing followed a similar path, with older students having a greater understanding of engineering concepts, though students with prior engineering experience outperformed their peers (Tafur et al., 2014).

There was also a final report presented to the district at the end of the longitudinal study (Institute for P-12 Engineering Research and Learning [INSPIRE], 2013). This report focused on student outcomes for the final years of the project, the years in which the participants in this study participated. Overall, engineering career knowledge and aspirations increased from the beginning of the year to the end of the year as seen in Figure 2.1. The highest possible score is 30, indicating high levels of understanding of the work that engineers do and interest in engineering as a career overall. Students did not have higher scores the second year.
Students did not have much loss in engineering knowledge over the summer and their knowledge increased as measured by the Student Knowledge Tests as shown in Figure 2.1. The questions relating to engineering knowledge remained the same on each test and students were not given feedback based on their responses; the tests were for research purposes only.
Figure 2.2 Change in students’ engineering knowledge grade (INSPIRE, 2013, p. 10)

Student conceptions of engineers as seen on the DAET became closer to the desired conception of engineer as designer over time, increasing both between years and over the school year as seen in Figure 2.3. The greatest change in understanding can be seen in the 2012 4th grade post scores, where the majority of students have drawn engineers as designers in some way.
Figure 2.3 Change in student conceptions of engineers (INSPIRE 2013, p. 8)
2.5 Conclusion

In studies performed on the data set used for this study, as in elementary engineering education literature as a whole, there is little exploration of individual elementary students’ experiences over the multiple years of this study. The data collected from students were typically analyzed using only one or two instruments, seeking generalizable results across many students. The data has not been holistically used to explore students’ individual experiences with engineering in an in-depth manner.

2.6 Chapter Summary

This chapter has presented an Overview Literature Review to provide a holistic view of the results found from the larger study thus far. A review of literature relating to elementary student perceptions of engineers and engineering has been provided.
CHAPTER 3. METHODS

The purpose of this study is to understand individual students’ experiences with and subsequent understanding of engineering. This chapter describes the research paradigm, methods, and methodology used to guide the design of this study.

3.1 Theoretical Framework

3.1.1 Paradigm

A pragmatic paradigm is the lens used for this study. The pragmatic paradigm focuses on the research question, using that as the guiding focus for choosing study methods and data types, rather than the paradigm itself (Mackenzie & Knipe, 2006). The study methods and procedures have followed the pragmatic paradigm, leading to a descriptive chronological case study analysis of students’ experiences with and understandings of engineering and culminating in a cross-case analysis to identify common patterns.

3.1.2 Theoretical Lens

The theoretical lens guiding this study is Constructivism. As children interact with the phenomena of engineers, engineering, technology, and design, schemas for these phenomena evolve. Children’s perceptions and understanding of a phenomenon change over time through assimilation, accepting information that aligns with an existing schema, and accommodation, revising a schema due to new information (Piaget, 1952).
All of the students in this study were exposed to similar engineering activities founded on the same definitions of engineers and engineering. Differing prior knowledge and experiences with engineers and engineering through the popular media and other sources have an impact on how individual students construct their understanding of engineers and engineering. The complex and changing nature of schemas, and therefore, understanding of concepts like engineers and engineering and how this conceptual change takes place through assimilation and accommodation is the guiding lens for this study.

3.1.3 Methodology

This study uses the Case Study methodology. One definition of case study research is “(a) the in-depth study of (b) one or more instances of a phenomenon (c) in its real-life context that (d) reflects the perspective of the participants involved in the phenomenon” (Gall, Borg, & Gall, 1996, p. 447). This study explores the phenomenon of student learning about engineering from the students’ perspective using multiple in-depth forms of data collected from three years of engineering education implemented in their elementary classrooms presented by their classroom teachers. Case studies are often used in educational research, commonly as program evaluations (Gall et al., 1996; Yin, 1993, 2005). Case studies are appropriate when the context and the phenomena to be explored are intertwined (Yin, 2014). The context of engineering instruction and the phenomenon of the evolution of students’ knowledge and perceptions are strongly linked in this study; one cannot consider one separate from the other. A case study is appropriate when multiple data sources are available to triangulate data and create a rich understanding of the phenomenon (Yin, 2014). Each student has six sets of four types of data that allow for
an in-depth exploration of how their conceptions of engineers and engineering evolve over time, resulting in a Descriptive Chronological Times Series Case Study (Yin, 2014).

A descriptive case study allows for a rich description of a phenomenon in its real-world context, in this case, the evolution of students’ knowledge and attitudes throughout elementary school where engineering is integrated into the curriculum. Rather than attempting to develop a causal relationship or evaluate the program, this study describes student experiences with the phenomenon of interest. This study follows student experiences over time, describing their experiences at each time point and the overall changes in their understanding of engineering over time, creating a chronological time series case study.

Exploring seven individual cases in this multiple case study provides additional insight into the phenomenon of interest, and comparing these cases for similarities and differences provides an additional dimension of understanding (Yin, 2014). After building a full description of how each student developed their understanding of interest, these individual cases were compared for further exploration of how students’ conceptions of engineers and engineering develop in a cross-case analysis. Cross-case syntheses allowed for more robust findings as they combined the results from multiple cases and were not the results of a single case (Yin, 2014).

3.2 Contexts

The data used for this study come from a longitudinal study of engineering in elementary schools from the fall of 2009 to the spring of 2013. This five-year NSF-funded project evolved from the Summer Academy, a week-long teacher professional development workshop presented by Purdue University’s Research Institute for Pre-
College Engineering (INSPIRE). This workshop was designed for elementary educators to:

(a) convey a broad perspective of the nature and practice of engineering;
(b) articulate the differences and similarities between engineering and science thinking; (c) develop a level of comfort in discussing with P – 6th grade students what engineers do and how engineers solve problems; and (d) use problem-solving processes (i.e., science inquiry, model development, and design processes) to engage elementary students in complex open-ended problem solving. (NSF Project Description)

After determining a school district with which to work, INSPIRE held yearly Summer Academies to teach second, third, and fourth grade teachers engineering content knowledge and pedagogical content knowledge to prepare them to incorporate engineering lessons in their classrooms. Each teacher attended a Summer Academy before and after their first year of teaching engineering lessons. Teachers were also offered support and expected to support each other in a learning community focused on engineering content and pedagogy. Teachers taught specific required lessons and were encouraged to incorporate additional engineering activities. Descriptions of these lessons can be found in Section 3.2.4, Instructional Materials.

As part of the large, longitudinal study, data were collected at the beginning and end of each school year from teachers and students. Teachers were also asked to complete online Lesson Debriefs during the school year after each in-class engineering experience and instruments connected to their Summer Academy experience. All types of student data are used in this study, and some of the teacher data was used to create
classroom profiles. Instruments and interview protocols are described in Section 3.3, Instruments, and included in the Appendices.

3.2.1 Participants

Over four thousand students were involved at some point during the five years of the longitudinal project. Over the five years, some student engineering experiences were changed and interview protocols were refined. In the final years of the study, the most in-depth student interview protocols were used, as shown in Appendix E. To improve consistency between cases and to explore cases to the fullest extent possible, cases were chosen if they had complete records of data including the Draw an Engineer Task (DAET), the Engineering Identity Development Scale (EIDS), the Student Knowledge Tests (SKT), and interviews at both fall and spring data collection points for years 3, 4, and 5 of the study (grades 2, 3, and 4). Seven potential candidates were identified for this study; all provided rich data that included detailed responses to interview questions and DAETs that showed various understandings of engineers and the work that they do. In addition to student participants, data from teacher surveys and interviews were used to contextualize student engineering experiences during the school year. Fifteen teachers taught the seven students during the three years of the study; three students were in the same second grade class at School One, two students were in the same second grade class at School Three, and three students were in the same fourth grade class at School Three, shown in Table 3.1. Individual teachers are numbered while student pseudonyms are used in the table.


<table>
<thead>
<tr>
<th>School</th>
<th>Case</th>
<th>Year One</th>
<th>Year Two</th>
<th>Year Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ashleigh</td>
<td>T11</td>
<td>T12</td>
<td>T15</td>
</tr>
<tr>
<td></td>
<td>Sofia</td>
<td>T13</td>
<td>T13</td>
<td>T16</td>
</tr>
<tr>
<td></td>
<td>Marcos</td>
<td>T14</td>
<td>T14</td>
<td>T17</td>
</tr>
<tr>
<td>2</td>
<td>Jake</td>
<td>T21</td>
<td>T22</td>
<td>T23</td>
</tr>
<tr>
<td>3</td>
<td>Mike</td>
<td>T31</td>
<td>T33</td>
<td>T36</td>
</tr>
<tr>
<td></td>
<td>Beth</td>
<td>T34</td>
<td>T34</td>
<td>T36</td>
</tr>
<tr>
<td></td>
<td>Elena</td>
<td>T32</td>
<td>T35</td>
<td>T36</td>
</tr>
</tbody>
</table>

### 3.2.2 Aim of Intervention

After the engineering intervention, students will ideally understand that engineers design technology, with a technical, not artistic, concept of design and a full understanding of technology. A complete, complex understanding of engineering will contain a complete, complex understanding of technology with the knowledge that an engineer might design even simple technology, such as the toothbrush example discussed in the student interviews (see Appendix E for full protocol). Through the intervention, student conceptions of technology are expected to start at a naïve or nonexistent understanding, likely incorporating the common misconception that technology requires electricity, and evolve to a more complex understanding incorporating the full definition and an understanding that engineers design technology.

### 3.2.3 Definitions

Throughout this intervention, there are specific concepts and ideas that students were expected to learn. Target definitions specific to the engineering context are as follows.
3.2.3.1 Design

Design refers to the process that engineers use to create technology, often operationalized in an Engineering Design Process. In this context, design does not include artistic design, but instead focuses on technological design.

3.2.3.2 Technology

During the INSPIRE Summer Academies, the three-part definition of technology was given as: 1. Any object, process, or system 2. Created/designed by man 3. To solve a problem (to improve the quality of life). One common misconception of technology is that it is electronic or requires electricity, like cell phones and robots, and does not include simple items like shoelaces or toothbrushes (Lachapelle & Cunningham, 2007; Solomonidou & Tassios, 2007).

3.2.3.3 Engineers and Engineering

Engineers design technology. During the INSPIRE Summer Academy, teachers learned of common student misconceptions so that they could be careful to not reinforce them, including: 1. Engineers physically build structures like bridges, skyscrapers hotels, and homes. They weld, hammer, nail, and bulldoze. 2. Engineers build furniture and walls; they are carpenters and bricklayers. 3. Engineers work on assembly lines in factories.

3.2.3.4 Engineering Design Process

An important component of engineering instruction is the process that engineers use to design technology. The Engineering Design Process (EDP) used throughout the longitudinal study was the five-stage model used by the Engineering is Elementary
curriculum as seen in Figure 3.1, modified by INSPIRE to include an explicit Test stage and end stage of the design cycle, Production.

Figure 3.1 Engineering Design Process as presented at the INSPIRE Summer Academy

This Engineering Design Process was designed to be easy for students to remember, five steps with grade appropriate words (Cunningham & Lachapelle, 2014). Each of these words is something that children have probably heard before, and have specific meanings in an engineering context. The Engineering is Elementary (Engineering is Elementary, n.d.-a) descriptions of each stage are seen in Figure 3.1 and the INSPIRE definitions are shown in Table 3.2.
Table 3.2 INSPIRE Engineering Design Process definitions

<table>
<thead>
<tr>
<th>Stage</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ask</td>
<td>Understand the problem</td>
</tr>
<tr>
<td>Imagine</td>
<td>Brainstorm ideas</td>
</tr>
<tr>
<td>Plan</td>
<td>Select one idea and develop fully</td>
</tr>
<tr>
<td>Create</td>
<td>Build technology</td>
</tr>
<tr>
<td>Test</td>
<td>Test for Criteria for Success</td>
</tr>
<tr>
<td>Improve</td>
<td>Use evidence to move forward</td>
</tr>
<tr>
<td>Production</td>
<td>Finalize design that satisfies the goal</td>
</tr>
</tbody>
</table>

3.2.4 Instructional Materials

Throughout the longitudinal study, various instructional materials and lessons were used including *Engineering is Elementary* units and additional activities provided by the INSPIRE team and created by the elementary teachers. A description of these materials and their implementation follows.

3.2.4.1 Required Engineering Lessons

The following are standard lessons that were expected to be a part of engineering instruction provided by each teacher during each year of the program, modified by grade level as appropriate. Each grade focused on a different type of engineer and standards as appropriate for the science content delivered through an *Engineering is Elementary* (EiE) unit. Each EiE unit consists of four lessons, a Story to introduce the problem, a Type of Engineer who would solve such a problem, a Science Lesson that provides the foundation for the Design Task, and a Design Task where students complete an engineering design project to solve the problem.
3.2.4.1.1 What is Technology?

A preparatory lesson was designed to help students consider what technology is as well as dispel misconceptions before beginning the *Engineering is Elementary* unit. This lesson included but was not limited to brainstorming about technology to help students define what is and is not technology and discussing examples of items that are and are not technology.

3.2.4.1.2 What is Engineering?

A second preparatory lesson was designed to help students consider what engineers are and what they do as well as dispel misconceptions before beginning the *Engineering is Elementary* unit. This often included an introduction to the Engineering Design Process.

3.2.4.1.3 Second Grade Unit: A Work in Process: Improving a Play Dough Process

According to the *Engineering is Elementary* website Unit Overview (Engineering is Elementary, n.d.-d):

If you’ve ever followed a recipe, you know that the amount of each ingredient and the order in which you mix them matters. Chemical engineers use these same principles when designing processes. When students read the storybook Michelle’s MVP Award, they learn about a girl who designs a better way to make play dough. The activities in this unit reinforce the science concepts “solid” and “liquid” as students explore the properties of different materials—and the properties of mixtures of
materials. The final engineering design challenge? Design a process for making high-quality play dough.

**Story**

In *Michelle's MVP Award*, Michelle, a Canadian hockey player, works with a chemical engineer to design a process to create play dough to help her team raise money to see the Toronto Maple Leafs play.

**Type of Engineer**

Students study chemical engineering through an activity involving liquids and food coloring.

**Science Lesson**

Students create rubrics for high-quality and low-quality play dough in order to perform experiments using different ingredient ratios.

**Design Task**

Using the knowledge they have learned about ingredient mixtures through the Science Lesson, students design a process for creating high-quality play dough.

3.2.4.1.4 Third Grade Unit: *Marvelous Machines: Making Work Easier*

According to the *Engineering is Elementary* website Unit Overview (Engineering is Elementary, n.d.-b):

Machines make work easier—as students learn when they read about a visit to a potato-chip factory in the storybook Aisha Makes Work Easier. This unit guides students to think like industrial engineers as they explore the surprising variety of simple machines people use every day. Students
also explore the pros and cons of assembly lines compared to making things by hand, then measure the force it takes to complete a task with and without a simple machine to help. Finally, they put their data to the test, combining a series of simple machines to create an assembly-line subsystem for a model potato chip factory.

Story

In *Aisha Makes Work Easier*, Aisha visits a potato chip factory with her brother, an industrial engineer, and learns about all of the simple machines used in the factory system. She creates a simple machine system for her own model factory school project.

Type of Engineer

Students learn about industrial engineering through making products in an assembly line.

Science Lesson

Students learn about simple machines through an experimental science lesson involving spring scales.

Design Task

Using their knowledge of industrial engineering and simple machines, students design factory subsystems to move a load from one point to another.

3.2.4.1.5 Fourth Grade Unit: *A Stick in the Mud: Evaluating a Landscape*

According to the *Engineering is Elementary* website Unit Overview (Engineerin is Elementary, n.d.-c):
The storybook that anchors this unit, Suman Crosses the Karnali River, takes students to Nepal, where people rely on innovative cable bridges called TarPuls to cross flooded rivers during monsoon season. Digging into the role of geotechnical engineers, students must select a safe, flood-proof, and erosion-proof location for a new TarPul. Working with a model riverbank, they study soil properties, examine maps to assess the potential for erosion at different sites along the river, and factor in the villagers’ preferences for a TarPul location.

**Story**

In *Suman Crosses the Karnali River*, Suman, a Nepalese boy, helps a geotechnical engineer convince the community that a new type of bridge, a TarPul, is a good idea for crossing the nearby river.

**Type of Engineer**

Students learn about geotechnical engineering as they take core samples from a building site to determine how deep the foundations must go for a model skyscraper.

**Science Lesson**

Students learn about erosion along a riverbank and perform experiments to understand how soil compaction can affect the foundation strength of a building.

**Design Task**

Students use what they have learned about soil and geotechnical engineering to design a site to build a TarPul bridge across a river.
3.2.4.2 Additional Engineering Lessons

There were additional engineering lessons used by the teachers throughout the study. Some of these lessons were provided by the INSPIRE team, others were created by the teachers themselves. Lessons provided by INSPIRE were intended to introduce or reinforce the Engineering Design Process and incorporated best practices for engineering activities such as establishing a client and criteria and constraints for success. Lessons created by the teachers are noted. The content and implementation of teacher-created lessons is mainly taken from details given during interview sessions and may not be fully accurate or complete.

3.2.4.2.1 Bat Puzzles

This project was created by the teachers at School One. A client, ABC Puzzle Company, asked students to design puzzles for kindergarteners that must be only five pieces, with pictures large enough for a poster board, and the students could decide how to cut the pieces to create the puzzle. These puzzles were then tested by kindergarteners.

3.2.4.2.2 Gumdrop People and Chairs

This project was presented at INSPIRE Summer Academies as a way for students to practice engineering concepts. Students had to use gumdrops and toothpicks to design a person that could sit on the side of a desk without falling over. They then had to design a chair out of gumdrops and toothpicks that would stand and allow the gumdrop person to sit on it.
3.2.4.2.3 Tower Power

This activity was presented at INSPIRE Summer Academies. Students were given index cards to design a tower at least 24” high that could hold a stuffed animal for a specified amount of time.

3.2.4.2.4 Paper Table

This activity was presented at INSPIRE Summer Academies. Students were given a cardboard rectangle and nine sheets of newspaper plus 24” of tape to create a recycled table that can hold books for at least 30 seconds.

3.2.4.2.5 Pop-Up Cards

This activity was presented at INSPIRE Summer Academies. As part of this engineering project, students designed pop-up cards with at least one pop-up component and one moving part that would function at least ten times and fit inside a 9”x12” envelope.

3.2.4.2.6 GT Pyramids

This project was implemented by one teacher at School One. In teams, students designed and created board games using the Engineering Design Process.

3.2.4.2.7 Model Eliciting Activity: Stickers

This project was presented at INSPIRE Summer Academies. Model Eliciting Activities are designed to allow students to create a mathematical model or procedure to solve a problem. These models are then tested for generalizability using a slightly different data set. In this example, a sticker company wanted children to create a
procedure to figure out how many square stickers can fit on one sheet of paper. To test
generalizability, the client next asked students to use their procedure to find out how
many triangular stickers will fit on a sheet of paper and to improve their model if it did not work.

3.2.4.2.8 Model Eliciting Activity: Paper Airplanes

This project was presented at INSIPRE Summer Academies. In this Model Eliciting Activity, students were asked to create a mathematical model to using measurements taken during a competition to decide which contestants win various prizes in a number of paper airplane competitions. They then traded with other teams to use their models to see if they were usable by others. Teams revised their models, then tested them with a new set of data, and revised them again if needed. Then they tested their models again using a third set of data.

3.2.4.2.9 Sally Ride Science Books

The Sally Ride Science Books are a set of age-appropriate books on Science, Technology, and Engineering careers that multiple teachers in the study have access to and have used to allow students to supplement the engineering activities ("Cool careers in STEM," n.d.).

3.2.4.2.10 PBS Design Squad Videos

According to the Design Squad website ("Design Squad global," n.d.), “The goal of Design Squad is to give kids a stronger understanding of the design process, and the connection between engineering and the things we all use in everyday life.” Design Squad is a children’s show featuring engineering problem solving performed by other
children. *Design Squad* videos use a different Engineering Design Process but have been used as examples of engineering in classrooms involved in this study, typically in conjunction with the *Paper Tables* activity.

### 3.3 Instruments

Three participant-completed instruments were used during the longitudinal study: the Draw an Engineer Task (DAET), the Engineering Identity Development Scale (EIDS), and the Student Knowledge Tests (SKT). In addition to these participant-completed instruments, semi-structured interviews were conducted with students. Teachers completed yearly debrief surveys and semi-structured interviews at the end of each school year.

#### 3.3.1 The Draw an Engineer Task (DAET)

The main instrument used in this study was the Draw an Engineer Task (DAET). Adapted from the Draw a Scientist Test (Chambers, 1983), the Draw an Engineer Task has been used to understand students’ perceptions and understanding of engineers and engineering (Knight & Cunningham, 2004). The format of the instrument is often changed between studies, with various ways to word the prompt, whether or not the student is asked to describe their image in writing, or whether the page is blank or a specific drawing area is defined through an outlined space on the page (e.g. Carr, Diefes-Dux, et al., 2012; English, Hudson, & Dawes, 2011; Knight & Cunningham, 2004; Oware, Capobianco, & Diefes-Dux, 2007). The format used for this study was developed by Brenda Capobianco in 2007. The prompt given at the top of the page is “In the space below, draw an engineer doing engineering work.” as seen in Appendix A, with space
outlined for the drawing. Below the drawing is a second prompt, “What is the engineer doing?” with lines so that the participant may explain their drawing.

3.3.2 Engineering Identity Development Scale (EIDS)

The Engineering Identity Development Scale (EIDS) has been used in research multiple times to measure students’ understanding of engineering, academic identities, and career aspirations (e.g. Capobianco, Ji, & French, 2014; K. S. Yoon, Duncan, Lee, Scarloss, & Shapley, 2007; Zoltowski et al., 2014). The EIDS is a twenty question instrument using a 3-point Likert-like scale intended for grades 1 – 5, (Capobianco, French, & Diefes-Dux, 2012). The EIDS was developed to include four theoretical subscales including “Engineering Aspirations,” with items relating to openness to engineering as a career, and “Occupational Identity,” with items relating to student perceptions of engineering career attributes (Capobianco, Diefes-Dux, & Habashi, 2009). The EIDS used for second grade students can be seen in Appendix B, and the version used for third and fourth grade students can be seen in Appendix C.

3.3.3 Student Knowledge Test (SKT)

To gauge changes in student knowledge, knowledge tests were created for each year of the study. These tests were not used to grade the students, but allowed the researchers to understand student growth in four main areas: science knowledge connected to the engineering unit; engineering knowledge; Engineering Design Process knowledge; and knowledge of technology (Tafur et al., 2014). The SKTs had fifteen multiple-choice questions, with three or four options, each with a desired answer. SKTs were given at the beginning of the year and at the end of the year. End of year tests had the same content as pre-tests with reordered questions and small changes like names used
for people. Two versions of the end-of-year tests were created each year. All nine SKTs (one pre and two post per year) are in Appendix D.

3.3.4 Teacher Debrief Survey

At the end of the school year, teachers were asked to complete a survey noting what engineering lessons and activities they had taught along with general demographic information including number of years and subjects taught. An example survey is in Appendix F.

3.3.5 Student Interview Protocol

Following collection of participant-completed instrument data during both fall and spring data collection periods, a semi-structured interview was conducted with students. The protocol was designed to explore the participants’ drawings of an engineer, their experiences with engineering, their ideas about and knowledge of engineers and engineering, their understanding of technology, their understanding of the Engineering Design Process, and their attitudes toward engineering as a career. During the interview, the students were shown their drawn engineer to prompt their memory. The interview protocol for each interview is in Appendix E.

3.3.6 Teacher Interview Protocol

At the end of the school year, during the spring data collection period, a semi-structured interview with teachers was conducted. The protocol was designed to gather data on how participants implemented the engineering lessons, how they felt their students reacted to the engineering lessons, and how engineering as a subject area integrated into their typical curricular requirements. The interview protocols for each year of the longitudinal study are in Appendix G.
3.4 Analysis

The analysis has two main sections, the Individual Case Study and the Cross-Case Analysis. The research question is answered at the individual student level and at the cohort level, focusing first on individual student experiences and secondly on common experiences and themes found across presented cases.

3.4.1 Individual Case Studies

Each case is a descriptive look at how each student’s conception of engineering evolved over three years of engineering instruction in a reflective analysis, relying primarily on the researcher’s judgement rather than a proscribed method for analyzing the data (Gall et al., 1996). These cases incorporate student responses in interviews and written instruments to build a profile of his or her conception of engineering at each time point of data collection chronologically, in a descriptive time series (Yin, 2014). A summary of the evolutionary path of each student’s knowledge of and attitudes toward engineering is presented. Each descriptive profile has been iteratively created using all available data to present a narrative for each student (Yin, 2010).

As the context is strongly intertwined into the phenomenon of interest, teacher survey data and interviews are used to paint a picture of how each teacher viewed engineering and how much experience he or she had with teaching the engineering lessons as well as what engineering experiences students were exposed to during the school year. Teacher interview data was available for all but one teacher in the sample. For this teacher, only survey data were used to understand what engineering experiences were present during the school year.
The primary data sources for building a description of how students understand and conceive of engineers and engineering were the Draw an Engineer Task and student interviews. These primary sources were used to answer the overarching research question for each individual student. Secondary data sources, the Student Knowledge Tests and the Engineering Identity Development Scale, were used to triangulate student knowledge, conceptions, and attitudes toward engineering and student conceptions of technology.

Student interview responses were the main source of data for building student profiles. Using student interview responses, student attitudes toward engineering; conceptions of engineers; and understanding of engineering, engineering design, and technology are presented to the reader through a descriptive narrative using the students’ own words and researcher interpretation of student responses (Yin, 2010). The Draw an Engineer Task along with descriptions of what engineers do during the interview were used to infer each student’s conception of an engineer at each point in time during the study. A description was built using the student’s own words and a coding scheme applied to the DAET as published by Carr, Diefes-Dux, and Horstman (2012) and seen in Table 3.3. The interview description of the drawing was used to triangulate and discern an engineering conception category when the drawing was unclear.

Table 3.3 Draw an Engineer Task Category Descriptions (Carr, Diefes-Dux, et al., 2012)

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designer</td>
<td>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.</td>
</tr>
<tr>
<td>Technician</td>
<td>Computer or electronic technician portrayed by a person fixing something electronic.</td>
</tr>
<tr>
<td>Design/Create Single</td>
<td>Hobbies, crafts, and designs for personal use or making one object for a specific person.</td>
</tr>
</tbody>
</table>
Table 3.3 Draw an Engineer Task Category Descriptions (Carr, Diefes-Dux, et al., 2012), Continued

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tradesperson*</td>
<td>Carpenters, plumbers, welders, etc. where a person is fixing something that is not mechanical.</td>
</tr>
<tr>
<td>Mechanic</td>
<td>Fixing a vehicle, engine, machine or something else that is mechanical.</td>
</tr>
<tr>
<td>Laborer/Builder</td>
<td>Building houses, roads or buildings through physical labor and other forms of manual labor not covered in other categories.</td>
</tr>
<tr>
<td>Driver</td>
<td>Drives or operates any type of vehicle including, but not limited to, cars, trains, trucks and airplanes.</td>
</tr>
<tr>
<td>Object/Engine</td>
<td>A person is not drawn and an object is intended as the “engineer”.</td>
</tr>
<tr>
<td>Factory/Make Quantity</td>
<td>Factory workers or individuals making a quantity of an item without the notion of design or process indicated.</td>
</tr>
<tr>
<td>Other Profession</td>
<td>Teachers, lawyers, doctors, policemen, scientists and other professions.</td>
</tr>
<tr>
<td>Other/None</td>
<td>Student was off-task or drawing is not discernable.</td>
</tr>
</tbody>
</table>

*Originally tradesman, has been modified for this study

In the Student Knowledge Tests (as seen in Appendix D), there are specific questions that relate to what engineers do. Responses to these questions were used qualitatively to triangulate and enhance the description of student perceptions of engineers and engineering. Responses to interview questions and descriptions of technology were qualitatively triangulated with responses to technology-related questions in the Student Knowledge Tests.

The Engineering Identity Development Scale includes questions about what engineers do and what students themselves would like to do when they grow up. Responses to these questions were used qualitatively to triangulate and enhance the descriptions of student understanding of engineers and engineering and student attitudes toward engineering, including student interest in engineering as a potential career.

The cases were further explored with a cross-case analysis to understand common student experiences.
3.4.2 Cross-Case Analysis

After each case was developed and explored in detail, all cases were compared and contrasted for common themes in a cross-case synthesis (Yin, 2014). Cases were compared and analyzed using Word Tables to provide structure to themes found across cases (Yin, 2010, 2014). Thematic analysis across cases is mainly inductive with a priori areas of consideration such as classroom atmosphere and teacher experience, gender, ethnicity, and outside knowledge of engineering.

3.5 Chapter Summary

This chapter has presented the underlying methodology, descriptive chronological time series case study and cross-case analysis, for this study, instruments used, and analytical methods performed. In addition, definitions for the terms and concepts used in the project and explanations of the required and optional engineering activities students may have seen are included.
CHAPTER 4. INDIVIDUAL CASE STUDIES

4.1 Introduction

In this chapter, each student’s experience is explored through their responses to recorded interview data and written instruments including the Draw an Engineer Test (DAET), the Engineering Identity Development Scale (EIDS), and the student knowledge tests (SKT). Lessons each student was exposed to and the attitude of the teacher toward engineering and his or her students’ reactions to engineering for each year of the study is included to contextualize the students’ academic exposure to engineering. The classroom context is developed through data provided during end-of-year teacher interviews and surveys.

4.2 Ashleigh

Ashleigh is a Black female. She learned about engineering in a K-6 elementary school in an urban fringe area in the South Central United States. Approximately 19.5% of the students in this school qualified for the free and/or reduced lunch program. The school was 52.6% male, with a demographic breakdown as seen in Figure 4.1. This school had a strong commitment to engineering, with multiple teachers in the 2nd, 3rd, and 4th grades participating each year of the study.
Figure 4.1 Student Demographics at School One

4.2.1 Overall

Ashleigh’s understanding of engineering and corresponding DAET conceptions became complex as she took part in engineering activities and learned about engineering in her 2nd, 3rd, and 4th grade classes (see Table 4.1). She initially had a positive but naïve opinion of engineers, believing they can help you learn and are very nice. All of the engineers she drew were helping someone, from helping people to learn in her first drawing to helping the family members and the homeless, something Ashleigh did as well. She continued to keep her positive view of engineers, believing they help people in their communities, while developing her understanding of the attributes of engineering from the broadest definition of design, including artistic design, to a more focused definition of engineering design. She did not develop the desired conception of engineers, but did understand that engineers would use the engineering design process to create things by her final interview.
Ashleigh’s conception of technology did not change throughout the study. She appeared to believe that to be technology, an item requires electricity, a common misconception. In her third year, her fourth grade teacher expanded the *What is Technology?* lesson into three lessons to ensure that students learned this concept. This focus does not alter Ashleigh’s strong misconception of technology as something that moves on its own or requires batteries. In her final interview, she explained that an engineer would create technology, connecting engineering and technology through design.

Ashleigh did not want to become an engineer at any point during the study but enjoyed the classroom-based engineering activities. She believed engineering is fun, rating engineering an eight or above on a scale of one to ten, but it is not a career she was interested in.

4.2.2 Year One: Second Grade

In her first year, Ashleigh was taught by a White, female teacher. Her teacher was a part of the study from the beginning and had taught the second grade engineering unit during the prior two years. Ashleigh’s class explored the topic of chemical engineering through the *Engineering is Elementary* unit, *A Work in Process: Improving a Play Dough Process*, though they did not read the book due to its length and complexity. In addition

<table>
<thead>
<tr>
<th>Conception</th>
<th>Gender</th>
<th>Skin Color</th>
<th>Notes</th>
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<tr>
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<td>F, F</td>
<td>Self also in DAET</td>
</tr>
<tr>
<td>Spring 2011</td>
<td>Other</td>
<td>F, F</td>
<td>Mother</td>
</tr>
<tr>
<td>Fall 2011</td>
<td>Other</td>
<td>F, F</td>
<td>Brown</td>
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</tr>
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<td>Fall 2012</td>
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<td>F, F</td>
<td>Planting a garden</td>
</tr>
<tr>
<td>Spring 2013</td>
<td>Design/Made Single</td>
<td>F</td>
<td>None</td>
</tr>
</tbody>
</table>
to the modules of the *Engineering is Elementary* unit, Ashleigh’s teacher included the preparatory lessons, *What is Engineering?* and *What is Technology?*, and two design activities, *Bat Puzzles* and *Gumdrop People and Chairs* throughout the school year.

The teacher had a positive attitude towards engineering and believed it was useful for her students; she rated student engagement, enjoyment, and learning all three out of four during the end-of-year interview. She described engineering as time-consuming, but a good way to both reinforce all subjects and to introduce new concepts from other subject matter for students while preparing students to meet state curriculum standards. When asked about student engagement, she responded “Oh yeah. They loved it. They were right in there. They loved doing it.” While her class had many students with behavioral problems, she found engineering to be beneficial to these students especially: “I think this whole group of – this whole grade of kids has struggles…you can see when the kids do something like this, that they’re – the ones that are really trying to think through it. I think that’s the most positive thing is they have to think through it. And it’s okay not to get it right the first time.”

4.2.2.1 Initial Data Collection

Ashleigh’s first representation of an engineer included two females with “pink dress, pink hair, brown face, and a big ponytail” as shown in Figure 4.2. One of the two females is the engineer, and Ashleigh assigned herself as the other female in the drawing. They are independently working at the same table. According to Ashleigh, the engineer was her best friend, someone who “helps you, help you learn, help you read, do anything.” Her text on the DAET in response to the prompt, “What is the engineer doing?” showed her positive but naïve understanding: “an engineer helps you do your
work and an engineer help you learn and learn how to read and engineer is very nice to you just ask tine [sic] they will.”

Figure 4.2 Ashleigh’s Year One pre-DAET
Ashleigh’s conception of engineers centered on the idea that engineers were helpful and generally nice people. In the SKT, she correctly identified that an engineer would design a quieter vacuum cleaner, but believed that an engineer would help clean up damage after a flood and that a chemical engineer would clean bathrooms. She reiterated her belief that engineers are nice during the interview; in response to the interviewer’s query “Can you give me an example of one kind of engineer?” Ashleigh responded, “They’re nice.”

She seemed to have a very high opinion of engineers and engineering, though engineering was not her first choice for a future career. When asked if she would like to be an engineer, Ashleigh paused briefly and then asked, “Can you have two jobs when you grow up?” “Some people do,” the interviewer responded. “Yes,” decided Ashleigh, in contrast with her EIDS response of ☐ to item 17, “When I grow up I want to be an engineer.” Ashleigh was willing to be an engineer, but only if she could also be a doctor because “you get paid.”

4.2.2.2 Final Data Collection

Ashleigh learned about engineers “at my class.” She recalled taking part in engineering activities during the school year, “we made a puzzle, we made people that sit in chairs, and we made the chairs.” The puzzle was engineering because “first we drew the puzzle, then, my teacher calls it engineering.” She didn’t recall learning from these activities because “I already knew about engineering, I love engineers.”

Ashleigh drew a female engineer from a show she saw, Kim from Design Squad, and explains that she is “making a wagon fly” as shown in Figure 4.3. She described engineering as design, but didn’t appear to understand the difference between designing
and making or engineering design compared to other types of design: In response to the interviewer’s question, “So you told me that she is designing a flying wagon. What does design mean?” Ashleigh responded, “Design means, like, you make something. It’s a different word for making things and, and it means like you can design, like clothes, and even like that thingy [the flying wagon].” She wasn’t sure what type of engineer she drew, “it’s an engineer that likes building.”
Figure 4.3 Ashleigh’s Year One post-DAET
Ashleigh believed that engineers are very hands-on, mainly based on her experiences with engineering. When she heard the word engineer, Ashleigh said “I think of building things ’cause I love building.” According to her, An engineer is someone “that builds things and helps people build things, they’re very nice, like you.” On the SKT, Ashleigh chose responses including the word create, though she chose “drive a train engine” as an example of a task an engineer might perform when there was no option that included the word create.

Ashleigh enjoyed her engineering experiences, but was not interested in engineering as a career. She did not want to be an engineer when she grows up and would rather be a teacher. According to her responses on the EIDS, she did not want to be an engineer or work on a team with engineers.

4.2.3 Year Two: Third Grade

In her second year, Ashleigh was taught by a White female teacher who had not taught engineering before. She did not feel that engineering or engineering pedagogies were difficult to add into her typical classroom, “It flowed with the way I teach anyway. I’m more of a facilitative kind of teacher, so it really flowed completely with our regular teaching, with everything. It wasn’t harder or any different.” All EiE lessons for the unit, Marvelous Machine: Making Work Easier, were completed along with the What is Technology? lesson and the class participated in an additional model eliciting activity, Paper Airplanes. The teacher had a positive attitude toward the engineering lessons, responding to most questions with “Extremely well,” including “Overall student engagement?” “Extremely well, everyone was on task, didn’t want to quit.” “Overall student attitude?” “They were extremely well also.”
Throughout the interview the teacher referenced connections between the Engineering Design Process and other classroom activities: “I almost feel like we’re doing it with writing sometimes, even though we are just creating a writing product. It’s kinda the same thing that we’re doing with that.” “’cause you imagine and then you plan your story.” “Exactly, exactly. We are doing it through writing, also, and their writing has really improved a lot because we are taking that extra time and going through the whole process to get the good stuff out there.” In addition to noting the parallels between the writing process and the Engineering Design Process, the teacher also described parallels in the science project her students were currently engaged in, “We are actually doing ecosystems now. I’m thinking they’re all in groups again, and they had to imagine it and they’ve planned it out, and they are creating whole ecosystems too.” In her first year integrating engineering into her third grade classroom, the teacher found many connections between the other subjects she taught and engineering, particularly the design process. She did not give explicit examples of connecting these subjects for her students, but made the connections throughout the year for herself.

During the later multiple-choice questions, the teacher maintained a positive outlook on engineering and how useful engineering can be as an integrated part of her curriculum. She read all of the possible options to each question, responding to each one. For responses she did not agree with, she typically stated, “No,” but forcefully rejected some statements: “Engineering takes away from other subject matters students need to learn. No, because it’s all integrated, they all need to learn everything. Engineering is good, but it’s not as important as other subject matter, like math, language arts, and science. That is just crazy thinking, because they all go together again.” “Engineering
examples are useful, but difficult to connect to other subject matter. Definitely not.”

“Engineering is not really a very good match for our state curriculum standards. Definitely not.” She believed that engineering was a good way to reinforce all subjects that students are learning and to introduce new concepts from other subject matter, “but you are still going to go deep into the deep stuff with all of it there.” She also believed that engineering was a good way to practice skills needed in other subject areas and that students benefit most from creative problem solving during engineering activities.

4.2.3.1 Initial Data Collection

Ashleigh learned about engineers “last year. And the first day of school this year our teacher burst in to talk about engineers.” She remembered watching Design Squad videos and the engineering projects they completed on the show, mostly building artifacts for people, and recalled making play dough but did not consider it to be engineering.

In the fall of Ashleigh’s second year, she drew two females with brown skin as seen in Figure 4.4. She identified one of them as the engineer, “my momma.” Ashleigh described the actions of her engineer, “She was painting a girl, then she wanted to sculpt her instead, so she painted her and sculpted her.”
Figure 4.4 Ashleigh’s Year Two pre-DAET
Ashleigh held a slightly fragmented conception of what engineers do, incorporating artistic design and building single items as engineering roles. On the SKT, Ashleigh identified things engineers do that include the words create and design, but also believed an engineer would “drive a train engine.” When asked “When you hear the word engineer, what comes to your mind?” Ashleigh responded, “That I like to imagine things and it seems fun to be an engineer.” Engineers pursue creative endeavors according to Ashleigh; it’s fun to be an engineer because “you can daydream, imagine, you can paint things.” She learned that engineers help people, “We learned that engineers are important because they help people do things, they help people that don’t have anything. Sometimes they feed the homeless like I’m gonna go do.” She believed An engineer is someone who “builds things?” The interviewer asked Ashleigh to explain further, “What kinds of things?” Ashleigh responded, “Things that people don’t have.” The interviewer probed again, “Like what?” Ashleigh was not quite sure, explaining, “Don’t know what they are, like chairs and beds, sometimes, I think, and roller skates.”

Ashleigh seemed to recognize that technology is anything man-made, but did not articulate why something is technology consistently. She seemed to connect engineers with technology, noting that engineers might build the items she identifies as technology. She tried to define technology but was not sure of her definition: “Because technology is I don’t know but I am going to guess. Technology is something that helps you learn about or pass grades or something like that.” On the SKT, Ashleigh chose “lightning” as an example of technology but recognized that Q:Simple machines are considered technology because they “are designed to solve a problem.” She thought a toothbrush might be an example of technology and that engineers might work with one, but was not sure why. A
flower was an example “of science yes, but not technology.” An engineer might plant a flower. While she did not know what a pulley was, she thought it was an example of technology “because sometimes technology can be metal things sometimes, like your glasses!” An engineer might work with a pulley because “Engineers like to build metal and they like to build things and help people with things like this.” A cellular telephone is an example of technology because “it’s awesome!” An engineer would work with phones “cause I’ve seen lots of engineers that build phones.”

Ashleigh had a positive view of engineers and engineering, but did not want to be one herself. While she was not sure if she wants to be an engineer on the EIDS, she tells the interviewer that she does not want to be an engineer. “I would like to be a teacher, or a baker, or a soccer teacher.”

4.2.3.2 Final Data Collection

Ashleigh states that she learned about engineers in school. She recalls the Gumdrop Person and Chair engineering activity from the prior year when asked about the Engineering Design Process.

Ashleigh drew a female engineer, but did not color in her skin as shown in Figure 4.5. The engineer is designing and building a playground “to help homeless people.” Her engineer has a second job at Taco Bell “because she likes tacos!” Ashleigh would have drawn a second engineer if she had more time “so she can, so they can help her.” Ashleigh uses the word “make” to describe what her engineer does.
Ashleigh believed engineers build things to help people. She described her conception of what engineers do, “help people or build stuff. It’s like workers that build...
houses, those are kinda like engineers.” “Working” came to Ashleigh’s mind when she heard the word engineer. She completed the sentence An engineer is someone who “helps people or makes stuff, sometimes they make stuff all around the world maybe.” She learned that “engineers could make stuff all around the world, or they make stuff all around you like this table.” She confirmed her belief that engineers build things with her answer on the SKT, choosing “build a house for a family” as an example of a task an engineer would perform and confirmed her belief that engineers would help by choosing “clean up damage and debris” as a role of engineers in the event of a flood. She did not recall any specific types of engineers.

Ashleigh seemed to hold a common misconception, the belief that technology is something that is powered by electricity, but also believed that technology is something that moves. She believed an engineer might use the examples of technology in their work, but did not connect engineering design with technology. She did not correctly identify technology in the SKT, responding that simple machines are considered technology because they use electricity and identifying “lightning” as an example of technology. She believed a toothbrush is not technology “because it doesn’t work. Only the toothbrushes that spin around maybe could be technology.” An engineer would use a tooth brush in their work, but she was not sure how, “I think it is a [pause] I don’t know.” A pulley was an example of technology “cause it moves.” An engineer might use a pulley “cause they can use it to maybe like, put a hook on it and measure something.” A flower was not technology “cause it doesn’t work, it doesn’t move or anything.” An engineer would not use one “cause they can’t use it on anything” though they might put a flower in a table for decoration. A cellular telephone was technology “because it works and you can turn it
on, but you can’t turn this [other object] on.” An engineer might work with one “‘cause they can call someone when they need help.”

Ashleigh had a positive attitude toward engineering, but did not want to be an engineer when she grows up. On the EIDS, she responded that she would not like to be an engineer or work on a team with engineers. Ashleigh wanted to be a doctor to help people and thought engineers can help people. “Engineering is fun,” says Ashleigh when she rated engineering an eight on a scale of one to ten. She did not like that engineers “live in a big, big place,” and would have rated engineering a ten if “they make something really, really cool like let’s say a video game.”

4.2.4 Year Three: Fourth Grade

In her third year, Ashleigh was in a fourth grade classroom taught by a White female who taught the fourth grade engineering unit for the past two years. This was the second year she taught this particular EiE unit. All EiE lessons for the unit, A Stick in the Mud: Evaluating a Landscape, were completed along with the What is Technology? lesson. The What is Technology? lesson was expanded to multiple lessons to reinforce the concept of what technology is. The introductory lesson, What is Engineering? was also expanded to incorporate additional Design Squad videos, Sally Ride books, and an innovation contest called the Big Idea that the district participates in. No additional engineering activities were done, but engineering ideas were integrated into the curriculum wherever possible, “I’m one of those teachers, any time it connects, we’re gonna talk about it.”

She was very positive towards engineering, rating student attitudes and engagement extremely high: “Oh, I would tell you it was on the top end, extremely well.
They love it. We set that up at open house, you know, that’s one of the things they come in to show their parents. You know, they take cores samples with their parents, and they put the washers in the TarPul, and the whole business.” Student learning was also rated highly for most students: “I would think that went very, extremely well. Other than when you look at the assessment, and I had, you know, kids and I’m just like, you know, you look at it and you go ‘Wow where have you been all year, because that is not what I taught you.’” pretty much.” She believed that engineering was a good way to reinforce content learned in other subject areas and that it could be helpful in meeting state standards. She believed that students benefit the most from teamwork experienced while participating in engineering activities.

4.2.4.1 Initial Data Collection

Ashleigh learned about engineering “in third, in first grade to fourth.” She recalled taking part in the *Gumdrop People and Chairs* engineering activity, “well, we made people, and then we made gumdrops, for a chair for gumdrops, and then we were trying to figure out if they would fall, ’cause like we put it at the edge to see if they would fall, but they didn’t.” She also remembered the *Paper Airplanes* activity and creating a game as engineering activities that were a part of her second-grade school year, though she stated that all of these activities happened during her third grade school year.

Ashleigh drew two females in her DAET as seen in Figure 4.6. Both engineers have light brown skin and darker brown hair. The engineers are helping the community, “they made a pretty garden for some people that didn’t really have food or didn’t have time to make the food so they can make salad for them to help the community. But first they picked up trash first and then, they made a garden out of it!” Her engineers are “a
garden, a one that likes to help, a one that likes to do flowers for, to make it look prettier to help the earth instead of making it junkier.”

Figure 4.6 Ashleigh’s Year Three pre-DAET
Ashleigh had a positive view of engineers and engineering based around her belief that engineers help their community. She chose “clean up damage and debris” and “build a house for a family” as examples of what engineers would do, both things that are in line with her conception of engineering as helping the community. When asked what came to her mind when she thinks of engineer, she said, “I kind of want to be an engineer,” as long as she can also be a doctor. She completed the sentence “An engineer is someone who…” with “helps the community fix its stuff and stuff like that.” When asked if she knows of any kinds of engineers, she stated that the interviewer is an engineer, a doctor engineer, someone who helps people medically. The interviewer may have been introduced to the class as an engineer with her title, “Dr.,” creating Ashleigh’s misconception of a medical engineer. When asked to name other types of engineers, Ashleigh responded, “Maybe an art engineer, or people that make brooms, they’re kind of like engineers, right?

Ashleigh seemed to believe the common misconception that technology requires electricity. She did not connect engineering design with the items discussed during the interview. To Ashleigh, a toothbrush was not an example of technology because, “Technology moves except for a few headphones or iPads or something like that. Like a robot, that’s technology. Lightning is technology. Stuff like that.” An engineer might work with a toothbrush, because “I don’t know.” A flower was not an example of technology “because it doesn’t move. It stays in the ground. It gets its air from the sun, water, and other routes, I think.” An engineer “would probably make a garden with it” but wouldn’t use it otherwise. A core soil sample was not technology and would not be used by engineers. A cellular telephone was an example of technology “cause it calls and
Ashleigh believed an engineer might use it while working to take a picture, but wouldn’t work on a cellular telephone.

Ashleigh had an enthusiastically positive attitude toward engineering but did not seem to be interested in engineering as a career. Through her in-class engineering activities, she learned that “You can make stuff if you believe you can,” sharing a positive attitude toward her engineering experiences. Ashleigh would like to be a doctor engineer “cause I really like helping people.” On the EIDS, she responded that she would not like to be an engineer when she grows up. She rated engineering highly, a nine on a scale of one to ten because “Engineering is really cool 'cause you get to help people.”

4.2.4.2 Final Data Collection

Ashleigh learned about engineers “in kindergarten.” In school, she “looked at some videos and learned that engineers help us. They build most, well, lots of stuff around us. Like pencils.” After seeing the core soil sample, Ashleigh recalled the entire Engineering is Elementary unit, Stick in the Mud: Evaluating a Landscape, but recognized it as a science, not engineering, activity. She learned “that there can be different types of engineers” from the TarPul unit.

Ashleigh drew a female engineer, as seen in Figure 4.7, but did not color in her engineer’s skin. She seemed to continue to have a positive attitude toward engineering; her engineer “loves her job and she enjoys making stuff for people.” Her engineer is wearing safety goggles while she makes a bunk bed “so that her cousins have somewhere to sleep.” When asked what type of engineer she has drawn, Ashleigh says she is “a worker. She makes stuff.” Her drawn engineer would also work at McDonald’s.
Figure 4.7 Ashleigh’s Year Three post-DAET
Ashleigh connected engineering to design and the Engineering Design Process, but focused on the hands-on aspects when asked what she envisions the engineer doing. When she heard the word *engineer*, Ashleigh said, “they plan, planning, creating, imagining, and that is all.” To Ashleigh, *An engineer is someone who* “plans, like where it’s gonna be at, or they can make stuff.” Ashleigh recognized that an engineer would “design a quiet vacuum cleaner” but believed that an engineer would clean up after a flood. She also believed that a geotechnical engineer would not talk with others about what they need and want, rejecting the social aspect of engineering while keeping the technical and hands-on aspects as something an engineer would do.

Ashleigh held a conception of technology that seemed to be based in electricity, believing that things would move on their own if they were technology. She did connect engineering design with technology, stating that engineers make technology. In the SKT, Ashleigh incorrectly chose “lightning” as an example of technology and identified “work that takes many people” as the reason that making soil more compact is considered technology. To Ashleigh, a toothbrush was not technology “cause you have to move it with your hands.” She believed a real flower was not technology, and a fake flower would not be either “because it’s plastic, and plastic is not really technology.” She was not sure whether a pulley would be an example of technology, but believed an engineer would work with one “cause it’s different.” A core soil sample was not an example of technology, but engineers would work with them “because engineers can plan what type of soil, topsoil, sand, and nothing.” A cellular telephone was technology “because it has batteries.” An engineer would work with one because “engineers really only make technology things, maybe, or sometimes they create different things.”
Ashleigh had a positive attitude toward engineering, but may not want to be an engineer when she grows up. Initially Ashleigh stated that she does not want to be an engineer, in line with her EIDS response, but she quickly changed her answer, “Well yes, 'cause I like building stuff.” She wanted to be an engineer and notes many other careers as something she might want to be because they are all fun. She wanted to be an engineer because engineers have fun, “Lots of fun. They get to paint, they get to raft[?], or whatever, they get to see different kinds of things, go on many adventures, and [pause] make something.” She continued to rate engineering highly, a nine on a scale of one to ten, because “engineering’s fun! It’s fun and I like being creative.” She again stated that she enjoys engineering because she enjoys building, and when she cannot think of what could make engineering a 10, she changed her response to a 10.

4.3 Sofia

Sofia is a Hispanic female. She attended the same school as Ashleigh.

4.3.1 Overall

Over three years of engineering instruction, Sofia’s concept of what an engineer does developed from common misconceptions of construction workers and mechanics to technicians, then naïve concepts of designers and finally she described a complex conception of engineers as those who plan and design, but not build, as seen in Table 4.2.

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<td>None</td>
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<tr>
<td>Spring 2011</td>
<td>Mechanic</td>
<td>F</td>
<td>None</td>
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</tr>
<tr>
<td>Fall 2011</td>
<td>Technician</td>
<td>M</td>
<td>None</td>
<td>Fixing a computer</td>
</tr>
<tr>
<td>Spring 2012</td>
<td>Technician</td>
<td>F</td>
<td>None</td>
<td>Fixing a computer</td>
</tr>
<tr>
<td></td>
<td>Design/Create Single</td>
<td>M</td>
<td>None</td>
<td>Brainstorming to build a single desk</td>
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Table 4. 2 Sofia’s Conceptions of an Engineer, Continued

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<tr>
<td>Spring 2013</td>
<td>Designer</td>
<td>M</td>
<td>None</td>
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Sofia never held the desired conception of technology. During the final year of the study, Sofia knew that the correct answer to the question of “What is technology?” was that technology is useful, but did not apply this classroom knowledge to the items discussed during the interview. She moved from a definition of technology that included both metallic and electrical items to one that is a common misconception, that an object must use electricity to be considered technology.

Overall Sofia had a positive attitude towards engineering and was never able to answer the question “What is not interesting about engineering to you?” There were some things that she believed would make engineering more interesting, from working in larger teams, to working fewer hours in the day, to taking a more hands-on role in what they do.

Even though she enjoyed engineering, rating it as high as an eight on a scale of one to ten, she did not want to be an engineer when she grows up, though considered it a possibility if she is unable to be a journalist or a nurse.

4.3.2 Year One: Second Grade

Sofia was in Ashleigh’s second-grade class, a class taught by a White female who taught engineering in a second grade classroom for the third time.

4.3.2.1 Initial Data Collection

Sofia was aware of engineers from some prior experiences. She took part in a summer activity regarding engineering, “we learned that they help people. We also did
this thing about what engineers do and some of it we did, we made an instrument and we watched ice cubes melt and we learned about, they work in the sun a lot and they most of the time work day, and that’s all, I think that’s all.” She also completed a puzzle about engineers at home.

Sofia drew a single engineer as shown in Figure 4.8. She initially told the interviewer that she is the engineer, and later used masculine pronouns to refer to the drawn engineer, “he’s wearing a uniform…he’s wearing a black and grey suit and he’s wearing a yellow hat and he’s wearing yellow gloves.” She drew an engineer who is fixing the ground under the house “because he loves to help people.” She stated the type of engineer is “a helping engineer?” Her engineer felt “excited to help people?” If she had more time, she would have drawn a partner to help the engineer.
Figure 4.8 Sofia’s Year One pre-DAET
Sofia initially believed that engineers are construction workers, working with houses and concrete, who help people, though her conception was not consistent across all data. On the SKT, she responded that engineers would “contact the families of the victims,” a helping role, but also “fix a car for a customer” and “drive a dump truck.” To Sofia, An engineer is someone who “helps people?” and when she heard the word engineer, she thought of “being an engineer.” “I think they build concrete?” Sofia responded when asked what she thinks engineers do. Sofia seemed hesitant when responding to what engineers do, as though there were a correct answer to those questions. Nearly every time she discussed engineers helping people, her voice rose as though questioning her answer. She did not seem to question any of her other responses. At the end of the interview, she asked, “Do engineers, do they kinda make concrete?” She was unsure of what engineers do and wanted to know the correct answer. She was excited to learn more about engineers and engineering. She rarely hesitated and asked for clarification from the White female interviewer when she was unsure of what has been asked; “What type of engineer is your engineer?” After a pause, Sofia asked, “Repeat that?” She had an answer for most questions and let the interviewer know when she was unsure. “Can you give me an example of one type of engineer?” “One type of engineer…I can’t think of any.”

Sofia told the interviewer that she would like to be an engineer when she grows up, though had indicated she was not sure on the EIDS instrument. She wanted to learn more and be able to tell others “hey, whenever I was a little kid we learned a lot of stuff about engineers and now I became one.”
4.3.2.2 Final Data Collection

Sofia learned about engineering in school but also believed that her aunt, uncle, and cousin are engineers. Sofia easily recalled some engineering activities from the past school year, like Design Squad videos, one of which was shown that day in her classroom, and a field trip about engineering. She stated that she was not sure if Design Squad was an engineering show, “I’m not sure if Design Squad is one but we watched those because they build stuff.” She recalled a drink-making activity where they made different colored liquids as an engineering activity because “we were making stuff?” She also recalled the Gumdrop Person and Chair activity, “And then one time, we were learning about engineers, you know the ice cream sticks? We got to make people out of those.” When prompted, “Did you do anything with play dough?” She excitedly recalled, “Yeah! We did something we play dough, we got to feel it and we got to build, make play dough but our team didn’t win.”

Sofia drew a single engineer inside a car, as shown in Figure 4.9. The engineer is “My uncle, my aunt, I meant, because she’s an engineer.” Her engineer is a mechanic, working on a car “fixing the engine and the window and the brakes,” she read verbatim from her written description of the picture. The engineer has “eyes like me,” she stated, as she described how her aunt looks. Her engineer “feels dirty because the car’s dirty?” Her engineer is “trying to be generous,” fixing the car for Sofia’s big brother. Sometimes when the White female interviewer asks pronoun-free questions like “What is your engineer doing in the vehicle?” Sofia responded with masculine pronouns, even though she stated that the engineer is her aunt. “He is fixing the window and the brakes.” She sometimes corrected herself; “I know he has his, her tools…he’s trying, she’s trying to be
generous.” If she had more time she would have drawn herself in the picture because she drew a picture of a real event and she was there when the car was fixed.

Figure 4.9 Sofia’s Year One post-DAET
Sofia’s conception of an engineer was mainly one of a mechanic, someone who fixes cars, based on personal experiences with family she believes to be engineers. She also held the idea that engineers can build things like houses and that they may not be the same type of engineer as ones that fix cars, though her responses across the data about what an engineer might do were inconsistent. She defaulted to male pronouns when talking about engineers and what they do, though she associated her aunt with engineering. When asked what comes to mind when she heard the word *engineering*, she referred to her aunt. “Sometimes, it comes to her, and sometimes it comes to my other uncle because he used to be an engineer but now he’s in the Navy.” *An engineer is someone* who “fixes stuff or builds stuff.” The interviewer asked for additional explanation, “Fixes what kind of stuff?” Sofia responded, “Cars, or schools, he builds school doors sometimes, houses.” She thought an engineer could help people, “They can help them by fixing their stuff, fixing fences or something.” On the SKT, she responded that engineers might “change the oil in cars.” She also believed that an engineer might “clean up damage and debris” in the event of a flood and chose “drive a train engine” instead of “fix a car for a customer” though the latter seems to be closer to her conception of what engineers do. She did not recall any specific types of engineers but seemed to believe that there are at least two types “I forgot what it’s called but it’s one of the ones that fix cars.” Later, when asked again, she was not sure but adds another type, one that builds.

*Interviewer:* Do you know an example of one type of engineer?

*Sofia:* My cousin.

*Interviewer:* What kind is your cousin?
Sofia: The one that fixes cars.

Interviewer: Do you know any other examples?

Sofia: Well, the kinds that build stuff?

Interviewer: Is there a specific type of engineer?”

Sofia: No, not that I know of.

Sofia had an incomplete conception of technology based on her SKT responses; “lightning” is an example of technology but Q: Play dough is considered technology because “it is human made.”

She had a positive attitude towards engineering and might have wanted to be an engineer when she grows up. She enjoyed the engineering activities she took part in because “we got to make it.” She also liked engineering because “we tried our best.” During this school year, she learned about engineers but seemed to have learned the misconception that engineers fix cars rather than design cars; “I didn’t know that engineers could fix cars until we went on an engineer adventure.” Sofia might have wanted to be an engineer when she grows up, but she also wanted to be a nurse or a teacher, though she indicated she wanted to be an engineer on the EIDS instrument. She wanted to be a teacher “cause you get to teach stuff.” She thought an engineer can “teach people how to build stuff?” She wanted to be a nurse as well. “You get to help people out when they’re hurt.”

4.3.3 Year Two: Third Grade

Sofia was taught by a White female. This was the teacher’s first time teaching engineering in her gifted and talented science class. In addition to the required What is Engineering? and What is Technology? lessons, the class completed the GT Pyramids
project, where teams of five students designed a game. She presented some components of the *Engineering is Elementary* unit *Marvelous Machines: Making Work Easier* somewhat, but did not have the materials so did not complete the full engineering design project. They also did not go into much detail with the engineering design process or other activity sheets. She felt that student engagement with the hands-on activities went pretty well, but did not feel that the student engagement with the reading materials and worksheets went well, “I felt it was too much for them…The more hands-on and the less reading they had to do was probably better for them.” Engagement for the engineering design project went extremely well, and the teacher believed that student learning during the EiE unit transferred to the *GT Pyramids* game design project, “I do think it helped them tremendously when they did do their game creativity and design.” “Do you think some of them used the engineering design process of testing and improving on their game?” “I saw a little bit of that, I did.” She felt that student learning overall was fair, “Really, I’m just going to say fair, because I saw some of the answers they picked on engineering. I saw what they drew and so they still had that picture of a mechanic, a carpenter, a construction worker, a train engineer. They might say it’s a train engineer fixing something that broke down. You’re getting a little bit of it, but…” She felt that engineering was well implemented throughout her class, “I try to use it in my vocabulary when they’re doing things, even in their writing.”

When it comes to engineering in the classroom, she believed that engineering was a way to both introduce new concepts from other subject matter and reinforce all subjects the students are learning. She believed engineering was a good way to practice process skills needed in other subject areas, “just because of the process. That’s big in our
science. You need processing skills.” Students benefitted most from learning and engaging in the engineering design process and engineering was the best way to prepare students for meeting the state curriculum standards. “It’s not a yes/no. You make a mistake and you fix it. And you don’t give up.”

She may not have had a complex concept of engineering as design, “They might say it’s a train engineer fixing something that broke down. You’re getting a little bit of it, but…” She also felt that the hands-on activities were better than reading or worksheet activities as engineering lessons and that engineering should emphasize the planning and testing, not the actual hands-on creation of a solution.

4.3.3.1 Initial Data Collection

When asked “where did you learn about engineers?” Sofia responded, “When I was in second grade, when [teacher] told us at the beginning of the year, she said, ‘Today we’re going to be learning about engineers’ and she’s like, ‘if you know what an engineer is raise your hand’ and [student] raised her hand and she explained that they help people.”

Sofia drew a single male engineer as shown in Figure 4.10. She drew a technician, working for a client, “he’s doing it for a person.” She was not sure what type of engineer she drew.
DRAW AN ENGINEER TASK

In the space below, draw an engineer doing engineering work.

What is the engineer doing? The Engineer is Fixing a Broken Computer.

Prepared by Brenda Capobianco, Purdue University 8/1/07

Figure 4.10 Sofia’s Year Two pre-DAET
Sofia believed that engineers help people and fix things, mixing elements of mechanics and technicians in her definition. When she heard the word *engineer*, she thought “they help people?” She also finished the sentence *An engineer is someone who* “helps people.” When asked about different types of engineers, she responded they “Fix cars, fix laptops.” Her conception of an engineer as a technician seemed to stem from an engineering experience during the last school year. “Last year whenever I was in second grade they had engineers come and this guy, he was fixing a computer and putting the wires back into place and stuff and this guy that was an engineer he was telling us about whenever he was little and when he was in boot camp.” In the SKT, for questions regarding what an engineer might do, Sofia chose “clean up damage and debris,” “fix a car for a customer,” and “build new cars.” Her responses were consistent with her conception of engineers as mechanics.

Sofia had a fractured conception of technology and did not conflate engineers and technology, either through the definition that engineers design technology or an idea that engineers work with or use technology. She seemed to understand the “correct” definition of technology, “playing the school game” through her SKT responses and verbal definition to the question, “What do you think technology means?” Technology meant “like something you use?” to Sofia, though she did not use this definition to explain why objects were or were not technology. She was not sure if a toothbrush was an example of technology even though her definition of technology was “something you use.” She did recognize a pulley as technology “because it helps things hold and it’s metal.” It would have something to do with the work of an engineer, “to help other people when they have a problem if they need something to hold it, they could use that.” A flower was not an
example of technology “because you plant it.” A phone was an example of technology “because it helps you do stuff and it has, I think, inside of it a SIM card in there to help you do stuff and it goes with a wire to charge it.” She was not sure whether an engineer would use it.

Sofia was not sure if she wanted to be an engineer when she grows up, though she enjoyed the engineering activities she took part in. On the EIDS, her responses indicated that she was not sure if she would like to be an engineer or work on a team with engineers when she grows up, and in the interview, she responded “I’m not sure” but “I am thinking about being an engineer.”

4.3.3.2 Final Data Collection

Sofia recalled learning about engineers and engineering in her second grade classes, her third grade classes, and at career day. “Well for Career Day this guy had a keyboard and it was like broken and he passed around the broken keyboard at the back it had all the wires messed up.”

In her drawing of an engineer, she drew Matt and “I think Cindy,” a male and a female engineer, as shown in Figure 4.11. Her female engineer is in the role of technician, fixing a computer keyboard for her parents. Her male engineer, Matt, is wearing a blue uniform with a nametag and is engaged in brainstorming, an attribute of engineer as designer. She talked about Matt as a general handyman; “He fixes, like he builds things for other people, like if they need a new model or something, like a vacuum or anything, he’ll fix it for you.” While he is engaged in brainstorming, it is for building a specific desk for a customer, “He is thinking of fixing, well, he’s gonna build a desk for a
customer.” He is making a circle map, using a tool that Sofia has learned in class to use while brainstorming. Her engineers are “a fixer, like she’s a fixer and he’s a builder.”

Figure 4.11 Sofia’s Year Two post-DAET
Sofia’s definition of what an engineer does was grounded in personal experiences with people she believes are engineers, describing what they do as jobs a technician or mechanic would do, and describing general engineering activities as fixing and building. On the SKT, she believed an engineer would “build a house for a family” and “replace roofs on damaged buildings” consistent with her general engineering beliefs. She learned the correct response for what an industrial engineer would do, “design assembly lines.” When she heard the word *engineer*, she thought of engineers, “like what they build.” When asked what they build, she responded, “Probably like homes or they, well like they fix things actually, and they might fix cars, fix keyboards, and like build things like desks and I think that’s all that comes to my mind.” *An engineer is someone who* “builds.” When asked if she can name a type of engineer, she kept her ideas of fixing and building as the two main types of engineers. “A builder? Probably build things for other people. No, a fixer. Because they fix things for other people and if somebody has their phone broken they can easily fix it for them, and again like fix a keyboard, yeah.” When relating her story of the engineer at career day, where an engineer passed around a broken keyboard, she was asked, “So would that person be an electrical engineer?” “Probably,” Sofia responded.

Sofia seemed to be unsure of her definition of technology, varying between the general misconceptions of technology as electricity or technology as metallic. She did not connect engineering design to any of the items presented. In discussing the toothbrush, she initially thought a toothbrush was not technology, then changed her mind as she tried to articulate a definition of technology. “I think technology is something you can use, or it’s electronical [sic]. I’m not sure, I think it is technology. Wait, no. No. I don’t think it’s
technology because I think technology means something that’s electronic [sic], I think so. I’m not sure though.” She did not keep a consistent definition of technology as she continued considering whether different objects were examples of technology or not. She was not sure what the pulley was, and believed it was a keychain. When prompted, “Do you think a keychain would be an example of technology?” Sofia responded, “Yes, because it’s metal. I think it is because it’s metal, yeah, that’s it.” On the SKT, her responses supported her definition of technology as metallic objects, choosing “scissors” as an example of technology and considering simple machines technology because they “are made of metal.” She continued to have an inconsistent definition of technology when presented with a cellular phone, “Yes, I think, wait, no. Because they can’t use, well, they can use it as their job for the phone, and they can’t, well, I think it is. Because at jobs they have phones in the office, in the boss’ office, buy like food, yeah.” An engineer might use any of these objects during their work, but would not work on any of them.

Sofia would like to be an engineer when she grows up and had a positive attitude toward engineering, but thought that engineers work too hard. “I think so, because like you’ll help people and it’s the right thing to do if you help people.” On the EIDS, she responded that she was not sure if she would like to be an engineer or work on a team with engineers. She might also like to be a nurse or a vet because she likes animals. She rated engineering a six on a scale of one to ten. While she said she would like to be an engineer, she rated them at six because she believed that engineers “work all day” and she did not want to work all day. She would find engineering to be more interesting if they only worked nine hours in a day. She thought engineering was interesting because
“you get to build, well you get to design things.” She enjoyed working in a team with her classmates to design a game.

4.3.4 Year Three: Fourth Grade

In her third year of the study, Sofia was in a fourth grade class taught by a White female who taught engineering during all four prior years of the study. In addition to the What is Technology? lesson, the teacher added multiple lessons discussing technology to ensure her students understood is the definition of technology. The students spent time reading Sally Ride Science books. Each student chose a specific engineer to research, then presented their engineer to the class. The class also completed all lessons within the Engineering is Elementary unit, A Stick in the Mud: Evaluating a Landscape.

Engineering was heavily integrated with other subjects in this classroom; the teacher found it difficult to estimate how long was spent on the engineering lessons because of the high level of subject integration.

That’s why it’s hard for me to say exactly how long was specifically spent on that piece [engineering] because I have to still tie in what the district gives us and we end up just integrating in those pieces based on how they tied in our curriculum which they really did do a good job of tying that all in for us…It’s hard to break apart how much time I spent on the engineering piece of it because at the same time you’re also integrating in lessons the district wants us to insert in certain pieces.

Student engagement and attitudes toward engineering were rated extremely well, “Overall their attitude is they want to do whatever it takes that they get to do the
engineering, so you know, they behave well, they seem to enjoy it, they seem very engaged in it.” Student learning was perceived to be high.

I definitely think they’re understanding the engineering design process and what the pieces are to it, I think that they should have a very good understanding of what the geotechnical engineers do at this point when we’re finished with it and I really think that they understand the importance of what their job is as far as securing the buildings and making sure that whatever their building is stable…I think it’s gone extremely well, I think that they get a lot out of it.

She saw engineering as a way to reinforce what students learned in other subjects, especially science and math, but also writing and general problem solving. She believed that students benefitted most from the ability to engage in creative problem solving through engineering activities.

I think any time you tie this piece into it, it makes a stronger connection with them, and I’m a firm believer in it…if they could figure out a way to tie this in, I definitely think it cements what they’re learning, as opposed to they get the lesson one day and we’re moving on to the next piece and not tying it to anything else that they understand and know.

4.3.4.1 Initial Data Collection

Sofia stated that she did not recall much about what she learned about engineering but does recall making games in her third grade class. She mentioned the Design Squad television show during the interview when asked what makes engineering interesting and focused on the creation step, “it looks fun 'cause you get to make things.”
Sofia drew two engineers, a male and a female, as shown in Figure 4.12. They are working together to test a sling shot that their company designs. When prompted to describe what she means by design, Sofia described their work as production rather than design. “They make ‘em, they get all the plastic stuff and make ‘em together and they tested it out to see if they would flex back.” They are wearing protective clothing to be safe while they work; “They have like a uniform on…they have to wear pants so they can keep their legs safe so they won’t get ‘em scratched up, and they have gloves on.” Sofia’s engineers continue to help others; “They’re helping to do it for children in need for Toys for Tots.” She also noted that she considered drawing a different engineering at first, “The first thing I was gonna draw was a cooking engineer…I think it’s like cooking because my friend, Betsy, her mom’s a cooking engineer.”
What is the engineer doing?

My engineer is testing a slingshot, and the other guy is her partner, cause their boss always tells them to test it out, and there company diseases. Sleg shoots.

Prepared by Brenda Capobianco, Purdue University 8/1/07
Sofia believed that engineers design, but when describing what engineers do focused on building and testing, the physical aspects of the Engineering Design Process, rather than design as the planning stage or entire process of design. Even when she noted that engineers brainstorm, she considered it a preparatory step saying, “engineers have brainstorm before they do it” rather than as an integral part of what engineers do. On the SKT, when asked what an engineer might do she correctly chose the response that uses the word “design” but also believed an engineer would “clean up damage and debris” in the event of a flood rather than “create a system to prevent future floods.” Hearing the word *engineer* made Sofia think “helping people?” *An engineer is someone who* “can help people, builds houses, if it’s damaged, fixes damage, probably.” She was not sure what type of engineer her drawn engineers were; “I’m not sure, I think it’s like, it’s an engineer that, well, a lot of engineers design things but I think it’s like one of those in a factory who makes toys.”

Sofia did not present a consistent understanding of technology, mixing a common misconception, requiring electricity, with part of the definition of technology, that it solves a problem or in her terms, is useful. She did not connect engineering and technology. When asked whether a toothbrush is an example of technology, she was not sure. “I don’t really remember what technology is.” When prompted to respond based on what she thinks, she responded, “Probably. I think technology is something you can use or something.” She recognized that a flower and soil sample would not be examples of technology and stated that a cellular telephone was an example of technology. “I think so because it’s electronic ‘cause I think technology either means something that’s electrical or could be used.” In her SKT responses, she correctly chose “scissors” as an example of
technology and noted that soil compaction is technology because it is “a process designed to solve a problem.” Of the artifacts shown during the interview, only a core soil sample might be used in the work of an engineer “if they had like, the thing that they make toys, they could use that to make some. Like, say if they were gonna make another toy, they could probably use rocks.”

Sofia had a positive attitude toward engineering but would prefer other careers when she grows up. Sofia responded that she does not want to be an engineer, “it’s a pretty good job, it’s just, I’d like to be a nurse. Like, it would be my third option if I can’t be a nurse or a journalist I’d be an engineer.” When asked why she would not want to be an engineer, she responded, “I’m not sure, I just, I’d like to but I’m not sure if I would because I’ve been wanting to be a nurse for a long time and I like writing.” She rated engineering highly, an eight on a scale of one to ten. She enjoyed engineering because “you get to help people and you get to design things.” She could not think of anything that she did not like about engineering, and thought engineering would be more interesting “if you have more partners because sometimes two people can’t come up with something but if you have like a whole group you might come up with something like for people. I think engineers have brainstorm before they do it.”

4.3.4.2 Final Data Collection

Sofia recalled watching Design Squad in her second grade classroom as the main place she has learned about engineering in the past. She also noted that during this school year, her class participated in engineering activities at the beginning of the year and had more recently done some additional engineering activities, but did not state what these activities were.
In Sofia’s final drawing, she recognized her earlier misconception of engineering as a builder and noted that engineers design, not build, as shown in Figure 4.13. She wrote, “My engineer is working on this house. But he is just designing not building a engineer is someone who designs things. I thought a engineer at first was a builder but I was wrong. Today now I know that a engineer is a designer” (spelling errors have been fixed for readability). The engineer is designing additions to the house “because he sees that it doesn’t have, it needs to be more safer so maybe he’s trying to fix something.” He’s trying to help someone, “another person that needs help in their house to be safe, maybe.” His tools are “a pencil and clipboard to plan.” She began describing the Engineering Design Process when asked what steps her engineer takes; “Maybe he plans it first and then, like my teachers says before he does something he asks people and all that, and then, yeah.” Her engineer works with others and she would have drawn others on his team if she had more time. She painted a complex idea of her engineer as a designer who would not build the house himself.
Sofia had a complex understanding of engineering as design, focusing on the planning stages. When Sofia heard the word *engineer*, she thought of “someone that
designs things.” An engineer is someone who “designs and works and asks questions.” Sofia responded correctly to all SKT questions about engineers, recognizing that they “design” and “create” but would not “run a machine that digs up soil and rock.” She recognized chemical engineering as a type of engineering, stating chemical engineers “maybe they have like chemicals and they sort them and test them.” She also questioned whether “a cooking engineer?” is an actual type of engineer, “I don’t know, it just came to me.”

Sofia held the common misconception that technology requires electricity but knew what she should say when asked what technology is. When asked, “What do you think technology means?” Sofia responded, “Something that can be used?” She chose “scissors” as an example of technology on the SKT, but believed that soil compaction was considered technology because it is work that takes many people. To Sofia, a toothbrush was not technology “because technology to me is probably like electrical.” A flower would not be technology because “it’s not electrical.” She was not sure whether a soil core sample is an example of technology. “I don’t know, I feel that it is what technology means, but then I don’t, that it’s electrical, I don’t think it is.” When pressed to decide whether various items are or are not examples of technology, she became less sure of her belief that technology is strictly electrical items. An engineer might use a core soil sample in their work “maybe to test stuff, maybe. Like a chemical engineer, maybe?” A cellular telephone was obviously an example of technology to Sofia, “cause it’s electrical, and, yeah.” An engineer might contact people or look things up on a cellular telephone in their work.
Sofia had a positive attitude toward engineering, enjoying her engineering experiences thus far, and considered engineering to be a possible career that would be fun while allowing her to help people. Sofia did not want to be an engineer when she grows up according to her interview responses, but was not sure according to the EIDS. She still wants to be a nurse and a journalist “because I like to write and I like helping people.” Engineers could help people, “helping people, yeah, but not too sure about writing.” She rated engineering at a five on a scale of one to ten because “I’m not sure because maybe if it doesn’t work then yeah I’ll do engineering. It looks fun because it like, as a nurse you get to help people and you get to help people as an engineer.” She liked engineering because “you get to design things and make things and help people.” She could not think of anything that was not interesting about her engineering experiences. Engineering would be more interesting “if they got to build things, maybe.”

4.4 Marcos

Marcos is a Hispanic male who attended the same school as Ashleigh and Sofia.

4.4.1 Overall

Marcos tended to keep the same conception of engineers over the summer. The final Draw an Engineer Task from his first year was nearly the same as the initial drawing in his second year while the final drawing from this second year was nearly the same as the initial drawing in his third year. What he learned in the classroom is reflected in his drawings; the final drawing during his first year shows an engineer creating play dough, like the class did in the Engineering is Elementary unit A Work in Process: Improving a Play Dough Process. The final drawing during the second year was a potato chip factory, drawn from an engineering-related video that was shown during the school year.
according to Marcos. Marcos’ final drawing during the third year showed an engineer involved in designing, reflecting his new understanding of engineering as design.

Marcos consistently drew male engineers, sometimes alone, sometimes helping other male engineers, as noted in Table 4.3. In all of his initial (pre) drawings, Marcos did not color in the skin of the engineers. In all of the final (post) drawings, he colored in the skin of the engineer a light brown, though when asked in the final interview of the first year he considered the engineer’s skin color to be peach.

Table 4.3 Marcos’ Conceptions of an Engineer

<table>
<thead>
<tr>
<th>Conception</th>
<th>Gender</th>
<th>Skin Color</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2010 Other Profession</td>
<td>M</td>
<td>None</td>
<td>His teacher</td>
</tr>
<tr>
<td>Spring 2011 Design/Create Single</td>
<td>M</td>
<td>Peach</td>
<td>Play Dough</td>
</tr>
<tr>
<td>Fall 2011 Factory/Make Quantity</td>
<td>M</td>
<td>None</td>
<td>Play Dough</td>
</tr>
<tr>
<td>Spring 2012 Factory/Make Quantity</td>
<td>M</td>
<td>Lt. Brown</td>
<td>Potato Chip Factory</td>
</tr>
<tr>
<td>Fall 2012 Factory/Make Quantity</td>
<td>M, M, M, M</td>
<td>None</td>
<td>Potato Chip Factory</td>
</tr>
<tr>
<td>Spring 2013 Designer</td>
<td>M</td>
<td>Lt. Brown</td>
<td>Uses computer to design</td>
</tr>
</tbody>
</table>

Marcos’s ideas of technology changed throughout the study. He generally held the common misconception that technology requires electricity, though at times his definition also included metal items or items an engineer would use in their work as potential examples of technology. In his final interview, Marcos understood the full definition of technology and applied it to all of the items. He also recognized that an engineer would design technology, noting that an engineer might design a toothbrush. At the end of the study, Marcos held a complex understanding of engineers as technical designers.

Marcos held a positive attitude toward engineering, enjoying the engineering activities he took part in though he did not consider engineering to be a desired career for
the majority of the study. Marcos wanted to be a police officer in many of the interviews. In the final interview, he decided he might like to be an engineer, but would rather be in a similar career that allowed him to build things as well as design. He rated engineering highly, either a nine or a ten on a scale of one to ten, and spoke of having fun during the play dough and simple machines engineering activities.

4.4.2 Year One: Second Grade

Marcos was a student in the same classroom as Ashleigh and Sofia during the first year of engineering instruction, taught by a White female with a positive view of engineering who had taught engineering during the prior three years.

4.4.2.1 Initial Data Collection

When asked to describe his drawing, Marcos read his drawing’s description verbatim, “The teacher is working on the computer in the room.” When the interviewer asked if there is an engineer in his picture, Marcos responded, “I dunno. I guess.” In continued prompting, the interviewer asked, “Can you point to the engineer?” Marcos points to his teacher and responded, “Right there?” Marcos drew his teacher, a White female, working on the computer “cause I always see her doing that” as seen in Figure 4.14. If he had more time, Marcos would have drawn the students in the classroom as well.
DRAW AN ENGINEER TASK

In the space below, draw an engineer doing engineering work.

[Hand-drawn image]

What is the engineer doing? [Handwritten text: The teacher is working on the computer in the room]

Prepared by Brenda Capobianco, Purdue University 8/1/07

Figure 4.14. Marcos’ Year One pre-DAET
Marcos did not seem to have any concept of what engineers are or what they do at this point. On the SKT, he responded that an engineer might “contact the families of the victims,” “build a house for a family,” or “create a new toothpaste.” When he heard the word *engineer*, “Nothing,” came to Marcos’ mind. *An engineer is someone who* “is working on a computer.” He did not know much about engineering at this point in time and learned what he does know about engineering “from my teacher.” The only engineer activity that he has done before is complete the Draw an Engineer Task as a pre-test and in preparation for the interview. Marcos did not seem to understand the question, “Can you give me an example of one type of engineer?” After a pause, he responded, “Of me or the classroom?” “Whichever one you want,” answered the interviewer, allowing Marcos to respond without priming him. After another pause, Marcos finished his answer, “I like watching TV.”

Marcos did not want to be an engineer because he wanted to be a police officer when he grew up. He responded ☹ (Not Sure) on the EIDS, and when asked if he wanted to be an engineer when he grows up, Marcos quickly responded, “No thank you.” He did not have a reason why he doesn’t want to be an engineer, but did want to be “a cop” so he can help keep people safe.

4.4.2.2 Final Data Collection

Marcos learned about engineers from “my teacher.” Marcos also learned about engineers from his brother. He stated his brother told him about the Engineering Design Process, explaining, “when they work they need to work really hard if they want to make more money.” Marcos recalled making play dough with his class as an engineering project, though he did not like the final product. He enjoyed learning about engineering
through the play dough unit. “Well the play dough, I liked because I never knew that chemical engineers can do that.” He described the *Gumdrop People and Chairs* activity in depth as an additional engineering activity, but he was not sure why these activities are engineering or how they were different from other classroom activities. Marcos noted that making a plan during the *Gumdrop People and Chairs* activity and recording the results was using science. In addition to the classroom activities, he discussed using engineering to create a paper glider to play with. He might use engineering at home “We will make homemade play dough and give it to people that don’t have any.”

Marcos drew a single male engineer making play dough like the class did in their engineering activity as shown in Figure 4.15. The engineer is following the directions to create the play dough. Marcos was not sure why the engineer is making the play dough, he might be making it “for kids?” The engineer seems to have dark skin, but Marcos stated “it’s peach.” Marcos noted that his engineer is a chemical engineer, and he learned about engineering from his teacher.
Marcos built his conception of what engineering on classroom experiences he’s had. When he heard the word *engineer*, Marcos thought, “Like when I grow up it reminds
me if I was the best engineer in the world.” An engineer is someone who “Makes [pause] stuff?” When prompted with “What kind of stuff?” Marcos tried to explain, “Play dough, do some make…I don’t know.” Marcos recalled chemical engineers as a type of engineer, noting that they work in a factory and make stuff, but he was not sure what engineers do in general. His responses on the SKT spoke to his confusion about engineering, choosing examples of engineering that include “clean up damage and debris,” “fix a car for a customer,” and “create a new toothpaste.”

Marcos learned some of the desired definition of technology, knowing that Q: Play dough is considered technology because “it is human made.” He chose “lightning” as an example of technology, showing some misconceptions regarding technology.

Marcos did not want to solve problems that help people according to the EIDS, but might want to be an engineer. During the interview, Marcos said that he does not want to be an engineer “because they work hard and sometimes I might be lazy.” He still wants to be “a cop, because they have pistols.”

4.4.3 Year Two: Third Grade

In third grade, Marcos was taught by a White female who taught engineering in her third grade classroom during the prior two years. She completed all Engineering is Elementary lessons in the unit Marvelous Machines: Making Work Easier along with the What is Technology? and What is Engineering? lessons. She did not incorporate additional engineering design activities into the curriculum. She did not seem to feel that all of her students learned or understood the engineering content, “What is technology was a real focus, but once you leave it and you don’t come back to it for a few months, then it’s gone. I was looking at the kids’ what is an engineer. Still have the train drivers.”
She felt her students learned about industrial engineers and “This year they were really good about the design process.” While her students “know that you can’t just go from planning to fixing, you have to test it” they did not always perform as she would have liked. “The class sees what one team did wrong and then they go and they still do the same thing, you’re like, okay, we can’t spend a lot of time talking about this but we already showed you that this is not going to work.” She thought the student engagement and attitudes overall were good. “Overall student engagement, pretty well. You’re always going to have those that are very engaged and those that just sit back...As far as excitement, yeah, they’re excited to do it. Engaged.”

She believed that engineering was important but that the time it took made it less enjoyable, “In the beginning, I thought that this would be fun but then it ended up taking a lot of time, so you’re like, ugh, I don’t want to do this, 'cause it takes so much time up and I have to get through everything else…integrating engineering is really important if we’re going to raise kids that are problem solvers and thinkers.” She saw engineering as a good way to reinforce all subjects the students are learning and practice ideas first learned in other subjects, “We learn how to do it and then we actually practice doing it when we’re doing the EiE.” She believed that students benefitted the most from problem solving and applying the knowledge they learned from other subject areas.

4.4.3.1 Initial Data Collection

Marcos stated that he learned about engineers and engineering “in second grade in the classroom.” He also said that he learned about engineering from his mother, “she did tell me a little bit about it.”
At the beginning of his third grade year, Marcos continued to think of engineers in the context of the play dough *Engineering is Elementary* unit. He drew a single tall male engineer making play dough as shown in Figure 4.16. The engineer is a chemical engineer who works in a factory making play dough.

Figure 4.16 Marcos’ Year Two pre-DAET
Marcos was still not sure what engineers would do based on his SKT responses, choosing “build a house for a family,” “clean up damage and debris,” and “design the recipe for a really strong cleaning solution.” When he heard the word engineer, Marcos thought, “Nothing.” According to Marcos, “An engineer is someone who [pause] makes things?” Marcos recalled chemical as a type of engineering, saying they work with chemicals, though he was not sure of any other types. Chemical engineers “do play dough, some people like use factory, they work in a factory, and I guess that’s all I know. Well, they do build houses.”

Marcos had a naïve view of technology and did not seem to recognize that engineers work with or design technology. Things that are electric are definitely technology to Marcos, however that isn’t the only requirement for something to be technology. This misconception is confirmed through his SKT responses, choosing “lighting” as an example of technology and $Q$: Simple machines are considered technology because they “use electricity.” He did not think a toothbrush was an example of technology. “Technology? Well, I don’t think so, ’cause it’s not electric.” He was not sure if a pulley was an example of technology. “Yes and no. Yes, it’s metal, and no, it’s not electric.” A cellular telephone was an example of technology, “Well, it has buttons and it is electric.” After further probing from the interviewer, “So anything electric you would think is technology?” Marcos agreed, “And that [the pulley].” An engineer would not work on any of the items except the cellular telephone, according to Marcos, and an engineer might “look at one of those. How they make them and they look at them. They study how so we can, they can work on them and that’s all I know.”
Marcos was not sure if he would like to be an engineer in the interview, though he would neither like to be an engineer nor work on a team with engineers according to his responses on the EIDS. He would need to learn more before deciding, “Well I don’t know that much of it but I think I will learn when I’m in college.” He would still like to be “a cop, like a police...’cause you get paid a lot.”

4.4.3.2 Final Data Collection

Marcos learned about engineering in the classroom but “more in a science museum…it has like engineering stuff too like they show us how to, how does it create a tornado and stuff like that.” He recalled the simple machines design project as well as an assembly line activity his class completed. He enjoyed the Engineering is Elementary design activity using simple machines, “I liked it that me in my group we did teamwork…I think I liked everything.”

In Marcos’ drawing of an engineer, there is a single male engineer working on an assembly line in a potato chip factory as shown in Figure 4.17. He colored his engineer’s skin the same color as the potatoes and potato chips in the assembly line. He did not seem to make a distinction between someone who would design the factory process, build and maintain the machines in a factory, and a factory line worker; tools his engineer would use include materials to build the potato chip machines. If he had more time, Marcos would have drawn another engineer “taking the chips to another place and maybe some more engineers can put ‘em in a bag for potato chips.”
Marcos was developing a conception of engineers that includes design. On his SKT, Marcos chose examples of engineering tasks including “drive a train engine,” “clean up damage and debris,” and “design assembly lines.” When he heard the word engineer, Marcos thought, “Workers that design a type of process.” 

An engineer is
someone who “creates.” Marcos was able to name multiple types of engineers, including mechanical and chemical. He described the work of mechanical engineers: “they have a lot of materials and they work on metal and mechanical stuff.” He also described what chemical engineers do: “in my pool, maybe some engineers make these chemicals that make my pool clean or there’s other types of chemicals for example like soap.”

Marcos continued to hold the incomplete misconception that something that is technology must involve electricity in some way, but also believed that technology could be metal. He described engineers as using technology in their work but not designing technology. His SKT responses agreed with a misconception that technology requires electricity, choosing “lightning” as an example of technology and “use electricity.” as the reason simple machines are considered technology. A toothbrush was not an example of technology “because it just has plastic and it doesn’t have wires on them to make a movement or something like that.” An engineer might use a toothbrush in their work, “it depends on what kind of process they’re working on.” Marcos still considered a pulley to be an example of technology because “a lot of engineers they have a lot of those to create stuff and it’s metal, but it does not have wires but it’s part of technology.” An engineer might use it as part of their work in a factory.

For an example if they’re trying to, if that was a strong pulley and they bought a wheel and axle for something that they’re creating, if they want to do that that’s called a simple machine so they can pull it up and if it was a factory and a person would be up, like up and there was a stairs and you come up and you pull it, something comes and the worker picks them up and puts them somewhere.
A cellular phone was an example of technology “because when it turns on what makes it turn on is like something inside of the phone that makes it work and if it doesn’t work it has a battery and it can be high that means it has enough battery to do stuff with it but if it doesn’t you cannot turn it on.” An engineer might work with one “because if they have a phone like that maybe another factory or workers create that. Maybe if the boss says to take a picture how they made something and they send it to the boss and the boss looks at it and sees that’s a good process to make work easier.”

Marcos seemed to enjoy the engineering experiences he had but may not want to be an engineer. Marcos was not sure if he’d like to be an engineer when he grows up on the EIDS or in the interview “because it’s sort of like a lot of work.” On a scale of one to ten, Marcos rated engineering a ten “because it would need a lot of work and if we test it, it would be one hundred percent good to make the process work.” Marcos could not think of anything that made engineering not interesting.

4.4.4 Year Three: Fourth Grade

In his third year, Marcos was taught by a White female who taught engineering in the fourth grade once previously. Only the required lessons, What is Technology?, What is Engineering?, and all of the units within the Engineering is Elementary unit, A Stick in the Mud: Evaluating a Landscape were completed during the school year.

At first, she was not happy with incorporating engineering into her classroom. She later found engineering to be an excellent way to introduce new concepts from science, though not other subjects. She also found that the lessons fit in well with the subjects that she was teaching in her science courses and taught important life skills, even though it took extra time.
I’m gonna be honest with you, when this all came down the pike I was not in favor of doing this, ’cause we have so much curriculum to cover anyway, I’m going, ‘how are we going to incorporate this?’ But I find that what we have used with the engineering has been a really good way like for instance with our study of weathering and erosion it really added a lot to that by doing the core sampling and by doing the TarPul experience, investigation, so it really introduced new concepts that supported what we were teaching…actually it went better than I anticipated. I was kind of dreading it ’cause I’d never done it before and I learned from my mistakes too…I just thought, ‘This is just going to be so hard! How are we gonna get all this stuff done, we’ve got to teach this and this and this and this and this!’ And then when I could see that we could incorporate, particularly this last one, it just fit in beautifully with our weathering and erosion. Now earlier in the year when we were doing the others, that was kind of something extra, I felt like it was really important, the things they learned from that, I felt they were important even if they didn’t fit in with what we were working on in science because it’s something they needed to know in life and this might be the only opportunity in the next few years or if ever they would get to dabble in it.

She felt that her students were engaged and enjoyed the engineering projects. “Extremely well, they really enjoyed this…didn’t have a negative attitude in the bunch.” She felt that student learning was okay overall, but not all students grasped all of the material. She chose the second-highest category for student learning; “Pretty well, I think
they got it, I’m not sure all of them got it as well as others, but I think they got a basic understanding.” Students gained the most from the problem solving involved in engineering activities. She found engineering to be an enjoyable addition to her classroom but did not find it beneficial for meeting state standards, because they prepare our tests to go with the current curriculum, not engineering, 'cause so many schools don’t do engineering so I don’t really think we need engineering for our state curriculum standards I just think it’s really a great cherry on top of the sundae to have it 'cause it gives them a little extra, you know, a lot of schools and students don’t have it. She also liked engineering because it gave students a chance to fail, try again, and eventually succeed.

I think that’s what I like about engineering is it does give you a chance to fail and turn around and succeed and I think they need to know that. I’m sure that Alexander Graham Bell didn’t get the telephone on the first little experiment. So I like the engineering and the fact that it’s okay to fail, but now what do you need to do to adjust it? And then they can carry that in to other life lessons of failing but don’t give up, you just keep on ‘til you get a success.

Even though initially she did not want to teach engineering in her classroom, the teacher found engineering to be an extremely valuable addition to her curriculum. But is it worth it? Yes, I feel like it was very valuable and I think it’s very worth it…any time you can have an opportunity to do hands on like this, and you see that smile on the kid’s face and you can see that ah ha
moment and you can observe all these things going on, then that’s what to me good teaching is all about. If engineering provides that, then I’m all for teaching engineering.

Overall, the teacher had a positive attitude toward engineering in her classroom. While she did not find engineering to be helpful for state testing or for subjects beyond science, she found engineering to instill life skills like problem solving and the ability to try again after a failure for her students.

4.4.4.1 Initial Data Collection

Marcos recalled learning the Engineering Design Process when asked what he has done related to engineering in school during prior years. He enjoyed the engineering design project from the Engineering is Elementary unit, Marvelous Machines: Making Work Easier, that he completed during the prior year in his third grade class. “I remember all of it…It was fun.” He also recalled watching a video about a potato chip factory, though the plot is similar to the book that accompanied the EiE unit and his teacher did not note showing a video. “Because we saw a video about this girl and her brother works in a potato chip factory and they say they try to make stuff easier and the brother said that he’ll take her to the factory.”

Marcos drew a potato chip making factory with multiple male engineers similar to the final drawing seen at the end of his second year as shown in Figure 4.18. All four people in the drawing are engineers. One is a factory line worker, putting the potatoes into the machine. One is trying to clear a potato blockage. One is fixing a broken pipe. The fourth engineer is operating a machine that allows the third engineer to reach the broken pipe on the ceiling of the factory. Marcos had not drawn a specific type of
engineer. Based on the drawing, it seemed as though Marcos has a conception of engineers as factory workers and maintenance workers based on classroom experiences with engineering during the EiE unit.
DRAW AN ENGINEER TASK

In the space below, draw an engineer doing engineering work.

What is the engineer doing?

There are four workers working at a potato chip factory. There is one man that langes, potatos. Two more men are fixing it.

Prepared by Brenda Capobianco, Purdue University 8/1/07

Figure 4.18 Marcos’ Year Three pre-DAET
Marcos believed engineers are hard workers who make things easier for others but was not quite sure what it is that they do. When he heard the word *engineer*, he thought, “hard workers” and *An engineer is someone who* “works to make things easier.” Marcos recalled mechanical as a type of engineer, but was not sure what they do. He also recalled a second type of engineer, “There’s, I forgot what they call it, but they drive a train, they like work in train, train engineering?” He also responded “drive a train engine” as an example of what engineers would do on the SKT, though he did recognize that engineers would “create a system to prevent future floods” in the event of a flood.

Marcos seemed to hold the common misconception that to be technology, items need to run on electricity. Marcos recognized that engineers would “make” a cellular telephone, the one item that he identifies strongly as technology, but did not clarify whether he means to design or to build the phones themselves. He recalled the *What is Technology?* lesson from his third grade class, remembering that he took a quiz and had TV and video games as his responses for what technology was; on the EIDS, he believed that “lightning” would be an example of technology. Marcos did not think a manual toothbrush was technology, “Maybe the electric kinds.” He did recognize that an engineer might work on a toothbrush “to clean your teeth easier.” At first, he believed a pulley is an example of technology, but changed his mind when asked why, “Well, no…’cause it doesn’t have wires in it?” He believes that “a lot of engineers use these [pulleys]…Sometimes they use these for special machines to make work easier.”

Marcos changed his definition of technology somewhat after talking about the engineering activities he participated in using pulleys during the prior school year. When asked if the soil core sample was an example of technology, Marcos replied, “It could
be…because even on the engineer on the paper he can use big large rocks to launch the potatoes,” referring to the engineer putting bricks onto the potato launcher in his drawing. The interviewer attempted to clarify Marcos’ definition of technology, “So if you can use it for something, does that make it technology?” Marcos responded affirmatively, “Uh-huh.” Marcos reverted to a more naive definition when asked if a cellular telephone was an example of technology. “It has a lot of electric wires and stuff and the buttons make the wires work for the screen.” Engineers would have something to do with phones, “They sort of make them.” The interviewer asked Marcos to further clarify, “Make them? What do you mean by make them?” Marcos explained, “Like, they make the phones for people who need them.”

Marcos still wanted to be a cop, but was not sure sure, “I don’t really know what I should be, like I can work in a store sometime.” On the EIDS, he responded that he would not like to be an engineer when he grows up, though he might like to work on a team with engineers. He enjoyed engineering and would rate it a nine on a scale of one to ten, “cause it’s fun learning about engineers…sometimes we do activities, sometimes we do a little quiz about it, and I like learning about engineers…I like how they work and they show us like in some videos that my teacher showed me last year.” Marcos could not think of anything that would make engineering more interesting.

4.4.4.2 Final Data Collection

Marcos recalled learning about engineering at school throughout elementary school. He particularly recalled the Engineering is Elementary unit Marvelous Machines: Making Work Easier. “Well in third grade, we did a, like, special machines, that we did something with a pulley and a wheel and axle, how we pull for make a design process,
makes life easier.” He did not recall any other specific engineering experiences and did not consider the activities he participated in during the current school year to be engineering-related.

Marcos drew a single male engineer with light brown skin as seen in Figure 4.19. His engineer is “designing something like designing process to take it to the factory where they make it.” When asked what he means by the word design, Marcos said his engineer is “creating a new thing that makes life easier.” The engineer is designing a product or process using computers to create the designs. The engineer may sketch on paper first, but uses the computers for the final design. “Well there’s crumpled papers so he’s probably like drawing and then puts them on the computer screens and designs, like, making something.”
Figure 4.19 Marcos’ Year Three post-DAET
Marcos had a complex, though inconsistent, idea of what an engineer is. When asked what comes to mind when he hears the word *engineer*, Marcos responded, “A person that makes, not makes, like, creates, or like makes it in his brain, picture it, asking what they want and he’ll make it but not like not make it, like maybe, designing?” *An engineer is someone who* “design a process that will help others.” On the SKT, however, he chose “drive a train engine” though he did recognize that an engineer might “create a system to prevent future floods” and would not “run a machine that digs up soil and rock.” Marcos recalled mechanical as one type of engineering “They make like mechanic stuff like for example mechanical pencil, they design it.” He also recalled the term industrial engineer but isn’t sure what an industrial engineer would do.

Marcos seemed to hold the desired conception of technology and understood that engineers design technology. On the SKT, Marcos chose “scissors” as an example of technology but did not recognize that making soil more compact is technology, choosing “done by nature.” instead of “a process designed to solve a problem.” A toothbrush was an example of technology “because it’s man-made and it will, it helps you brush your teeth, make ‘em cleaner.” Marcos also understood that engineers can design anything, even a toothbrush. “He designs it, he makes it, and then they go out to the factories and they will make it just how the engineer wants it to be.” He recognized that a soil core sample and a flower were not examples of technology while a cellular telephone was an example of technology.

Marcos was not sure if he wanted to be an engineer at first but decides that he does, “I don’t think, well, yes, actually, because you can change people’s life, and you can help them, and I guess that’s it.” On the EIDS, his responses indicated that he would
like to be an engineer but would not like to work on a team with engineers. He would like to be “a creator, make stuff…they both think about and create in their mind, like picture it in their mind like how what they’re gonna need, like they’re gonna need this, they’re gonna need that.” He rated engineering a ten on a scale of one to ten. “It’s kind of fun because I’m into, like, the LEGO building and so, the picture, maybe if I be an engineer that creates, maybe it could help because I’m really good with the building….My math, science teacher said they don’t make it, they design it and that really bummed me out because I thought they made it, they make the thing, then they go to the factories and make a copy of what they do.”

4.5 Jake

Jake is a White Male. He learned about engineering in a K-6 elementary school in an Urban area in the South Central United States. His school was a Title One school with approximately 62.2% of students eligible for free and reduced lunches and a student to teacher ratio of approximately sixteen to one. The school was 52% male with a demographic breakdown as seen in Figure 4.20. This school had a strong commitment to engineering, with increasing numbers of teachers in the 2nd, 3rd, and 4th grades participating each year of the study.
4.5.1 Overall

Jake began with almost no idea of what an engineer is, thinking they shovel coal without knowing why they might do so. His conception evolved through common misconceptions of someone who makes single items or builds houses and settled on the desired overall conception of engineer as designer during his second year in the study. It remained there for the rest of the study, as shown in Table 4.4.

<table>
<thead>
<tr>
<th>Year</th>
<th>Conception</th>
<th>Gender</th>
<th>Skin Color</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2010</td>
<td>Other Profession</td>
<td>M</td>
<td>None</td>
<td>Shoveling coal</td>
</tr>
<tr>
<td>Spring 2011</td>
<td>Design/Make Single</td>
<td>M</td>
<td>Brown</td>
<td>Building a chair - Gumdrop Chairs Activity</td>
</tr>
<tr>
<td>Fall 2011</td>
<td>Laborer/Builder</td>
<td>M</td>
<td>None</td>
<td>Building a house</td>
</tr>
<tr>
<td>Spring 2012</td>
<td>Designer</td>
<td>M</td>
<td>Peach</td>
<td>Designing a computer</td>
</tr>
<tr>
<td>Fall 2012</td>
<td>Designer</td>
<td>M</td>
<td>Brown</td>
<td>Designing guns</td>
</tr>
<tr>
<td>Spring 2013</td>
<td>Designer</td>
<td>M</td>
<td>None</td>
<td>Designing guns</td>
</tr>
</tbody>
</table>
Jake’s conception of technology also quickly evolved to the desired understanding of technology as anything man-made. In the first interview of the second year of the study, he held the misconception that technology must have “energy” while also noting that examples of natural things were not technology because they are “not man-made.” At the end of his second year and all through his third, Jake recognized that technology was anything man-made. He did not fully comprehend the connection between engineers and technology, providing some examples of how an engineer might work with or design the examples of technology such as creating a powered toothbrush.

Overall, Jake did not want to be an engineer. According to the EIDS, he would typically like to solve problems to help people when he grows up, but in the interviews favored careers that involve physical activity like the Marines or playing baseball. He never provided examples of things he does not like about engineering and at the end, rated engineering highly, stating that he would like to be an engineer if he can also play baseball. He seemed to have a positive attitude toward engineering.

4.5.2 Year One: Second Grade

In his first year of engineering instruction, Jake was taught by a White female who had taught engineering once before in the prior school year at the same grade level. She felt that she taught engineering “much much better than last year!” In addition to the required Engineering is Elementary unit, A Work in Process: Improving a Play Dough Process, the What is Technology? and What is Engineering? lessons, the students completed three additional engineering activities and the Modeling Eliciting Activity: Stickers. The three engineering activities the students completed were Pop-Up Cards,
Tower Power, and Gumdrop People and Chairs, along with reading a book to complement the activity, A Chair for My Mother.

She believed that engineering is most connected to mathematics and science, “they benefit from subject matter, math and science connections to engineering, because I think that’s how I relate it most to my children,” though it is not limited to these subjects.

“But it also can go into writing because I need them to record and reflect what they’ve done, they can make a list, they can do a plan, they can make predictions, which is all part of the reading and writing process.” She believed that her students enjoyed the engineering activities and had high levels of learning, “I think it went really well. I mean they just absolutely loved it and they understood more about it.” She felt that engineering was a positive addition to her classroom and her own personal learning after initial feelings of hesitation towards adding engineering, “And even though I was so shy and timid about it, the more I’ve learned about it and the more exposure I had to it, it’s – I can just see the value in it for children of all ages.”

4.5.2.1 Initial Data Collection

Jake did not recall having any experience with or knowledge of with engineering before he started second grade. Jake drew a single male engineer who is “scooping up the coal and throwing it into the fire” as seen in Figure 4.21. His engineer works on a train, and he isn’t sure why is engineer is doing what he is doing, “Well, I don’t know, I just think that engineers just scoop up coal and throw it in the fire, I think, I don’t know.”
Jake did not have much to say about his drawing, but had a strong conception of engineers as people who work with trains in some way. When he heard the word
he thought of “somebody scooping coal and throwing it in the fire.” He was able to give an example of one type of engineer, “an engineer who fixes a train.” He seemed to have a concept of engineers connected to vehicles, answering that engineers would “change the oil in cars” and “fix a car for a customer” on the SKT. According to the EIDS, he was not sure what engineers do aside from using science and creativity, but responds with ☹ to the items “Engineers design everything around us.” and “When I grow up I want to be an engineer.” When asked if he’d like to be an engineer when he grows up in the interview, Jake responded, “I don’t know yet.” Jake also did not have a strong concept of technology based on his SKT responses, indicating that “lightning” was an example of technology and that Q: Play dough is considered technology because “it is made of more than one ingredient.”

4.5.2.2 Final Data Collection

Jake recognized that he learned about engineering during the past school year. He recalled working on various projects in his classes that he would consider engineering, “those things that go outside and the wind makes them spin around, like I forgot what those were called, but one time we made one of those. And one time in the science room, it’s like engineering and science, like we made play dough.” When asked, “So what makes those projects engineering?” Jake responded, “The first one that I said it’s ’cause we were building it, the play dough, well, the play dough like science and engineering, so, well, [pause] ’cause like, we were like, mixing stuff together to get play dough.” Jake enjoyed making play dough, and learned that “some engineers put chemicals together” during the school year.
Jake drew a single male engineer with dark skin, “He’s brown,” as seen in Figure 4.22. He is a craftsperson, “building a stronger chair.”

Figure 4.22 Jake’s Year One post-DAET
Jake recognized that there are multiple types of engineers who engage in different activities. His conception focused on hands-on activities an engineer might perform, from mixing chemicals, as he did in the EiE activity, to building items, as he did in supporting engineering activities. His responses on the SKT supported this conception; he chose responses that either use the term “build” or “create” for all of the engineering questions, one of which, “build a house for a family,” is the incorrect response. When he heard the word *engineer*, Jake hesitated for a long time before answering, “Nothing, I guess.” He finished the sentence *An engineer is someone who* “I like, but there’s more than one engineer, so here’s one of the engineers, someone that builds something.” Jake recognized that there are multiple types of engineers, “One is a chemical engineer that mixes chemicals together…a train engineer that like, drives a train…the building kind of engineer…like they build stuff…there’s like, lots of engineers.”

Jake developed the desired conception of technology based on his responses to the SKT. He recognized that “scissors” are technology and that *Q: Play dough is considered technology because “it is human made.”* He seemed to also recognize that engineers design technology, responding ☺ to the item “Engineers design everything around us.” on the EIDS.

Jake was not sure of his future. When asked if he would like to be an engineer when he grows up, Jake responded, “Well, I don’t know.” He responded ☹ (Not Sure) to all “When I grow up…” items on the EIDS. He might like to be a UFC fighter, but isn’t sure. He had a positive attitude toward engineering and enjoyed the engineering activities he participated in during the school year, but was unsure of his future career.
4.5.3 Year Two: Third Grade

During his second year in the study, Jake was in a classroom with a White female who taught engineering in the third grade for the third year. In addition to the required What is Technology? and What is Engineering? lessons and the Engineering is Elementary unit, Marvelous Machines: Making Work Easier, the class completed the Tower Power and Paper Tables engineering activities.

She believed her students had high levels of engagement and positive attitudes toward engineering, “Yeah, their engagement is good. They’re usually really interested…They like doing stuff like that. They liked all of the little activities and they liked the book.” Regarding connections to other subjects, she stated, “I do think it reinforces what they learned. It just does take a lot of time.”

4.5.3.1 Initial Data Collection

Jake recalled learning about engineers “like in second grade.” Both the toothbrush and the flower, artifacts used during the Technology and Engineering portion of the interview, reminded Jake of a windmill activity he completed in second grade. This was not noted as an engineering activity by Jake’s second-grade teacher, but was noted by Jake in his final second grade interview. He was reminded when the interviewer asked, “Does this object [a toothbrush] remind you of any engineering activity at school?” After a pause, he responded, “Yeah, like in second grade whenever we built like a little hand thing like when the wind blows the thing spins around ‘cause we used like a pencil and some paper.” Focusing back on the original question, the interviewer asked, “But any activity with a toothbrush?” Jake responded, “No we didn’t do an activity with a toothbrush but it does remind me of that windmill thing.” He is reminded again of what
he considers an engineering activity, the windmill activity, by the flower “well, yeah, kind of ’cause the petals, you know, like it, that windmill that we made in second grade, it looks like that thing.”

Jake drew a single male engineer as shown in Figure 4.23. He “did not have time to color it in.” His engineer is a builder/laborer, building a house for his cousin who needed a house. He was not sure what type of engineer he drew. When asked, after a pause, he responded, “I don’t know what engineer is called, it’s like one of those engineers that builds stuff, I don’t know what they’re called.”
DRAW AN ENGINEER TASK

In the space below, draw an engineer doing engineering work.

What is the engineer doing?  
building a house using cement, bricks, and shingles.

Prepared by Brenda Capobianco, Purdue University 8/1/07

Figure 4.23 Jake’s Year Two pre-DAET
Jake’s conception of an engineer was tied to an engineer building things. When he heard the word *engineer*, Jake thought, “like an engineer building something.” He believed *An engineer is someone who* “builds stuff and like, tries stuff, an engineer can do lots of things.” When asked to name types of engineers, Jake thought of two, “Like an engineer that would like, drive a train, that kind of an engineer?... Like an engineer that builds something.” He answered similarly on the SKT, choosing responses of “drive a train engine” and “build new cars.” for examples of what engineers might do.

Jake had an incomplete variation on a common misconception of technology, stating that something is technology if it uses energy rather than the more common requirement of electricity, though he may mean electricity when he says energy. On the SKT, he answered “Simple machines are considered technology because they” with “use electricity,” though he did recognize that “scissors” are an example of technology. He seemed to have some understanding of the desired definition of technology, responding that naturally-occurring items, like the flower, were not technology because an engineer does not make them. Jake did not think a toothbrush is an example of technology “because it doesn’t use energy, like an engineer didn’t build it but it’s, it doesn’t use energy, it’s not a machine.” He did not think a pulley is an example of technology, again because “technology is something that uses energy.” He did respond that an engineer might use a pulley in their work. He did not believe a flower was an example of technology. When asked why, he responded, “it wasn’t man-made, an engineer didn’t build it.” He believed a cellular telephone is an example of technology because “an engineer made it and it uses technology” but doesn’t think an engineer would use it in
their work. Building from his technology misconceptions, Jake responded negatively to the EIDS item, “Engineers design everything around us.”

Jake was unsure if he’d like to be an engineer when he grows up, “I don’t know yet.” He would like to be a Marine “cause I like Marines. My Grandpa was a Marine.” He responded Not Sure (2) to all questions asking what he’d like to do when he grows up on the EIDS.

4.5.3.2 Final Data Collection

Jake recalled learning about engineering “from class” but did not provide additional examples of engineering he learned about or engineering activities he took part in.

Jake drew a single male engineer with light skin, “he’s peach” as seen in Figure 4.24. The engineer is a designer. “He is designing a new computer that can run ten times faster than a regular computer,” Jake said twice during the interview, reading verbatim from what he has written in the text on his DAET. When prompted to explain what exactly his engineer is doing, “Okay, what does ‘designing a new computer’ mean?” Jake was unsure, though he does recognize that his engineer is using a pencil and paper as the tools he is using to design. He was also unsure whether his engineer is working to help someone.
What is the engineer doing? He is designing a new computer that is 10 times faster than a regular computer.

Prepared by Brenda Capobianco, Purdue University 8/1/07

Figure 4.24 Jake’s Year Two post-DAET
Jake had a strong conception of an engineer as a designer. According to Jake, an engineer is someone who “designs stuff.” He was unsure about different types of engineers, describing his engineer as the type “who designs stuff.” His complex conception of an engineer as a designer is borne out in the SKT; he answered all questions about engineers correctly. His responses on the EIDS paint engineers as people who work in teams to solve problems that help people, using mathematics, science, and creativity, and he recognized that there is more than one type of engineer.

Jake seemed to hold the desired concept of technology, noting that items are technology if they are man-made, but did not make the connection that engineers design technology. This was consistent with his response on the EIDS; he did not agree with the statement “Engineers design everything around us.” Jake recognized that a flower was not an example of technology “'cause it’s not man-made, it’s made in nature.” It did not have anything to do with the work of an engineer “'cause an engineer didn’t design it 'cause it was made in nature.” Jake recognized a pulley as an example of technology. “I think so. Yeah, yeah it is.” When asked why, he responded, “'cause it’s man-made, 'cause it isn’t made in nature.” He also recognized a toothbrush as technology. “Yes, 'cause it’s man-made.” He did not believe a core soil sample was an example of technology “'cause people didn’t make it, it’s not man-made.” His correct understanding of technology was borne out in his responses on the SKT, answering all technology-related questions correctly.

Jake’s attitude toward engineering overall could be summed up as “I don’t know.” Jake was not sure whether he would like to be an engineer. On the EIDS, he noted that he does not want to be an engineer, though he does want to solve problems that help people.
He was unsure if he would like to design different things or work on a team with engineers. He was unsure why that is or what he would like to be when he grows up. He was also not sure what his interest in engineering would be on the number line, and is prompted three times before choosing “three or four” and was not sure why he chose that. He was not sure what he likes about it or what would make it more interesting. He changed his response to a five, but did not share his feelings about engineering with the interviewer beyond “I don’t know.”

4.5.4 Year Three: Fourth Grade

In his third year, Jake was taught by a White female who incorporated project-based and cooperative learning into her mainly traditional lecture-based, mastery learning classes. She taught engineering in her fourth-grade class every year of the study; this is her fifth year teaching engineering. As a science teacher for the grade, she taught the majority of the hands-on and inquiry-based engineering lessons but cooperated with other teachers to integrate engineering across the fourth-grade curriculum. She also taught social studies and writing. The reading teacher read the text with the children and the mathematics teacher incorporated What is Technology? lessons in her classroom.

In addition to the required Engineering is Elementary unit, A Stick in the Mud: Evaluating a Landscape, and the What is Engineering? and What is Technology? lessons, she incorporated engineering through the Tower Power and Paper Table engineering activities. While she didn’t read the book, she did reference the content in the engineering- and science-focused lessons in the EiE unit. “For me it was more, going back and looking, they had that illustration of the TarPul, going back and talking about what was going on in the village, why was the engineer brought in.” She connected
engineering with other subjects throughout the year, “I try to use every opportunity, even writing, with the engineering design process, guess what, we do that whole thing when we’re writing!” She felt her students enjoyed the EiE unit, “The kids were real interested.” She felt that engineering integrated well with what she was teaching. “My thinking is it would be nice if we could incorporate it with all subjects but I think engineering is a major focus on math and science, but of course I knew how to bring it in, incorporate it to writing as well…Engineering does go hand-in-hand with what we’re teaching.”

4.5.4.1 Initial Data Collection

Jake recalled learning about engineering at school, “like in second and third grade.” He did not provide additional details about specific activities or things he has learned about engineering. He recalled using the Engineering Design Process in second grade, but did not recall what he used it for.

Jake drew a single male engineer as shown in Figure 4.25. He is a designer, according to the caption, “He is designing a new gun that will help the Marines during the war.” When asked “What does ‘designing’ mean?” Jake responded “Like planning out, like planning out how it’s gonna be put together and like [pause] planning out what he’s, like how he’s gonna put it together and then he’ll have to like, test it and see if it works.”
Figure 4.25 Jake’s Year Three pre-DAET
Jake seemed to have a complex conception of an engineer as designer, planning and testing his designs to see if they work and creating designs for a client, in this case, designing a gun for Marines to use. He had a strong conception of engineer as designer, answering “like someone that designs stuff?” when asked, “When you hear the word ‘engineer’, what do you think about?” Jake completed the sentence An engineer is someone who “like designs something like test, he like designs it, and he like tests it, and he like, and if it doesn’t work he has to like, improve it.” He answered the SKT questions correctly, identifying engineers as designers, except for the question relating to geotechnical engineering. He chose “plan a process to reduce erosion,” the response most consistent with his conception of engineering, to the question which asks “Samantha is a geotechnical engineer. In her job, she is likely to do all of the following EXCEPT”.

Jake continued to hold the desired concept of technology and seemed to have a partial understanding that engineers design technology. He identified powered toothbrushes as something an engineer would design, but did not identify anything else. He seemed to believe that engineers only design things that use electricity, as shown by the wires (multicolored squiggles) on his DAET. This was consistent with Jake’s EIDS response, disagreeing with item 12, “Engineers design everything around us.” Jake believed a toothbrush was an example of technology “cause it’s man-made.” He believes an engineer would design a toothbrush, “One they already designed already, it’s like, this other toothbrush that like, vibrates or spins.” A pulley was also an example of technology “because it’s man-made,” but an engineer would not use it in their work. “cause it’s not man-made, it was made by nature.” Jake identified a cellular telephone as an example of technology, but did not believe it would have anything to do with the work of an
engineer. He recognized scissors as an example of technology on the SKT, but answered “Making soil more compact before building on it is considered technology because it is” with “done by nature.” This question related directly to concepts he would be learning in the coming school year and is consistent with his response in the interview, soil is not technology, though the SKT question is asking about the process, not the soil itself.

Jake had a strong positive opinion of engineering, even though he did not want to work with or be one. According to his EIDS responses, Jake did not want to be an engineer, design different things, or work on a team with engineers, though he did want to solve problems that help people when he grows up. In the interview, Jake responded that he does not want to be an engineer when he grows up, but he would like to be a baseball player. On a scale of one to ten, he rated engineering as a nine because “you get to design new things, like, that would help people.” He saw how engineering could be connected to his favorite thing, baseball. “Engineers could design stuff for baseball like a new helmet or design like a new bat.”

4.5.4.2 Final Data Collection

Jake recalled learning about engineering “at school.” He recalled learning “that they, kind of like, design new things.” Jake recalled using core soil samples in an activity when he saw one during the interview, but could not remember anything more about that activity.

Jake drew a single male engineer as shown in Figure 4.26. He continued to hold a complex conception of an engineer as designer. When asked what his engineer is doing, Jake responded, “He is designing a new gun.” He was unsure what type of engineer he drew. Later during the interview, Jake was only able to recall industrial engineers as a
type of engineer and did not recall anything more about them. He responded negatively to the EIDS item, “There is more than one type of engineer.” Jake seemed to connect engineers to technology, providing a definition of technology when asked what comes to mind when he heard the word *engineer*, “something that’s made by like, something that’s man-made.” He believed *An engineer is someone who* “designs something or like, I can’t really explain it.” His strong conception of engineers as designers is reinforced by his SKT responses, with all questions about what engineers do answered correctly.
Jake continued to hold the desired concept of technology. A toothbrush was an example of technology “because it’s a man-made thing.” Engineers might work on toothbrushes, “kind of like, [pause] like, try to make it better, like kind of design, like,
design some new ways for it to work better, something like that.” A flower was not an example of technology “because it’s not a man-made thing, it’s just [pause] natural.” A core soil sample was not an example of technology because “it’s not a man-made thing” and an engineer would not work with soil samples. He recognized a cellular telephone as an example of technology, noting that engineers “probably could, probably make like, little notes on it.” According to the EIDS, he was unsure if engineers design everything around us. He responded correctly to all the SKT questions on technology, including “Making soil more compact before building on it is considered technology because it is,” responding, “a process designed to solve a problem.”

Jake would still prefer to play baseball, but had some interest in engineering as a career and had a strong positive attitude toward engineering. When asked if he would like to be an engineer when he grows up, after a pause Jake responded, “Well, if I could play in Major League Baseball and be an engineer, I would.” He rated engineering a ten on a scale of one to ten because “you get to design, like, new things, and without engineering, like, there wouldn’t be all this stuff that we have today.” He could not think of anything he doesn’t like about engineering. In his EIDS responses, Jake did not want to be an engineer and was unsure if he’d like to design different things or work on a team with engineers. He wanted to solve problems that help people when he grows up.

4.6 Mike

Mike is a White Male. He learned about engineering in a K-6 elementary school in an Urban Fringe area in the South Central United States. There were approximately 31.1% of students eligible for free and reduced lunches and a student to teacher ratio of approximately seventeen to one at his school. The school was 49.8% male with a
demographic breakdown as seen in Figure 4.27. This school began integrating engineering in the third year of the study and was used as a control or comparison school during the first two years of the study.

![Pie chart showing student demographics at School Three.](image)

Figure 4.27 Student Demographics at School Three

4.6.1 Overall

Mike’s conceptions of an engineer did not evolve to the ideal complex conception of an engineer as designer as seen in Table 4.5. He continued to state that an engineer would fix things throughout the study, including describing what a mechanical engineer does as “he fixes mechanical things” in his final interview. At the end of his second year, Mike’s naïve conception of an engineer seemed to match the naïve conception held by his teacher, and he focused on the ideas of helping and fixing throughout the study.
Table 4.5 Mike’s Conceptions of an Engineer

<table>
<thead>
<tr>
<th></th>
<th>Conception</th>
<th>Gender</th>
<th>Skin Color</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2010</td>
<td>Mechanic</td>
<td>M</td>
<td>Peach</td>
<td>Fixing a car</td>
</tr>
<tr>
<td>Spring 2011</td>
<td>Design/Create Single</td>
<td>M</td>
<td>None</td>
<td>Making Play Dough</td>
</tr>
<tr>
<td>Fall 2011</td>
<td>Factory/Make Quantity</td>
<td>M</td>
<td>Brown</td>
<td>Making chair for self and others</td>
</tr>
<tr>
<td>Spring 2012</td>
<td>Design/Create Single</td>
<td>M</td>
<td>Brown</td>
<td>Rebuilt a chair</td>
</tr>
<tr>
<td>Fall 2012</td>
<td>Design/Create Single</td>
<td>M</td>
<td>Peach</td>
<td>Fixed a chair</td>
</tr>
<tr>
<td>Spring 2013</td>
<td>Technician</td>
<td>M</td>
<td>Orange</td>
<td>Building/fixing a computer</td>
</tr>
</tbody>
</table>

Mike’s conception of technology also evolved throughout the study, taking on some aspects of the desired definition of technology but not fully incorporating them into a coherent definition. He began to understand that technology is something that is used at the beginning of his second year, then converted to an incomplete definition where technology requires electricity by the end of the year. This definition is incomplete because he also believed that a flower is an example of technology due to how it grows. In the beginning of this third year, Mike believed that technology is something an engineer would use, while at the end he believes that technology must be used with “no hands,” so a toothbrush was not technology but a pulley was.

Mike did not want to be an engineer throughout the study. He seemed to enjoy the activities he recalls, including the play dough, pulley, and assembly line activities, but believed engineering requires hard work, something he is unwilling to provide. He recognized and enjoyed the products of engineering, but does not want to be an engineer himself.
4.6.2 Year One: Second Grade

In his first year of the study Mike was taught by a White female teacher. This was her first year integrating engineering into her classroom though she was involved in prior data collection as a comparison or control classroom. She rotated around all second grade classes to be sure all students were exposed to *What is Technology?* and *What is Engineering?* lessons. In addition to the required lessons and the EiE unit, *A Work in Process: Improving a Play Dough Process*, she incorporated the *Bat Puzzles* activity to teach and reinforce engineering concepts like the Engineering Design Process.

Student engagement and attitudes were “very high, very high, they loved it. When I would come in and say we’re going to do engineering today, ‘oh yay!’ so they were real excited. I think that word, engineering, it just sounds cool.” Overall, “engineering is a good way to introduce new concepts from other subject matter” though “it should be incorporated so that you’re working on it at the same time.” She was also able to integrate what was learned in the EiE unit with other classroom activities, such as creating an assembly line process for a Junior Achievement activity.

4.6.2.1 Initial Data Collection

Mike wasn’t sure about engineers initially, but spoke with his father after he took the DAET and his father discussed engineering with him. “Well, I thought that engineers would fix cars like you, but my dad told me that different engineers do that.” He doesn’t give further details beyond learning engineering from “my father.”

Mike drew a single male engineer “fixing a car” with “blonde hair and peach skin” as shown in Figure 4.28. Mike was not sure what engineers do overall, answering ☹ (not sure) to all of the questions about what engineers do on the EIDS. When he heard
the word *engineer*, “don’t know” came to his mind, and *An engineer is someone who* “helps fix stuff.” He was not sure about specific types of engineers. He had a basic conception of engineers as mechanics, answering “change the oil in cars.” and “fix a car for a customer” as examples of what an engineer might do on the SKT.
DRAW AN ENGINEER TASK

In the space below, draw an engineer doing engineering work.

![Drawing of an engineer fixing a car]

What is the engineer doing? **Fixing a car**

Prepared by Brenda Capobianco, Purdue University 8/1/07

Figure 4.28 Mike’s Year One pre-DAET
Mike did not seem to have a solid conception of technology. He believed that “lightning” is an example of technology and that Q: Play dough is considered technology because “it can be made into different shapes.”

Mike tells the interviewer he would like to be an engineer. “Yes. I would like to be a fixing car one.” Mike was not sure if he would like to solve problems that help people or design different things, but did not want to be an engineer or work on a team with engineers according to his EIDS responses.

4.6.2.2 Final Data Collection

Mike learned about engineers “at school.” He recalled the EiE unit paly dough activity and “two tests about engineering.” He enjoyed the hands-on aspects of the activity, “I liked that we used cups and teaspoons,” but did not like “that it might got a little bit messy.” During the school year, he learned “that they [engineers] work together.”

Mike drew a single male engineer creating play dough like he did in class as shown in Figure 4.29. The engineer is “one of the kids in my school, working.” He is a chemical engineer and is “fixing play dough, trying to figure out how to make the play dough, to figure out if he needs more salt or less salt.”
Mike’s conception of an engineer was evolving, though is still incomplete. On the SKT, he answered that an engineer would “design a quiet vacuum cleaner” and “create a
system to prevent future floods” but responded that a chemical engineer would be likely to “change the oil in cars.” His prior conception included engineers as mechanics, and this conception did not seem to be fully dispelled. Mike seemed to most strongly believe that engineers work in teams. When he heard the word *engineer* he thought, “People that work together.” He also believed that *An engineer is someone who* “works together.” Engineers “stick together as they work.” He could recall only chemical engineers as a type of engineer, and stated that “he works together with a group.” Mike seemed to understand that technology is anything man-made based on his responses to the SKT; he chose “scissors” as an example of technology and believed that Q: Play dough is considered technology because “it is human made.” He did not believe that engineers design everything around us, according to his EIDS response of ☐, indicating an incomplete understanding of what engineers do.

Mike would not like to be an engineer when he grows up “because probably it might be hard.” He would like to be “an army man so I can fight in the army.” Mike has answered ☐ for all items on the EIDS regarding what he wants to do when he grows up, indicating he did not want to be an engineer, work on a team with engineers, solve problems that help people, or design different things.

4.6.3 Year Two: Third Grade

In the second year of the program Mike was taught by a White Female who was implementing engineering in her classroom for the second year. She taught her classroom for most of the supporting engineering lessons including *What is Technology?* and *What is Engineering?* lessons however all of the third grade teachers divided up some of the *Engineering is Elementary* unit, *Marvelous Machines: Making Work Easier*, to keep the
classroom setups easier. She taught the industrial engineering lesson where students created folders using an assembly line process to all third grade students. In addition to these required lessons, the class participated in the *Pop-Up Cards, Model Eliciting Activity: Stickers*, and the *Tower Power* engineering activities.

Overall, throughout the engineering lessons her students were “Extremely engaged, I think anything that’s hands-on is extremely engaging…The strugglers, the kids who struggle academically, sometimes it’s hard to get them involved.” She thought that they had positive attitudes toward engineering, “I think they really enjoy it because it is so hands-on.” She thought her student learning was “just okay” overall, in part because multiple students transferred in and out of her class or were absent for portions of the engineering lessons. She may not have had a complex concept of engineering herself, incorporating prototyping as something an engineer would do as part of their job and stating that engineers work for outside consulting firms and not large corporations in the lesson she describes during her interview.

“We talked about the ice chest. I said, ‘Okay, what’s the name of the ice chest?’ They said, ‘Igloo.’ I’d say well, ‘What would an engineer do?’ And so they look at it, ‘Maybe he’d design the wheels on it.’ But he doesn’t work for that company, that company is going to make them. With me questioning them, more questioning, they would realize, okay, a lot of them know he doesn’t make those [Igloo coolers] for a living, and I said, ‘So how many would he make?’” and it was a chorus response of, ‘One.’ But there probably were a few that may think he just makes them as a living. But that was my goal that they realize that they [engineers] work
for a client and they use their imagination to create what they think suits what the client wants.”

She thought engineering was a good way to introduce new concepts and reinforce what students are learning, “sometimes I think it helps to have a little bit of prior knowledge and sometimes I think it’s useful to be used as a springboard into measuring.” She believed engineering was an excellent way to integrate all subjects, though the EiE unit cannot be used to replace social studies or vocabulary lessons because they do not have the depth required for the third grade standards.

“What I do like about engineering is that it is math, it is science, it is reading, and it is writing. And that’s the great thing, with Aisha, that there is a literature, so it’s literature-based, there’s a social studies activity, there’s a map activity with it, yet sometimes though the activities are not as deep as we need them to be.”

4.6.3.1 Initial Data Collection

Mike learned about engineers “when I was in grade two.” He did not recall any specific engineering activities, but did recall that “we did like, pictures, and we did some engineering process stuff and we also talked about what an engineer does.” Later in the interview, Mike recalled the Junior Achievement assembly line activity as an engineering activity, where “we make a conveyor belt.”

Mike drew himself as the engineer in his DAET as shown in Figure 4.30. He’s “building a chair that like, flies around.” He’s building it for “lots of people so whenever they’re tired, they can just go like, ‘hey let’s go to the movies and drink a slushy in our flying chairs!’ so they go to the movies in their flying chairs and drink a slushy.” While
he initially described his engineer as making a single item and the DAET shows a single engineer “hammering a nail to wood in the hot sun,” it is unclear whether the intent of his engineer’s creation is as a prototype or if his engineer will be creating all of the chairs for the people he describes using the chairs.
Figure 4.30 Mike’s Year Two pre-DAET
Mike’s full concept of engineering was slightly more complex than his drawing would seem to show, but did not seem to be the ideal conception of engineer as designer. His engineer is a “local engineer.” He could only think of chemical engineers as a type of engineer, stating they work on “heavy metal stuff.” On the SKT, Mike seemed to have a strong conception of engineers as designers, choosing both correct responses that contain the word “design” but choosing “contact the families of the victims” as the role of an engineer if a city were hit by a flood; the correct response would be “create a system to prevent future floods”. Mike believed that engineers spend a lot of time working. When he heard the word engineer, he thought, “A person that works all the time” and finishes the sentence, “An engineer is someone who…” with “always works.”

Mike seemed to have some understanding of the desired conception of technology, focusing on the third aspect of the definition: To solve a problem (to improve the quality of life). Mike recognized a toothbrush as an example of technology. He believed it was “because you hold it and then you use it to brush your teeth.” He did not believe a toothbrush has something to do with the work of an engineer. He agreed with the EIDS item, “Engineers design everything around us.” though his responses during the interview did not seem to support this statement. Mike believed a pulley is an example of technology because you use it with string, and that an engineer would use it in their work, “they will use it to lift like, if they were trying to lift a metal up to build a house, they could use this and then pull the string and the metal goes.” A flower was not an example of technology “because engineers do not, you don’t do anything with it, you just smell it.” A cellular phone was an example of technology “because people use it to call somebody and text with it and they, if they wanna talk to someone on the speaker they
can just press a button and it says speaker.” An engineer would put the phone together, according to Mike. His incomplete understanding of technology is apparent in his SKT responses; he believed that “lightning” is an example of technology and Q: Simple machines are considered technology because they “are made of metal.”

Mike stated that he would like to be an engineer when he grows up so he can make a chair like the one in his DAET. Mike answered negatively to all “When I grow up…” EIDS items, even though he drew himself as the engineer in his DAET and stated he would like to be an engineer when he grows up.

4.6.3.2 Final Data Collection

Mike recalled learning about chemical engineers in his third grade class, though he actually learned about them during the prior year, but did not recall specific engineering activities he took part in.

Mike drew a single male engineer with “brown skin” as shown in Figure 4.37. The engineer fixed the chair for a client, and “The engineer is an engineer who works on chairs.” According to Mike, “The client is the one who makes the chairs for the company.” This conception of the engineer working for the client, the company that creates the chairs, is in line with his teacher’s slightly incorrect conception that an engineer would make one item for a company that would produce the product. His engineer is “a person who does stuff but doesn’t do it for a living.”
According to Mike, An engineer is someone who “fixes.” He continued to recall only chemical as a type of engineer, “he makes chemical stuff,” stating that his engineer who would fix the chair is also a chemical engineer. Mike seemed to continue hold some conception of engineers as designers at least when “playing the school game” based on
his SKT responses. He chose the correct responses to questions about what engineers do when “design” is part of the response but continued to respond incorrectly when asked what an engineer would do if a city were hit by a flood, choosing “replace roofs on damaged buildings” instead of the correct “create a system to prevent future floods”.

Mike seemed to have an inconsistent view of technology. Mike believed a toothbrush was an example of technology, though may have misspoke because “it does not involve electricity.” He did not believe it would be involved in the work of an engineer. He did not believe that an axle was an example of technology because “it does not involve electricity.” An engineer might use an axle in their work to pull things up. A flower would be an example of technology because “design gives it pressure to grow.” A cellular telephone was an example of technology “because it uses electricity.” On the SKT, Mike recognized “scissors” as technology and responds that Q: Simple machines are considered technology because they “are designed to solve a problem.” He did not believe that assembly lines are technology. Mike did not seem to have a coherent view of what technology is.

Mike had an overall negative attitude toward engineering, in large part based on his belief that engineers work very hard. Mike would like to be a baseball player when he grows up. He would not like to be an engineer when he grows up because “I wouldn’t want to work a lot.” He rated engineering as a one on a scale of one to ten. He thought that engineering would be better if “we could let them have breaks and let them only work on one thing except let them build houses if a person is lonely.” Mike answered negatively for all items on the EIDS regarding what he wants to do when he grows up,
indicating he does not want to be an engineer, work on a team with engineers, solve problems that help people, or design different things.

4.6.4 Year Three: Fourth Grade

In his third year in the study, Mike was taught by a Female teacher who was not interviewed. She first taught engineering during the prior school year and completed all of the required engineering lessons, including What is Engineering?, What is Technology?, and the EiE unit, A Stick in the Mud: Evaluating a Landscape.

4.6.4.1 Initial Data Collection

Mike learned about engineering in school and at home. “My mom talks about it sometimes. She tells about, that engineers are people that help a lot of people.” He learned that “engineers do stuff to make life easier for people and do stuff to make life a lot easier.”

Mike drew a single male engineer as shown in Figure 4.32. Mike drew his engineer as a handyman; “He is fixing a swivel chair for a customer 'cause he said it was broke 'cause he keeps on falling out of it.” Mike focused on fixing as the main role of an engineer. When he heard the word engineer, he thought of “somebody that fixes stuff for people and makes life easier.” Mike did not know “the kind of engineer he is but I could say he’s the kind of engineer who likes to fix stuff.”
DRAW AN ENGINEER TASK

In the space below, draw an engineer doing engineering work.

What is the engineer doing? He has fixed a swivel chair.

Prepared by Brenda Capubianco, Purdue University 9/1/07

Figure 4.32 Mike’s Year Three pre-DAET
Mike recalled only chemical as a type of engineering, believing a chemical engineer “mixes chemical stuff.” His responses on the SKT, choosing correct responses where engineers “design” and “create,” match with a later statement in the interview where he says engineers “design and they improve their test.” These responses seemed to be “playing the school game,” only appearing after Mike is asked to recall the Engineering Design Process in the interview and answer questions on a test given in the classroom. His personal conceptions of an engineer seemed to focus around fixing, as seen by his responses in the interview before he is asked about the Engineering Design Process.

Mike seemed to have a concept of technology as something an engineer would use in their work, connecting engineering and technology but not in the desired way. He stated that “engineering is interesting because they build technology” but did not seem to make that connection consistently. Mike did not believe that a toothbrush was an example of technology “because a toothbrush is not something that an engineer would use for making stuff.” A pulley was technology “because it can be used for helping people lift heavy stuff.” An engineer might use it “like if they can’t lift metal up by themselves they would use the pulley to lift up the metal.” A core soil sample was not technology because “engineers would not build anything with rocks, sand, or soil.” A cellular telephone was an example of technology “because cell phones help you talk to people and they could help you text someone like if you’re lost you could call the police.” Mike recognized “scissors” as an example of technology, something an engineer might use. On the EIDS, he responded that he was not sure whether engineers design everything around us.
Mike would like to be a comedian but not an engineer when he grows up. Mike rated engineering as a five on a scale of one to ten

“because engineering could always make life easier for a bunch of people. Engineering is interesting because they build technology and they design and they improve their test. What’s not so interesting is that, what they do with the technology, they would probably test it on a phone but it’s probably inconvenient to know so would rate it a five because it’s, I’m really not very much interested.”

Engineering would be more interesting if “that they could make floating chairs so that you wouldn’t have to like, walk all the time, because walking makes my legs feel so tired.” Mike answered negatively for all items on the EIDS regarding what he wants to do when he grows up, indicating he does not want to be an engineer, work on a team with engineers, solve problems that help people, or design different things.

4.6.4.2 Final Data Collection

Mike learned about engineering in class. “I learned that they like to always help people and likes to use tools.” He also learned that “there are many different types of engineers out there.” After seeing the pulley, he recalled doing an activity with pulleys but did not connect it as an engineering activity himself. From this activity, he learned about engineers, “they use mathematics to draw conclusions and they use it to try to figure out how much they need to make it.”

Mike drew a single male engineer as shown in Figure 4.33. His engineer is a technician who helps people by “like if they have a broken computer he can take some tools and then fix it back up.” The engineer is fixing a computer to add a voice activated
component for someone “who is having problems with always typing so that’s why he wanted the voice activated.” The text on the drawing says “building” however Mike continuously used the term “fixing” for what his engineer is doing in the interview. He was not sure what type of engineer he has drawn.
Mike focused on fixing and helping as the two major components of engineering.

When he heard the word *engineer* Mike thought of “someone who helps improve other
peoples’ lives.” According to Mike, *An engineer is someone who* “helps other people and does these things to improve life.” When asked how an engineer would help other people, Mike responded, “He builds new things then test it out then give it to customers.” Mike was able to remember mechanical as a type of engineer, “he fixes mechanical things,” but did not recall any others. On the SKT, Mike again chose responses that include “create” and “design” instead of “replace” or “fix,” terms that are more consistent with the ideas of engineering Mike presents during the interview. This may be an example of Mike knowing the “correct” answers and “playing the school game” even though his personal conceptions do not match.

Mike continued to have a fragmented conception of technology. Mike did not believe a toothbrush is an example of technology “because it’s used by the hand and technology is used somewhat kind of used by no hands.” It would have something to do with the work of an engineer “because an engineer would probably make an electric toothbrush to make it go around in circles.” A pulley was an example of technology “because it helps lift things when you can’t lift them by yourself.” An engineer might use them “if they can’t lift a heavy object they use a pulley to.” A soil core sample itself was not technology “but the soil is technology because it helps plants grow.” A cellular telephone (iPhone) was technology “because it helps you figure out math problems if you can’t.” Mike “plays the school game” on his SKT, correctly noting that “scissors” are an example of technology and recognized that *Q:* Making soil more compact before building on it is considered technology because it is “a process designed to solve a problem.” These responses do not seem to connect to the responses he has given during the interview and show a fragmented view of technology, potentially one where he knows
what the correct responses are in the classroom but believes that, in reality, technology means something different.

Mike did not seem to be interested in the work of engineers but recognized and enjoyed using the products of engineering. Mike did not want to be an engineer when he grows up “because I would want to help people but my guess is that it would be a little bit too hard.” He would like to be a comedian “because I like to make people laugh.” He rated engineering a four on a scale from one to ten “because some people would like people who, ’cause I really like to have new improved things.” Engineering was interesting because “it helps like, if you don’t always like to put your phone up to your ear to talk you can just take a Bluetooth and use that.” Engineering was not interesting because “sometimes the work can just break down a little and lose pieces.” Engineering would be more interested if the engineers “like use better glue and better things to glue the things together more and not let them be lost.” Mike answered negatively for all items on the EIDS regarding what he wants to do when he grows up, indicating he does not want to be an engineer, work on a team with engineers, solve problems that help people, or design different things.

4.7 Beth

Beth is a White female. She attended the same school as Mike.

4.7.1 Overall

Beth’s conception of an engineer began as an airplane driver. She realized her conception is not correct and told the interviewer so. She later corrected her assumptions based on the experiences she had, drawing on her class learning about play dough during the EiE unit. She began to think of engineers as designers, working on products through
the Engineering Design Process, after believing engineering design includes artistic design. Her final conception of engineers incorporated the Engineering Design Process, but also included the misconception that engineers would be involved in creating a product in an assembly line as part of the Process. To her, engineers typically worked to help someone else, and often worked in teams.

Table 4.6 Beth’s Conceptions of an Engineer

<table>
<thead>
<tr>
<th>Conception</th>
<th>Gender</th>
<th>Skin Color</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2010 Other Profession</td>
<td>M</td>
<td>None</td>
<td>Flying a plane</td>
</tr>
<tr>
<td>Spring 2011 Other</td>
<td>F, F, F, M, M</td>
<td>None</td>
<td>Self, learning about being an engineer with Play Dough</td>
</tr>
<tr>
<td>Fall 2011 Other Profession</td>
<td>F</td>
<td>Peach</td>
<td>Drawing a picture for a shirt</td>
</tr>
<tr>
<td>Spring 2012 Designer</td>
<td>F</td>
<td>Peach</td>
<td>Testing products</td>
</tr>
<tr>
<td>Fall 2012 Designer</td>
<td>M, M</td>
<td>None</td>
<td>Working on a blueprint</td>
</tr>
<tr>
<td>Spring 2013 Factory/Make Quantity</td>
<td>M, F, F</td>
<td>None</td>
<td>Working on an assembly line</td>
</tr>
</tbody>
</table>

Beth quickly grasped the full definition of technology and the idea that engineers design technology as seen by her responses during the second year of the study. During the summer between the second and third years of the study, she learned what the “real” definition of technology was, describing technology as something that “operates itself.” She re-learned the desired definition during her fourth grade year, again describing technology as anything designed by an engineer to help others.

Beth would like to be an engineer in the first year of the study. In the second year, she would like to be an engineer, but believed that engineering design includes artistic design and would like to design clothing. In her fourth grade year, Beth was not sure if she would like to be an engineer. Throughout the study, she had a positive attitude toward engineering, enjoying the activities she has taken part in and rating engineering highly on the number line.
4.7.2 Year One: Second Grade

Beth was in Mike’s second-grade class, a class taught by a White female who taught engineering in a second grade classroom for the first time.

4.7.2.1 Initial Data Collection

Beth learned a little bit about engineering from her mother and her teacher after she took the initial instruments but did not give any specifics on what she has learned.

Beth drew an airplane, thinking an engineer might fly a plane, as shown in Figure 4.34. “I didn’t know what really an engineer meant so I was thinking it might be like a guy who drives an airplane maybe, but my mom told me what it is so I didn’t really get this page right. It’s kind of a picture of an engineer driving the airplane.”
Figure 4.34 Beth’s Year One pre-DAET
Beth thought of engineers as creative people, based on what she learned in class since she has taken the instruments initially. When she heard the word *engineer*, Beth thought “now that I know what it means, it puts the word creative in my head.” The interviewer followed up by asking, “I see, and what do you mean by ‘creative’?” Beth responded, “Like, making something.” She completed the sentence *An engineer is someone who* “creates things, like maybe a chair or something like that.” She did not know any types of engineers. On the EIDS, Beth was unsure of what engineers do, answering ⊘ to all items but one; she responded ⊘ to “Engineers design everything around us.” She responded in common naïve ways on the SKT, choosing “drive a train engine” as an engineering task and “lightning” as an example of technology.

Beth would like to be “maybe an engineer or a singer.” She would like to be an engineer because “I just kind of like to make things.” Beth was not sure if she would like to design different things or work on a team with engineers, but did not want to be an engineer and does want to solve problems that help people according to her EIDS responses.

4.7.2.2 Final Data Collection

Beth recalled learning about engineers during the first data collection period at the beginning of the school year. She recalled making play dough as an engineering activity and “we did something else but I can’t remember what it was, I forgot what it was!” She also learned about engineers throughout the school year “in class. I thought at first, my last drawing, was, I thought it was an airplane driver. It just sounded familiar to me, ’cause she said, our teacher said nothing about engineers she just said tell us about what you think is
an engineer and I drew an airplane. And then later in the middle of the year she taught us about what an engineer is and then we took a test about, where, like, if I wanted to be an engineer when I grow up and like, what do engineers do, and, like, do engineers use math and reading and that stuff.”

Beth drew her class as the engineers in her drawing, a mix of male and female students including herself and the female teacher as shown in Figure 4.35. The class, including the teacher, is learning about engineering, “they’re all learning about it, they’re in, like a group kind of talking and asking questions to each other.” They are in the Ask stage of the Engineering Design Process, “like, they’re asking questions, they’re in that part of the progress” and working on the play dough EiE project “to figure out what they should do to make the play dough better.” Beth drew on her own personal experience with engineering to draw herself and her classmates as engineers, working on the EiE engineering project they completed during the school year. She was not sure what type of engineer they are and later states, “I don’t really know the name of any type of engineer, but an engineer that would design a house?” She also recalled a type of engineer as “an engineer that might [pause] might design a new car?”
Figure 4.35 Beth’s Year One post-DAET
Beth had a very experience-based understanding of engineering with an additional understanding of engineering as design. When she heard the word *engineer* “it reminds me of the time in first grade when engineers came, no this was the second grade, and they took us and we went and we, it kind of reminds me of what we’re doing now. Like, they asked me these questions.” She believed *An engineer is someone who* “helps people and designs new things.” The interviewer probed her answer further, asking “And what kind of things might an engineer design?” Beth responded, “Maybe if a house got destroyed they would design a new, better house, maybe.” The interviewer probed again, “And what does design mean?” Beth explained, “As in like make different objects and like, where to put them in the house.” On the SKT, her correct responses show an understanding of engineering as design and technology as things that are man-made.

Beth would like to be an engineer when she grows up, “Designing, just the word, sounds kinda fun. It just kinda sounds really fun.” She did not have any other careers she would like to be when she grows up. She was ambivalent about engineering on the EIDS, responding 😞 to the item asking if she’d like to be an engineer when she grows up.

4.7.3 Year Two: Third Grade

In her second year of the program, Beth was taught by a White female who taught engineering for the first time during this year. She also was involved in the third grade Engineering Day where each classroom was set up for different aspects of the EiE unit and all students in the grade rotated through each classroom. She taught some of the simple machines to the students.

Her overall student attitudes, engagement, and learning went “pretty well” and she felt that “engineering is a good way to reinforce a few subjects, obviously with the
engineering, the science and the math just comes natural, that you can throw that in.” She believed that engineering is time-consuming, but did help to integrate subjects and prepare students to meet state curriculum standards.

4.7.3.1 Initial Data Collection

Beth recalled learning about engineering through making play dough in her class the prior school year.

Beth drew a single female engineer as shown in Figure 4.36. She drew an engineer that is an Other Profession, an artistic designer. “She’s drawing a picture, like a design for a shirt.” The interviewer asked Beth to clarify what her engineer is doing, “You said that your engineer is designing a shirt, can you tell me what designing means?” Beth responded, “Like, kind of drawing.” Beth’s engineer is working for others “so people can have shirts that look good.” The engineer is a “designer” according to Beth when asked what type of engineer she has drawn; her SKT responses also support her conception of engineering as design.
Beth seemed to have a strong definition of engineering is design but a broad conception of design that includes artistic design. She also believed that engineers help
people. When she heard the word *engineer*, Beth thought “Somebody, a bunch of people working together to make something that will help people.” *An engineer is someone who* “designs stuff to help people.” When asked what types of engineer she knows, she responded, “An aircraft designer?” This type of engineer would “design planes and stuff.”

Beth had a complex conception of technology, incorporating all aspects of the definition of technology as she answers the interview questions about technology. She responded correctly to each example and to the questions about technology on the SKT. She also understood that engineers design technology, noting that an engineer would design the toothbrush and stating that an engineer would design but not build the pulley. Beth believed a toothbrush is an example of technology “because it helps clean your teeth.” It would have something to do with the work of an engineer, “Yes, they design it.” A pulley was an example of technology, “because it helps you, like if you needed to, like, pull something up.” An engineer would work with pulleys, “They wouldn’t build it but they would design like how it works and stuff.” A flower was not an example of technology because “it’s not man-made, it’s natural.” A cellular telephone was an example of technology “because you can call people if you needed to in an emergency or something.” An engineer would work with a cellular telephone; “they design like the buttons.”

Beth stated she would like to be an engineer “because I’d like to help people.” On the EIDS, Beth was not sure what she would like to do when she grows up, answering “Not Sure” (2) to all “When I grow up…” items.
4.7.3.2 Final Data Collection

Beth recalled learning about engineers during this school year and the prior one, “in second grade.” She recalled learning about “simple machines” when she sees the pulley, “We learned about how it helps us.” She enjoyed the engineering activity because “it was fun to create something that could help other people.”

Beth drew a single female engineer as shown in Figure 4.37. “She is making a new product to help clean tables, stovetops, windows and mirrors.” Beth described her engineer going through the Engineering Design Process, “She’s going to create it and then most likely she’s going to mess up the first time, the first couple of times, and try again and keep improving it.”
What is the engineer doing?

The engineer is making a new product to help clean messes of tables, stove tops, windows and mirrors. She is mixing different ingredients to make the product. She must try again and again until it works back from testing perfectly.
Beth combined her conception of engineers with the idea that engineers create technology, and technology is something that improves the quality of life. Beth thought, “making, making things easier” when she hears the word engineer. An engineer is someone who “makes things easier, makes life easier for people.” Her responses on the SKT and examples of technology in the interview displayed an understanding of engineering as design. She knew “there’s like, a lot of different types of engineering.”

*Interviewer:* Could you think of any?

*Beth:* I don’t really know the names of them, but I know what they do.

*Interviewer:* Can you tell me what some of them do?

*Beth:* They make a liquid, like my engineer is doing, making a liquid product.

*Interviewer:* Is there anything else you can think that other engineers do?

*Beth:* They fix things, maybe.

Beth retained her complete, complex understanding of engineering and design. Beth believed a toothbrush is an example of technology “because it helps you clean your teeth” and an engineer would use it in their work “because they create it.” A pulley was “because it can lift up something to get it to another place” and an engineer would “create it.” A flower was not technology because “it can’t help people” and would not be involved in the work of an engineer “because it’s natural, it grows.” A cellular telephone would be an example of technology “because you can use it for a GPS…The only thing it has to do with an engineer is really that they create it.”

Beth had a positive attitude toward engineering, enjoying the engineering activities she has taken part in at school and states an interest in engineering as a career. When asked what she would like to be when she grows up, Beth responds, “I want to be a
engineer that designs things, like clothes and things” because “it’s fun to help other people.” Her statements in the interview do not quite align with her EIDS responses; when she grows up, Beth would like to be an engineer, design different things, and work on a team with engineers, but she did not want to solve problems that help people. She rated engineering a nine on a scale of one to ten, with ten being science, something she loves, and one being math, something she hates, “because it’s part of science and I think it’s fun.” She enjoyed engineering because “you design it and then you have to recreate it again.” She could not think of anything that she doesn’t find interesting about engineering, “I think it’s all pretty great!”

4.7.4 Year Three: Fourth Grade

Beth was in Mike’s fourth grade class, a class taught by a White female who was teaching engineering in a fourth grade classroom for the second time.

4.7.4.1 Initial Data Collection

Beth learned about engineers throughout her elementary experience. “I’ve learned about them in every grade, we kind of learn more every year about ‘em.” She recalls the play dough activity from her second grade class. She has learned “that they build most of everything around us.” In school, Beth likes to “learn about the engineering process and I really like learning about it ’cause it’s fun to go and create all the stuff and see if it works and then if it doesn’t work, you know, we make another version of it and see if it works.”

Beth drew two male engineers, “two people that are sharing their ideas on a blueprint,” as shown in Figure 4.38. They are “sharing ideas on a blueprint so they could go over them and maybe add their ideas together and make something or use the better
idea.” They are planning for “a new and safer aircraft.” She was not sure what type of engineer she has drawn.

Figure 4.38 Beth’s Year Three pre-DAET
Beth seemed to have a fairly complex understanding of engineers and engineering, focusing on creating and building. She recalled other types of engineers beyond what she has drawn, “types that create gases, maybe, there’s types that create aircraft and they create different things. Some of them test the stuff, some of them can do, some of them just do, they create other things, they test it and see what happens, they don’t, they create it and just see what happens and if it’s good they make a lot of it.”

“Building and creating” came to Beth’s mind when she heard the word engineer. According to her, An engineer is someone who “goes through the engineering process and creates and builds stuff for better, to make people’s lives better.”

Beth seemed to have learned the common misconception that technology is electronic, or at least, is something that “operates itself.” She initially believed that toothbrush is an example of technology “because it can help you in life, it’s not literally technology but [pause] it’s not, [pause] no it’s not technology but it’s designed to help you.” An engineer would work with a toothbrush because “it’s something that they can build and almost everybody uses it.” She knew the school definition, “it’s designed to help you,” and chose scissors as an example of technology on the SKT, but also knew that a toothbrush is not “literally technology.” She first agreed that a toothbrush is an example of technology, but took her statement back because she knew it was not really technology. She was still aware that an engineer would create a toothbrush, but changed her definition of what technology really is. A pulley was not an example of technology, “it can be used, it’s used for not every day, but it is used by many people to build.” Engineers use pulleys “quite often for building… maybe to, if there needs to be something up high, somebody could be on a ladder and you could pull the string up there.
so they could reach it.” A flower was not technology because “it’s part of nature and it’s, it’s not created by people.” A cellular telephone was an example of technology because “it’s man-made but it’s also, it’s just technology because it has, like, for instance, it’s, a toothbrush isn’t technology because it doesn’t do anything, you operate it yourself, but a phone operates itself, kind of.”

Beth had a positive attitude toward engineering and enjoyed the engineering activities she has taken part in. She might like to be an engineer when she grows up, “maybe. I think it would be kinda fun to design stuff.” In her EIDS responses, Beth would not like to be an engineer, work on a team with engineers, or design things to help people, but she might like to design different things. On a scale of one to ten, Beth rated engineering a nine “I think it’s really fun to go through the engineering process and actually get to create your own little thing and just, see, test it like, see what happens if you were to freeze it, does it melt again or does it stay cold.” She found engineering interesting because “it’s fun 'cause you never know what’s going to happen when you’re purring two things together you never really know what’s going to happen.” She did not like engineering sometimes because “Sometimes the things don’t work that you think are or something else happens that’s really not supposed to happen.” She would enjoy engineering more if “at school if we could maybe create our own thing and then put our ideas together to try to make something like, of all of our ideas combined.”

4.7.4.2 Final Data Collection

Beth recalled learning about engineering “in school.” She learned “that they help makes peoples’ lives easier and a few types of like, kinds of engineers.” To learn more, the interviewer asked, “What types, what kinds of engineers?” Beth responded, “I don’t
think we learned the actual names, just like what some of them do, some of them work on technology, some of them work on making new gases, like fumes or something, and like, stuff to prevents stuff from happening, bad stuff from happening.” After seeing the core soil sample, Beth recalled using science to “study the layers of the earth and how sturdy were and like, we built like a little building, structure thing and put it in there and kind of shook it and see what happened to it.” Beth learned “how engineers could maybe build better structures to keep it from falling down.”

Beth drew three engineers, two girls, one boy, as shown in Figure 4.39. Her engineers are “three people working on an assembly line and they’re creating a new phone that you can use your voice to connect, pretty much, anything on your phone. It’s called the V-Phone.” The interviewer asked her to define what her engineers are doing further, “What do you mean by ‘creating’?” Beth was not really sure, but responded, “They are making something.” In her written response, she noted that the engineers “are in the 3rd step of the process, the creating step.” She was not sure what type of engineer she has drawn, “I guess they work on technology, I don’t really know what it’s called.”
Beth described a complex but incomplete understanding of engineers and engineering, with engineers who create things to make life easier. She did not
differentiate creating, making the item, from creating the design for the product an engineer might work on. Her drawing described engineers that are involved in the Engineering Design Process, but these engineers were portrayed as making phones in a factory assembly line. When Beth heard the word engineer, she thought “like, the words, like, helping people, creating something new to help people live their lives easier.” An engineer would help someone “by making their lives easier, by creating something that’s easier than what it was before.” An engineer is someone who “creates something to help somebody’s life easier, to make somebody’s life easier.”

Beth had a complete understanding of technology and understood that engineers design technology. Beth believed a toothbrush is an example of technology “because it help you clean your teeth.” An engineer would work with a toothbrush “because they created it to make life easier to keep your teeth clean.” A flower was not an example of technology “it naturally grows, nobody like, invented the flower.” An engineer would not work on a flower “because they didn’t create it.” A core soil sample would “not really” be an example of technology “it might be because like, engineers, like, some types of engineers might create, like for instance the fertilizer, that wasn’t there, somebody had to create that.” A cellular telephone was an example of technology “because an engineer created it to make someone’s life easier.” An engineer might work on one “by creating it and making it better, making it a better phone than others.” On the SKT, Beth showed an understanding of technology, choosing “scissors” as an example of technology and responding that technology is “a process designed to solve a problem.”

Beth was unsure what she’d like to do when she grows up, answering “Not Sure” (2) to all “When I grow up…” items on the EIDS. She told the interviewer “I don’t know
yet!” when asked if she’d like to be an engineer when she grows up. She would like to be a photographer. On a scale of one to ten, she rated engineering at an eight “‘cause it’s pretty fun creating stuff and seeing if it works and if it fails then it’s fun to think of other things you can do to make it better.” She found engineering interesting because “you know that it’s like, going to help somebody or you’re just creating it and it’s fun to create stuff and see if it works or not.” She did not enjoy engineering when “maybe failing a few times and you get kind of irritated.” Engineering could be made more enjoyable by “maybe getting to do it a lot more often.”

4.8 Elena

Elena is a Hispanic female. She attended the same school as Mike and Beth.

4.8.1 Overall

Elena fixated on the “create” aspect of the Engineering Design Process in her conceptions of engineers as shown in Table 4.7. The engineers in her drawings were always working on a physical object, often fixing something. Elena’s engineers were working to help others, whether it is a single client or her neighborhood. Her concept of the engineer’s client became broader over time, starting with the family of the engineer and ending with the community and “the elderly.” In contrast to her representation of engineers and open-ended thoughts on engineers and engineering, by her final year Elena learned how to answer the question on the SKT correctly, playing “the school game” and responding that engineers design and create rather than fix or build.
Table 4.7 Elena’s Conceptions of an Engineer

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<th>Conception</th>
<th>Gender</th>
<th>Skin Color</th>
<th>Notes</th>
</tr>
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<tbody>
<tr>
<td>Fall 2010</td>
<td>Mechanic</td>
<td>M</td>
<td>None</td>
<td>Also female washing car</td>
</tr>
<tr>
<td>Spring 2011</td>
<td>Mechanic</td>
<td>F</td>
<td>None</td>
<td>Self</td>
</tr>
<tr>
<td>Fall 2011</td>
<td>Mechanic</td>
<td>M, F, F</td>
<td>None</td>
<td>Male is main engineer</td>
</tr>
<tr>
<td>Spring 2012</td>
<td>Design/Make</td>
<td>F</td>
<td>None</td>
<td>Self, making a table and chairs</td>
</tr>
<tr>
<td>Fall 2012</td>
<td>Tradesperson</td>
<td>F</td>
<td>None</td>
<td>Self, fixing lamp</td>
</tr>
<tr>
<td>Spring 2013</td>
<td>Mechanic</td>
<td>F</td>
<td>Lt. Brown</td>
<td>Fixing a car to help the elderly</td>
</tr>
</tbody>
</table>

Elena never considered the toothbrush to be technology and did not fully grasp the desired definition of technology. She learned how to respond on the SKT by the middle of her third year, correctly answering the questions on technology while still describing technology as something that requires power or is used by engineers. In her final interview, she recognized that anything man-made is technology, but was not sure why; she just knows that it is. She stated that engineers design all man-made items, recognizing that an engineer would design a toothbrush, even though she did not believe the toothbrush was an example of technology. Elena seemed to understand that man-made objects (technology) are designed by engineers, but did not consider what engineers do to be design or all man-made objects to be technology. She developed a fragmented, one-way understanding of the overarching concept, engineers design technology.

Elena enjoyed the classroom-based engineering activities, recalling the EiE unit, *Marvelous Machines: Making Work Easier*, as an engineering activity through the end of the following school year, her final interview. She was somewhat ambivalent about engineering as a career and seemed as though she did not want to tell the interviewer that she does not want to be an engineer. She typically did not respond directly to the question “Do you want to be an engineer when you grow up?” Instead, she talked about what she
does want to be, though she responded negatively to that question when answering the EIDS. She enjoyed engineering, recognized that engineers help people, and stated that she wants to help people but does not want to be an engineer herself until the final interview when she told the interviewer that she would like to be an engineer.

4.8.2 Year One: Second Grade

In her first year in the study, Elena was taught by a White female who had not taught engineering before. In addition to the required lessons, What is Engineering?, What is Technology?, and the EiE unit, A Work in Process: Improving a Play Dough Process, students completed the Model Eliciting Activity: Stickers.

She felt student engagements, attitudes, and learning were high, “They enjoyed it and they learned from it.” She believed engineering was a good way to introduce concepts from other subjects and that engineering examples are useful for teaching other subject matter, though she did not see that engineering is related to standards students are required to learn, “Engineering is not really part of, like when you look at the scope and sequence for science, it doesn’t specifically address engineering, although the concepts from engineering are helpful in their learning for what they [standards-creators] want, what we’re supposed to be teaching them.”

4.8.2.1 Initial Data Collection

Elena learned about engineers “last week, I think, in the first week.” She drew one male engineer and a female washing the car as shown in Figure 4.40. She drew a mechanic, “well I thought that engineering was just fixing cars and those kind of stuffs and if someone had a broken car they would fix it.” She was not sure what type of engineer she has drawn, “I forget!”
Figure 4.40 Elena’s Year One pre-DAET
Elena had an inconsistent conception of engineers and engineering. She considered engineers to be doctors, mechanics, and laborers, based on her different responses. On the SKT, she responded that engineers would “build a house for a family,” “replace roofs on damaged buildings,” or “change the oil in cars.” but does not choose “fix a car for a customer,” contrasting with her interview responses. She stated “engineerings [sic], they do a lot of things, a lot of type of things, like they take care of peoples and like, they use, for this people they use like hammers and screws and like, stuff to clean the windows and things and like the doctors use shots and they take care of their blood and that. That’s all.” Elena was not sure what engineers do, responding ☐ (Not Sure) to most of the items on the EIDS relating to engineering work, though she was sure that there is more than one type of engineer, they design everything around and us, and they use mathematics, as shown by a response of ☐, and she was sure that they are not creative, responding ☐ to that item. When Elena heard the word engineer, she thought, “people fixing cars.” “An engineer is someone who [pause] take cares of things and stuff.”

Elena was not sure what she wants to be when she grows up, but she was sure she does not want to be an engineer, “Like if I was one of the engineers that take care of people I’m just afraid that I would do something wrong.” According to her EIDS responses, Elena did not want to be an engineer, design different things, or work on a team with engineers, but she might want to solve problems that help people.

4.8.2.2 Final Data Collection

Elena learned about engineering at home and school, “I learned it like I asked questions to my dad and he answers it and I learned more, a lot more, at school.” She
thought her father may be a type of engineer, “I think he’s a type of engineer 'cause he kind of builds things and does stuff for my brother and he fixes stuff, he opens doors for other people.” She recalled the activities from the EiE unit as engineering activities, both the science lesson with food coloring and liquids and the play dough design project. Elena enjoyed making the play dough but did not enjoy working in her team during the activity, “I didn’t really get what they’re talking about so I had to think more by myself.”

Elena drew a single female with a car as shown in Figure 4.41. “I’m drawing a girl and she’s by herself and she’s trying to put the wiper on the car so it can work whenever there’s rain and like, wash it and put some more seats in the back and the front, and that’s it.” She envisioned herself as a potential engineer in her drawing, “Well, I’m not sure when I grow up I’m gonna be an engineer so that’s me trying to, that’s me that I might be doing that.” The engineer was “doing it for her family and for her.” In addition to fixing up the car, “She like, makes, she makes like chairs and she, she makes different clothes, and, like, shoes.” In the other work that her engineer does, “She use like, knitting, like needles, when she does clothes, and she use like, screws to put in the cars and tires, she use baby wipes to maybe wash the car and, yeah, that’s all.” Her engineer was “a car engineer.”
Figure 4.41 Elena’s Year One post-DAET
Elena did not have a solidified conception of what an engineer might do. Her engineer was a knitter and works on cars. She described engineers as people who fix things, mechanics, and craftspeople. She was not sure if engineers work in teams or design everything around us, based on (Not Sure) responses to these items on the EIDS, and she was not sure what types of engineers exist beyond her “car engineer” or one that “builds streets” or “builds schools.” When she heard the word engineer “a car comes into my mind and I imagine lots of people trying to make a car and they’re in a hurry for something.” According to Elena, An engineer is someone “who fixes something.” The interviewer asked, “And what do you think they fix?” Elena responded, “Lots of things, buildings, cars, shelves, they like, imagine things what they want. To help people.” The interviewer probed deeper, “So what does fix mean?” Elena explained, “It means to put together things so it’s not going to be broken.” While she shared an image of an engineer who fixes cars during the interview, she chose “design a quiet vacuum cleaner” instead of “fix a car for a customer” on the SKT as an example of a task an engineer would perform, and also chose “replace roofs on damaged buildings” and “change the oil in cars.” She did not seem to have a consistent conception of engineers and engineering. Elena shared that she did not quite understand all of what was going on during her in-class engineering activity, but she still learned more about what engineers do.

Elena: I thought they only build cars, but then my teacher told me that they build almost everything.

Interviewer: And what is ‘almost everything,’ do you have any examples?

Elena: Like a shelf or like, they make books and streets and houses.
Interviewer: If they make a shelf what do you think they would do?

Elena: They would like, they might have to think it out and give it to other people to help them if they have stuff everywhere, they can put it on shelves.

Elena did not seem to understand what technology is, having chosen “lightning” as an example of technology on the SKT. In response to “Play dough is considered technology because” she further showed her misunderstanding of technology by choosing “it is made of more than one ingredient.”

Elena was not sure if she’d like to be an engineer or work on teams with engineers, choosing ☹ (Not Sure) to these items on the EIDS, but she would like to design different things and solve problems that help people. Elena did not directly answer the interviewer when asked whether she would like to be an engineer when she grows up. Instead, she said, “Well, I also want to be a teacher too.” She would like to “because I like children and I like reading books and like, and it’s just fun.” The interviewer returned to her initial evasion, asking “And why would you want to be an engineer?” Elena responded, “Because engineers, I think they get paid a lot for making things that people need a lot, and they make good things and I want to make good things too to help my family and to raise money for them and the churches.”

4.8.3 Year Two: Third Grade

Elena was taught by a White female during the second year of the study. This was her first time teaching engineering. She taught the required lessons, What is Engineering?, What is Technology?, and the EiE unit, Marvelous Machines: Making Work Easier, but did not implement any additional activities. She did not describe
involvement with the other third-grade teachers in teaching the simple machines to the entire grade, but she was noted by other teachers as participating.

She felt that her students were not engaged, but they had okay attitudes toward engineering, “They enjoy the engineering but when it came to reading the book, they weren’t very interested in that.” They did not have high levels of student learning, “I don’t know if they have a full grasp on the whole engineered design plan and following all the steps.” She believed “Engineering is a good way to reinforce a few subjects the students are learning. It helped reinforce math and of course science all throughout the year. We didn’t do much of it in reading or social studies.” She felt that engineering was time-consuming and was not better than their typical curriculum for teaching students material required by state standards.

4.8.3.1 Initial Data Collection

Elena learned about engineers in “first grade, first or second grade.” She recalled taking part in the data collection and interviews the prior year and “in first grade my teacher would like, tell us everything about ‘em.” She did not describe specific engineering activities she worked on in class. She recalled learning about what technology is with a cousin, “like I did it with my cousin, and she’ll say ‘is it technology or not?’ and I’ll guess what it is.” She recalled using the Engineering Design Process when she designed a drawing of a flower with chalk, considering the artistic design a part of engineering design.

Elena drew two girls and a boy, the engineer, working on a car as shown in Figure 4.42. She described her drawing “Like the boy’s trying to paint the car blue and he’s the one that fixed the, under the car.” When asked to point to the engineer in her drawing,
Elena said “the boy,” but when asked if the girls were also engineers, she agreed that they were, “They’re working all together and they’re helping each other.” Her engineers were mechanics, “They don’t make the cars, they just fix it up for the person.” She was not sure what type of engineer they are. “I don’t know the word, but she’s a person who fix cars, they’re all people who fix cars.”
Elena’s view of engineers centered around fixing things, whether as a mechanic, fixing cars, a general handyman, fixing things around the house, or as a technician, fixing phones. When she heard the word *engineer*, Elena thought of “my dad because he kind of
fixes things sometimes and he’ll fix the attic when something’s broken, he’ll fix our car when it’s broken, he’ll fix my toys, he’ll fix my brother’s toys, and the TVs, and that’s what I think of.” According to her, An engineer is someone “who fixes things.” When asked if she can name different types of engineers, she seemed to have an even broader definition, answering “there’s an engineer that can take care of pets” and “an engineer that fixes chairs.” On the SKT, Elena’s conception of what engineers do seemed to broaden further, choosing “drive a train engine,” “replace roofs on damaged buildings,” and “design the recipe for a really strong cleaning solution.” as examples of what an engineer might do.

Elena seemed to hold a fragmented and inconsistent conception of technology. According to Elena, a toothbrush was not an example of technology. She explains, “I think technology means it uses power and this one doesn’t use power.” She seemed to believe that an engineer might design a toothbrush, “an engineer would connect everything together, he can make the words easily, he can make the toothbrush make your hands feel good.” Elena may have understood that engineers design things used in daily life. She believed that a living flower is an example of technology “because flowers like, use sun and like, air and everything so I think, so it uses some of the things that other things need.”

Her misconception may have been that technology requires inputs, whether power or sunlight, though she also believed that a pulley is technology because “engineers use this for things so it’s technology.” On the SKT, Elena chose “lightning” as an example of technology and when asked “Simple machines are considered technology because they” she chose “use electricity.” Engineers may use pulleys when they build houses, she
explained. A cellular telephone was an example of technology “because it uses batteries and it takes energy and it needs energy for it to work.” An engineer would work with a phone in the role of a technician. “He would work on it because people need phones and engineers fix things so he’s gonna fix the phone for somebody like the energy broke down so he’ll fix it up and put the new batteries in and make it work.”

Elena was not sure if she’d like to be an engineer or work on a team with engineers according to her EIDS responses. During the interview, Elena was asked if she’d like to be an engineer when she grows up and responded, “I’m really not sure because I want to be a vet, I wanna be a teacher, and it’s hard to decide.”

4.8.3.2 Final Data Collection

Elena stated she learned about engineering from her teacher, “I learned it in kindergarten 'cause that’s where I first like, heard the word and that’s how I started like, learning about it and knowing about it.” She first learned about engineering in school in second grade, but seemed to recall learning about it much earlier. Elena also learned about engineering outside of school, “Well at my dad’s work he’s kind of an engineer 'cause he works for other people and if something breaks he’ll come in and start fixing it.” She recalled using the pulley in an engineering activity during the past school year, “Well we had to make this process where you had to get this soda can of rocks all the way to the table and you had to use pulleys and levers and inclined planes and double pulleys and we used like, two of those to help it get up on the table.” She enjoyed the activity, “I liked how we had to work in teams and how we had to use math and science and how we had to work together and think about it.” Through this activity, she learned “that we have to work hard and stuff, and we can’t just give up.”
Elena drew herself as the engineer as shown in Figure 4.43. Elena described her drawing further, “She’s building a table, like it’s a horseshoe table with some chairs and, around it for school.” The interviewer asked for further explanation, “What does ‘building’ mean?” Elena defined what she thinks of building, “It means to work on something and you make it to something different or to help other people.” The interviewer asked Elena to further clarify, “So she helps people? So can you tell me a bit more about why she helps people, or how she helps people?” Elena explained, “She helps them by like, if they’re getting tired of picking up something from the ground, she’ll make a system that will help the people.”
DRAW AN ENGINEER TASK

In the space below, draw an engineer doing engineering work.

What is the engineer doing? She is building a horseshoe table with some chairs.

Prepared by Brenda Capobianco, Purdue University 8/1/67

Figure 4.43 Elena’s Year Two post-DAET
Elena understood that engineers create things to help others, but believed an engineer would make the items themselves rather than understanding that engineers would design the product. This was consistent with her EIDS response; Elena did not agree with the statement “Engineers design everything around us.” On the SKT, she correctly responded that an engineer would “design a quieter vacuum cleaner” but also chose “build new cars.” as an example of what an engineer might do. When she heard the word *engineer*, “I think about like, the engineer step process and like, how they work, like in teams or individuals, and I think about what they do to help other people.” *An engineer is someone* “who helps other people.” Elena could not name any specific types of engineers, but described “maybe like, a person who builds like, towers maybe.”

Elena seemed to have an understanding of technology based on the common misconception of needing electricity and a belief that something is technology if engineers would use it. She gave the desired responses, answering all of the technology questions correctly on the SKT, but did not provide similar responses during the interview. Elena did not believe a toothbrush would be an example of technology “because it doesn’t really, like, use any power or those kind of thing, you need to use your hands and stuff to make it work.” An engineer might use it to clean things, but would not work on a toothbrush in their work. A pulley was an example of technology “it’s like an object that helps engineers and then engineers help them.” A flower was not an example of technology “because I don’t think engineers need to use flowers during their working, but [pause] I’m not sure if it does use technology ’cause our teacher taught us if it’s technology or not but I was absent that day.” A cellular telephone was an
example of technology “because it uses electricity and it helps people.” An engineer might use a phone to look up things online or use it as a flashlight during their work.

Elena had an overall positive attitude towards the engineering activities and even drew herself as the engineer in her DAET, but she did not want to be an engineer when she grows up. Elena avoided the question in the interview, responding “I don’t know because I want to be lots of things when I grow up.” Even though she drew herself as the engineer, on the EIDS she responded that she would not like to be an engineer or work on a team with engineers when she grows up. On a scale of one to ten, Elena rated her interest in engineering an eight or a nine “cause I’m not really sure if I’m gonna be an engineer and I really like engineers so I wouldn’t pick around like, six or five, or like, three, two, or one.” She found engineering interesting because “Engineering like, you build something and you really get lots of money.” What she did not like about engineering is “Well, you have to build the things and it takes lots of time.” She was not sure what would make engineering more interesting.

4.8.4  Year Three: Fourth Grade

Elena was in the same fourth grade class as both Mike and Beth, a class taught by a White female who was teaching engineering in a fourth grade classroom for the second time.

4.8.4.1  Initial Data Collection

Elena “learned about engineering when I was in kindergarten ’cause that was the first time I heard the word and pretty sure I may have asked my teacher what it meant and she told me.” She started learning about engineering in second grade but thought it was earlier. She also talked about engineering at home “sometimes with my dad.” From him,
she learned that engineers “usually fix things for people and to help everybody.” She also recalled using the Engineering Design Process to complete a project with pulleys and other simple machines, “I learned you always have to use the engineer design process before you just make it.”

Elena drew herself as the engineer as shown in Figure 4.44. She is “trying to fix a lamp for a customer, well it’s not for a customer, it’s for her community so they could have like, lights on the street.” Her engineer would do “anything that a customer would need me to do or the community.”
Figure 4.44 Elena’s Year Three pre-DAET
Elena’s conception of engineers was generally someone who fixes things and helps people. She understood that engineers design when talking about technology and engineering design, correctly choosing responses related to design on the SKT, but when asked about engineers and what they do, Elena thought of fixing things and helping people. When she heard the word *engineer*, Elena thought, “helping other people.” She believed *An engineer is* “somebody who [pause] I think works with technology.” Elena could not think of any types of engineer. “I really don’t know,” she says, though with further probing she responded “the only type of engineer I know is the one who fix things for people.”

Elena held the common misconception that technology is something that requires electricity, but understood that engineers design man-made items. She knew what responses she should give on the SKT, choosing “scissors” as an example of technology and noting that compacting soil is considered technology because it is “a process designed to solve a problem.” According to Elena, a toothbrush was not an example of technology because “technology’s really supposed to be like, electronics sometimes and like, different things that not really made out of plastic” however an engineer would work with a toothbrush “cause almost everything in this world is made with engineers 'cause they made it and nobody else could have made it without them.” She described the Engineering Design Process as how an engineer would create a toothbrush. A pulley was technology “cause I remember from last year there’s pulleys and like those all, other ones, and I think that’s something technology 'cause they’re having to do lots of things with it and it’s supposed to work.” An engineer would work on a pulley “cause they would need to find metal, and like what I said, sketch and do the engineer process, they
need to find the right gold or silver they’re supposed to use and the right shape around it unless it won’t work.” A core soil sample was not technology because engineers don’t make it. A cellular telephone was an example of technology “because engineers had to, if they made it, they had to use technology ‘cause it’s electronical and test it out a lot to make sure the buttons will work and design new ones of them.”

Elena enjoyed the engineering experiences she had and had a positive attitude toward engineering but felt it is a lot of work. On a scale of one to ten, she rated engineering a nine, “I like engineering a lot.” She found it interesting because “helping people, like we’re just making the world much better for everybody.” When asked what she doesn’t find interesting about engineering, she responded, “Well you always have to do the design process every time you make something and have to do it a couple tomes for one project and I think it will get like, sometimes you’ll get annoyed or frustrated.” Engineering would be more interesting “if an engineer did it they would make, I don’t know, make something that helps the other engineers do their work, like it helps them engineer process, maybe a screen that shows, and you just type the object in and the tools you need instead of writing it down on paper, keeping it in your pocket or a board.” Elena might want to be an engineer when she grows up, but she was not sure yet. “It’s hard because I don’t want to be an engineer fully, ’cause I want to help people but I want to be a doctor or a teacher or a veterinarian.” Even though she drew herself as the engineer, on the EIDS she responded that she would not like to be an engineer or work on a team with engineers when she grows up.
4.8.4.2 Final Data Collection

Elena “learned about engineers, like, in kindergarten.” She described being involved in this series of interviews starting in kindergarten as her first engineering experience, though she did not take part in learning about engineering or this study until she was in second grade. She also learned about engineering “in books,” she has learned “one of the books said how engineers were working in teams together and how they make stuff to create something.” Elena recalled the EiE unit, *Marvelous Machines: Making Work Easier*, using the pulley in an engineering design project during her third grade year. She “like how we all had to work together to find how to move the potato sack.”

Elena drew a single female engineer as shown in Figure 4.45. Her engineer was a mechanic, “fixing a car, like she’s fixing the engine of it to like, help the older people.” She did not provide a specific type of engineer for the engineer in her drawing, describing her as “she’s one who makes things. Helps and makes.”
What is the engineer doing?

This engineer is trying to make a car for the elderly. But also fixing cars. She has her own desk with tools, lights, paints, and screws.

Prepared by Branda Capobionto, Purdue University 8/1/07

Figure 4.45 Elena’s Year Three post-DAET
Elena thought of engineers as people who help others and fix things. She did not hold the idea of engineers as designers as strongly as she did in the fall, choosing “design a quiet vacuum cleaner” and “replace roofs on damaged buildings” as things an engineer might do; she also did not talk about how engineers might design the various examples of technology discussed during the interview. When she heard the word engineer she envisions “someone helping people and someone making things too,” and An engineer is someone who “helps people.” Elena could not think of specific types of engineers but described “one that fixes things.” While she saw engineers as working for others, she may not have perceived engineers as working with others. She believed an engineer would not “talk with others about what they need and want.” according to her SKT response. She also would not like to work in a team with engineers, based on her EIDS response.

Elena seemed to understand that anything man-made is technology, but was not sure why. She believed that a toothbrush was technology because “I don’t know, I just think it is.” An engineer might make a toothbrush powered, “I think the engineer made it to where you can push a button and it moves for you.” A pulley was technology “because if you put something on it, it makes the wheel spin.” An engineer might use it, “I think it uses like to fix a car, it pull something like a rope around it.” A core soil sample was not technology, and an engineer would use one “to practice like on their, to see if they can, like a pot, to see if the pot can hold the soil.” A cellular telephone was an example of technology, and an engineer might use it “they can use the camera to go in and see closer on it, they can go on the internet and look up things about it.”
Elena seemed to have decided that she enjoys engineering and may want to be an engineer when she grows up. She told the interviewer she would like to be an engineer when she grows up, “cause it helps people and people will, like, always remember you” though she was not sure if she would like to be an engineer according to her EIDS response. She rated engineering as an eight on a scale of one to ten, “because like, I like it but I also want to do other things when I grow up, I want to be an engineer though.” She found engineering interesting because “I liked how people work together to create something really good for other people. I like how they make good things to help us.” She could not think of anything she did not like, though it would be more interesting “if you get to make crazy inventions and then, like, I really don’t know.”
CHAPTER 5. CROSS-CASE ANALYSIS

5.1 Introduction

This study intended to answer the following question: “How do elementary students’ knowledge of, attitudes toward, and overall conceptions of engineering evolve over three years of engineering instruction?” To address this question, the seven student cases presented in CHAPTER 4 are compared here using a cross-case analysis. Student conceptions of engineering as expressed in the DAET, described in the interview, and triangulated from the SKT and EIDS is the first theme explored. As a result of the engineering intervention, students were expected to learn that engineers design technology. For a student to have a complete or comprehensive understanding of engineering based on this definition, they must have understood what was meant by design, technological design generally operationalized by the Engineering Design Process, and technology. Students’ knowledge of engineering as design is explored in the first section entitled Students’ Conceptions of Engineers, while their knowledge of technology and the connection between engineering and technology is explored in two additional sections, entitled Students’ Understanding of Technology and Knowledge that Engineers Design Technology. The section entitled Student Attitudes toward Engineering describes students’ interest in engineering as a career and attitudes toward engineering activities and experiences. Engineering experiences that
students discussed in the interview are noted as Experiences with Impact. Lastly, findings related to Teacher Professional Development are also discussed.

5.2 Students’ Conceptions of Engineers

All of the student participants began the study with a naïve, often inaccurate conception of engineers and engineering as shown in Table 5.1. All of the students in the study described engineers as designers on some level during the study, though only four of the seven achieved the most accurate conception of Designer in their engineering drawings. Each student’s engineering perception evolved over time and along a different path. Elena had a strong misconception of engineers as individuals who work on cars in four of her six drawings. Marcos had a consistent understanding of engineers between different classroom activities; his end-of-school-year and subsequent beginning-of-school-year drawings were nearly the same between the second and third years of the study. Ashleigh reverted back to a more personal understanding of engineering at the beginning of each school year, and drew a more accurate conception of an engineer at the end of each year. The remaining students seemed to accommodate an understanding of engineering as designers throughout the study.

As is commonly seen in prior DAET literature, only female students in this study drew female engineers. All female students in this study drew a female engineer at least once, and only Ashleigh consistently drew female engineers in all her drawings. Elena initially drew a male engineer, but all subsequent drawings had at least one female engineer present. Beth and Sofia did not seem to have a clear pattern of gender representation in their drawings. All of the female students in the study drew multiple
engineers at least once, while only one male student drew multiple engineers in one drawing.

One additional goal of the EiE units was to introduce a specific type of engineer. The types of engineer presented were chemical, industrial, and geotechnical for the second, third, and fourth grade EiE units taught during this study, respectively. Teachers were encouraged to discuss additional types of engineers each year of the study as well. In their interviews, Sofia, Marcos, Jake, and Mike recalled chemical as a type of engineer, the focus of the second grade unit, but were unable to describe what these engineers do. Marcos and Jake recalled industrial as a type of engineer, the focus of the third grade unit, but neither could describe what an industrial engineer might do, and they only recalled this type at the end of their fourth grade year. No student recalled geotechnical engineering, the focus of the fourth grade unit. Marcos and Mike recalled mechanical as a type of engineer, though none of their activities explicitly focused on mechanical engineering.
### Table 5.1 Basic Conceptions of Engineers

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</table>
5.3 Students’ Understanding of Technology

The most difficult question for students during the Technology and Engineering portion of the student interviews (see Appendix E, Fall 2011 and later protocols) was whether a toothbrush is an example of technology. All of the student participants with the exception of Elena noted that a toothbrush might be technology at least once. Ashleigh, Sofia, and Mike stated that a toothbrush might be an example of technology in at least one interview, but were unsure as to why. They recognized the correct answer, but had not yet accommodated their prior schema regarding technology to fully understand what technology is and why a toothbrush might be an example. Jake, Marcos, and Beth were able to apply a comprehensive definition of technology, particularly with regard to a toothbrush, at least once during the study. Student responses to items in the Technology and Engineering portion of the student interviews can be seen in Table 5.2 – 5.6.

5.4 Students’ Knowledge that Engineers Design Technology

Two students demonstrated understanding that engineers design technology along with a complex understanding of engineering design and the desired definition of technology. Marcos understood that an engineer would design a toothbrush, which he considered technology, during his last interview. Beth made the connection between engineering and technology while demonstrating an understanding of technology in the second year of the study. She regressed over the summer between the second and third year, becoming unsure of her definition and describing technology as things that required electricity, in line with common cultural understandings of technology. She still believed that an engineer would design a toothbrush, but she was no longer certain that a
toothbrush was an example of technology. Beth reverted to a complete understanding at the end of the year after continued instruction.

All other student participants showed an incomplete understanding of how engineers are connected to technology at least once during the study, describing technology as something that engineers would use, but not something that engineers design.

Jake and Elena recognized that engineers design technology, though they did not have a full understanding of is the definition of technology. They recognized that the items they identified as technology are designed by an engineer, but did not correctly identify all items that were technology. Some students recognized that a toothbrush might be technology if it were motorized and that an engineer might design a motorized toothbrush.
Table 5.2 Student Responses to a Toothbrush as an Example of Technology

<table>
<thead>
<tr>
<th>Date</th>
<th>Is technology?</th>
<th>Why?</th>
<th>Engineer use?</th>
<th>How?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashleigh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall 2011</td>
<td>I think</td>
<td>I don’t know</td>
<td>I don’t know</td>
<td></td>
</tr>
<tr>
<td>Spring 2012</td>
<td>No</td>
<td>Because it doesn’t work. Only the toothbrushes that spin around maybe could be technology</td>
<td>Yeah</td>
<td>Maybe one of them could clean the floors with the toothbrush</td>
</tr>
<tr>
<td>Fall 2012</td>
<td>No</td>
<td>Because technology moves except if you have phones or iPads or something like that like a robot that’s technology. Lightning’s technology.</td>
<td>Maybe</td>
<td>I don’t know</td>
</tr>
<tr>
<td>Spring 2013</td>
<td>No</td>
<td>Because you have to move it with your hands</td>
<td>Nope</td>
<td>I don’t really know</td>
</tr>
<tr>
<td>Sofia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall 2011</td>
<td>Not sure</td>
<td></td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Spring 2012</td>
<td>No</td>
<td>Well I think technology is something you can use or it’s electronical. I am not sure. I think it is technology. Wait no. I don’t think it’s like technology because I think technology is only something that is electronical. I think so. I am not sure though.</td>
<td>Probably</td>
<td>So maybe clean something if they don’t have a brush</td>
</tr>
<tr>
<td>Fall 2012</td>
<td>Probably</td>
<td>I think technology is something you can use</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Spring 2013</td>
<td>No</td>
<td>’cause technology, to me, is probably like…electrical?</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>
Table 5.2 Student Responses to a Toothbrush as an Example of Technology, Continued

<table>
<thead>
<tr>
<th></th>
<th>Date</th>
<th>Is technology?</th>
<th>Why?</th>
<th>Engineer use?</th>
<th>How?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marcos</td>
<td>Fall 2011</td>
<td>I don’t think so</td>
<td>Well because it’s not electric</td>
<td>No</td>
<td>Well it depends on what kinds of process they’re working on.</td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>No</td>
<td>Because it’s just plastic and it does not have wires on it to make a movement or something like that.</td>
<td>Yes</td>
<td>Well I haven’t heard of any toothbrush engineers. Maybe they make them to clean your teeth much easier.</td>
</tr>
<tr>
<td></td>
<td>Fall 2012</td>
<td>No</td>
<td>Maybe the electric kinds</td>
<td>Maybe</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2013</td>
<td>Yes</td>
<td>Because it’s man-made and it will…like, yeah, because it helps you, like, brush your teeth, make ‘em cleaner.</td>
<td>Yes</td>
<td>He designs it. He makes it, and then they go to the factories and they’ll make and…just how the engineer wants it to be.</td>
</tr>
<tr>
<td>Jake</td>
<td>Fall 2011</td>
<td>No</td>
<td>Because it doesn’t use energy, like an engineer didn’t build it. It doesn’t use like energy. It’s not a machine</td>
<td>I don’t know</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>Yes</td>
<td>It’s man-made</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fall 2012</td>
<td>Yes</td>
<td>Because it’s man-made</td>
<td>Yeah</td>
<td>Well, they already design it. There’s like these toothbrushes that vibrate or spins.</td>
</tr>
<tr>
<td></td>
<td>Spring 2013</td>
<td>Yes</td>
<td>Because it’s a man-made thing</td>
<td>Yes</td>
<td>Try to make it better. Kind of design some new ways for it to work better or something.</td>
</tr>
<tr>
<td>Date</td>
<td>Is technology?</td>
<td>Why?</td>
<td>Engineer use?</td>
<td>How?</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>----------------</td>
<td>----------------------------------------------------------------------</td>
<td>---------------</td>
<td>---------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Fall 2011</td>
<td>Yes</td>
<td>Because you hold it and you use it to brush your teeth</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring 2012</td>
<td>Yes</td>
<td>It does not involve electricity</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall 2012</td>
<td>No</td>
<td>Because a toothbrush is not something that an engineer would use for making stuff</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring 2013</td>
<td>No</td>
<td>Because it’s used by the hand and technology is somewhat used by no hands</td>
<td>Yes</td>
<td>Because an engineer would probably make an electric toothbrush to make it go around in circles</td>
<td></td>
</tr>
<tr>
<td>Fall 2011</td>
<td>Yes</td>
<td>Because it helps clean your teeth</td>
<td>Yes</td>
<td>They design it</td>
<td></td>
</tr>
<tr>
<td>Spring 2012</td>
<td>Yes</td>
<td>Because it helps you clean your teeth</td>
<td>Yes</td>
<td>Because they create it</td>
<td></td>
</tr>
<tr>
<td>Fall 2012</td>
<td>No</td>
<td>Yes because it can help you in life, it’s not literally technology, but…it’s not - , no it’s not technology but it’s designed to help you.</td>
<td>Yes</td>
<td>It’s something that they can build, and almost everybody uses them.</td>
<td></td>
</tr>
<tr>
<td>Spring 2013</td>
<td>Yes</td>
<td>It helps you clean your teeth.</td>
<td>Yes</td>
<td>They created it to make life easier. To keep your teeth clean</td>
<td></td>
</tr>
</tbody>
</table>
Table 5.2 Student Responses to a Toothbrush as an Example of Technology, Continued

<table>
<thead>
<tr>
<th>Date</th>
<th>Is technology?</th>
<th>Why?</th>
<th>Engineer use?</th>
<th>How?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elena</td>
<td>Fall 2011</td>
<td>No</td>
<td>Yes</td>
<td>He would like put the- an engineer would do this like stick it in and connect everything together, he would like- he can make the words easily and he can make the toothbrush have make your like hands feel good.</td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>No</td>
<td>Yeah</td>
<td>They could maybe like use it to brush off some stuff like maybe in a tire or on something new or like that’s dusty maybe or needed to like fix something.</td>
</tr>
<tr>
<td>Fall 2012</td>
<td>No</td>
<td>Because it doesn’t really use any power or does nothing you just you need to like to use your hands and stuff to make it work.</td>
<td>Yeah</td>
<td>Yeah cause almost everything in this world is made from engineers, cause they made it, and nobody else could have made it</td>
</tr>
<tr>
<td>Spring 2013</td>
<td>Yes</td>
<td>I don’t know, but I just think it is</td>
<td>Yes</td>
<td>To brush his teeth. They can make it, like, where…well, I think the engineer made it to where you can push a button and it moves for you</td>
</tr>
</tbody>
</table>
Table 5.3 Student Responses to a Flower as an Example of Technology

<table>
<thead>
<tr>
<th></th>
<th>Date</th>
<th>Is technology?</th>
<th>Why?</th>
<th>Engineer use?</th>
<th>How?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashleigh</td>
<td>Fall 2011</td>
<td>No</td>
<td>Technology is something that helps you learn about or pass grades or something like that</td>
<td>Yes</td>
<td>Plant it</td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>No</td>
<td>'cause it doesn’t work it doesn’t move or anything.</td>
<td>No</td>
<td>'cause they can’t use it on anything.</td>
</tr>
<tr>
<td></td>
<td>Fall 2012</td>
<td>No</td>
<td>Because it doesn’t move</td>
<td>Probably</td>
<td>Making a garden</td>
</tr>
<tr>
<td></td>
<td>Spring 2013</td>
<td>No</td>
<td></td>
<td>No</td>
<td>Well maybe if they plant</td>
</tr>
<tr>
<td>Sofia</td>
<td>Fall 2011</td>
<td>No</td>
<td>Because you plant it</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>No</td>
<td>Because it’s a plant</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fall 2012</td>
<td>No</td>
<td>Because I don’t think you can be using it, or maybe</td>
<td>I don’t think so</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2013</td>
<td>No</td>
<td>'cause it’s not electrical</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Marcos</td>
<td>Fall 2011</td>
<td>Interviewer did not ask</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>Interviewer did not ask</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fall 2012</td>
<td>Interviewer did not ask</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2013</td>
<td>I don’t’ think so</td>
<td>Because maybe sometimes it doesn’t, like, do many things that will help</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Jake</td>
<td>Fall 2011</td>
<td>No</td>
<td>It wasn’t man made. Like an engineer didn’t build it</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>No</td>
<td>Because it’s not man-made</td>
<td>No</td>
<td>Because an engineer didn’t design it because it was made in nature.</td>
</tr>
<tr>
<td></td>
<td>Fall 2012</td>
<td>Interviewer did not ask</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2013</td>
<td>No</td>
<td>Because it’s not a man-made thing, it’s just natural.</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>
Table 5.3 Student Responses to a Flower as an Example of Technology, Continued

<table>
<thead>
<tr>
<th>Date</th>
<th>Is technology?</th>
<th>Why?</th>
<th>Engineer use?</th>
<th>How?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mike</td>
<td>Fall 2011</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fall 2012</td>
<td>Interview did not ask</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2013</td>
<td>Interview did not ask</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beth</td>
<td>Fall 2011</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>No</td>
<td>No</td>
<td>Because it is something that is natural, it grows</td>
</tr>
<tr>
<td></td>
<td>Fall 2012</td>
<td>Interview did not ask</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2013</td>
<td>No</td>
<td>No</td>
<td>They didn’t create it</td>
</tr>
<tr>
<td>Elena</td>
<td>Fall 2011</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fall 2012</td>
<td>Interview did not ask</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2013</td>
<td>Interview did not ask</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5.4 Student Responses to a Pulley as an Example of Technology

<table>
<thead>
<tr>
<th></th>
<th>Date</th>
<th>Is technology?</th>
<th>Why?</th>
<th>Engineer use?</th>
<th>How?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashleigh</td>
<td>Fall 2011</td>
<td>Yes</td>
<td>Because sometimes technology can be metal things like your glasses</td>
<td>Yes</td>
<td>Engineers like to build metal and help people with things, and build things like this</td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>Yeah</td>
<td>Because it moves</td>
<td>Yeah</td>
<td>'cause they can use it to maybe put a hook on it and then measure something.</td>
</tr>
<tr>
<td>Sofia</td>
<td>Fall 2011</td>
<td>Yes</td>
<td>Because it helps things hold and it is metal</td>
<td>Yes</td>
<td>To help other people when they have a problem and if the need someone to hold it they could use that</td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>Yes</td>
<td>Because it’s metal</td>
<td>Probably</td>
<td>Probably they can use this to probably do this with it or something</td>
</tr>
<tr>
<td>Marcos</td>
<td>Fall 2011</td>
<td>Yes and no</td>
<td>It’s metal and no it’s electric</td>
<td>I don’t know</td>
<td>For an example if they’re trying. If that was a strong and they brought a wheel and axle for something they are creating</td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>Yes</td>
<td>Because a lot of workers a lot of engineers have a lot of those to create stuff and its metal but it does not have wires but it’s part of technology.</td>
<td>Yes</td>
<td>For an example if they’re trying. If that was a strong and they brought a wheel and axle for something they are creating</td>
</tr>
<tr>
<td></td>
<td>Fall 2012</td>
<td>No</td>
<td>'cause it doesn’t have wires in it</td>
<td>Yes</td>
<td>Sometimes they use these for special machines, to make work easier.</td>
</tr>
<tr>
<td>Jake</td>
<td>Fall 2011</td>
<td>I don’t think so</td>
<td>It doesn’t use energy</td>
<td>Probably</td>
<td>Because you lift for something</td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>Yeah</td>
<td>Because it’s man-made, because it wasn’t made in nature</td>
<td>I don’t think so, no</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fall 2012</td>
<td>Yes</td>
<td>Because it’s man-made</td>
<td>I don’t think so</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Is technology?</td>
<td>Why?</td>
<td>Engineer use?</td>
<td>How?</td>
<td></td>
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<tr>
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<td>----------------------------------------------------------------------</td>
<td>---------------</td>
<td>------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Fall 2011</td>
<td>Yes</td>
<td>The rope goes here and you pull it and the heavy thing goes up</td>
<td>Yes</td>
<td>They would use it to lift like, if they were trying to lift metal to build a house, you could use this and pull the string</td>
<td></td>
</tr>
<tr>
<td>Spring 2012</td>
<td>No</td>
<td>It doesn’t involve electricity</td>
<td>Yes</td>
<td>The engineers use for if anything is heavy to lift if they pull the string and let the thing go up</td>
<td></td>
</tr>
<tr>
<td>Fall 2012</td>
<td>Yes</td>
<td>It could be used for helping people lift heavy stuff.</td>
<td>Yes</td>
<td>Like if they can’t lift metal up by themselves they would lift, they would use the pulley to lift up the metal</td>
<td></td>
</tr>
<tr>
<td>Spring 2013</td>
<td>Yes</td>
<td>Because it helps lift things when you can’t lift them by yourself</td>
<td>Yes</td>
<td>If they can’t lift a heavy object they use a pulley</td>
<td></td>
</tr>
<tr>
<td>Fall 2012</td>
<td>No</td>
<td>Well, again it can be used – it’s used for not every day but it’s used for many people that build things.</td>
<td>Yes</td>
<td>They use it quite often for building</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.4 Student Responses to a Pulley as an Example of Technology, Continued
Table 5.4 Student Responses to a Pulley as an Example of Technology, Continued

<table>
<thead>
<tr>
<th>Date</th>
<th>Is technology?</th>
<th>Why?</th>
<th>Engineer use?</th>
<th>How?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elena</td>
<td>Fall 2011</td>
<td>Yeah</td>
<td>Yes</td>
<td>Like if he was going to fix a building, he would put it on top and pull like if there was a missing screw or and he needed to put it up there he would put this screw on a rope and he would like connect it to the rope and pull it and it would go up.</td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>Yes</td>
<td>Yes</td>
<td>You work on it with like work on it to help people carry stuff up so they don’t have to lift it up and use their backs so it because it helps other people um like pull it so it gets to another place.</td>
</tr>
<tr>
<td></td>
<td>Fall 2012</td>
<td>Yeah</td>
<td>Yeah</td>
<td>Cause they will need to find some metal and like, what I said- sketch and do the engineer process. They need to find the right, like, gold or silver they’re supposed to use, find the right shape around it, unless it won’t work.</td>
</tr>
<tr>
<td></td>
<td>Spring 2013</td>
<td>Yes</td>
<td>Yes</td>
<td>I think it uses, like, to fix a car? Like, it pulls a thing, like a rope around it so it can pull the car up or down.</td>
</tr>
</tbody>
</table>
Table 5.5 Student Responses to a Soil Core Sample as an Example of Technology

<table>
<thead>
<tr>
<th>Date</th>
<th>Is technology?</th>
<th>Why?</th>
<th>Engineer use?</th>
<th>How?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashleigh</td>
<td>Fall 2012</td>
<td>No</td>
<td>No</td>
<td>'cause they just stay on the ground</td>
</tr>
<tr>
<td></td>
<td>Spring 2013</td>
<td>No</td>
<td>Yes</td>
<td>Because engineers can plan what type of soil, top soil, sand, and nothing.</td>
</tr>
<tr>
<td>Sofia</td>
<td>Fall 2012</td>
<td>No, I don’t think so</td>
<td>Maybe</td>
<td>If they had like, like the thing that they make toys, they could use that to make some. Like, say if they were gonna make another toy, they could probably use rocks.</td>
</tr>
<tr>
<td></td>
<td>Spring 2013</td>
<td>No</td>
<td>Maybe</td>
<td>To test things, maybe</td>
</tr>
<tr>
<td>Marcos</td>
<td>Fall 2011</td>
<td>No</td>
<td>I think so</td>
<td>Because maybe they can study them and then they can like make more.</td>
</tr>
<tr>
<td></td>
<td>Fall 2012</td>
<td>It could be</td>
<td></td>
<td>Because, even on the engineer on the paper (referring to DAET), he can use big large rocks, to launch the potatoes.</td>
</tr>
<tr>
<td></td>
<td>Spring 2013</td>
<td>I don’t think so</td>
<td></td>
<td>No</td>
</tr>
</tbody>
</table>
Table 5.5 Student Responses to a Soil Core Sample as an Example of Technology, Continued

<table>
<thead>
<tr>
<th>Date</th>
<th>Is technology?</th>
<th>Why?</th>
<th>Engineer use?</th>
<th>How?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jake</td>
<td>Spring 2012</td>
<td>I don’t think so</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Because people didn’t make it, it’s not man-made</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall 2012</td>
<td>No</td>
<td>Because it’s not manmade, it was made by nature.</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Spring 2013</td>
<td>No</td>
<td>Because it’s not a man-made thing</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Mike</td>
<td>Fall 2012</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Because engineers would not build anything with rocks, sand, or soil.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring 2013</td>
<td>No</td>
<td>Because it could not help in anyway but the soil is technology because it helps plants grow</td>
<td>No</td>
<td>Because I’m just guessing they would not use soil or sand in one of their projects</td>
</tr>
<tr>
<td>Beth</td>
<td>Fall 2012</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>It’s part of nature and it’s not created by people</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring 2013</td>
<td>Not really</td>
<td>It might be because, like engineers, like some types of engineers help like create – for instance the fertilizer. That wasn’t there, it just, somebody had to create that so.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elena</td>
<td>Fall 2012</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>’cause they couldn’t make the rocks or anything. It just grows out of that</td>
<td></td>
<td>They might work on the outside, but not on the rocks or anything</td>
</tr>
<tr>
<td>Spring 2013</td>
<td>No</td>
<td>Because you can’t use it to do anything</td>
<td>No</td>
<td>Like they can maybe use the soil to practice if the pot can hold the soil</td>
</tr>
<tr>
<td>Date</td>
<td>Is technology?</td>
<td>Why?</td>
<td>Engineer use?</td>
<td>How?</td>
</tr>
<tr>
<td>------------</td>
<td>---------------</td>
<td>-------------------------------------------</td>
<td>---------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Ashleigh</td>
<td>Fall 2011</td>
<td>Yes</td>
<td>Yes</td>
<td>I have seen lots of engineer that build phones</td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>Yes</td>
<td>No. Well maybe.</td>
<td>By calling someone. Maybe they can build, maybe they wanna build the same thing and they build it.</td>
</tr>
<tr>
<td></td>
<td>Fall 2012</td>
<td>Yes</td>
<td>Probably</td>
<td>They can take pictures</td>
</tr>
<tr>
<td></td>
<td>Spring 2013</td>
<td>Yes</td>
<td>Yes</td>
<td>Because engineer really make technology things maybe. Or sometimes they create different, different things.</td>
</tr>
<tr>
<td>Sofia</td>
<td>Fall 2011</td>
<td>Yes</td>
<td>I am not sure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>Yes</td>
<td>Yes</td>
<td>Well they can to like if it’s broken, they can like fix it.</td>
</tr>
<tr>
<td></td>
<td>Fall 2012</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2013</td>
<td>Yes</td>
<td>Yes</td>
<td>To contact people.</td>
</tr>
</tbody>
</table>
Table 5.6 Student Responses to a Cellular Telephone as an Example of Technology, Continued

<table>
<thead>
<tr>
<th>Date</th>
<th>Is technology?</th>
<th>Why?</th>
<th>Engineer use?</th>
<th>How?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marcos</td>
<td>Fall 2011</td>
<td>Yes</td>
<td>I don’t know</td>
<td>They can look at one of those. How they make them and they look at them. They study how so we can they can work on them and that’s all I know.</td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>Yes</td>
<td>Maybe</td>
<td>Because if they have a phone like that maybe another factory or workers create that. Maybe if the boss if one of the bosses says to take a picture how they made something and they send it to the boss and the boss looks at it and sees that it’s a good process to make it easier.</td>
</tr>
<tr>
<td>Fall 2012</td>
<td>Yes</td>
<td>It has a lot of electric wires and stuff, and the buttons make the wires work for the screen.</td>
<td>Yes</td>
<td>They sort of make them</td>
</tr>
<tr>
<td>Spring 2013</td>
<td>Yes</td>
<td>Because you can…for that you can call or you can text or you can, like, play or something, and that will…it helps, it’s better because it’s touchscreen and like for the other buttons you have to like press some cell phones.</td>
<td>Maybe</td>
<td>Make a new app</td>
</tr>
<tr>
<td>Date</td>
<td>Is technology?</td>
<td>Why?</td>
<td>Engineer use?</td>
<td>How?</td>
</tr>
<tr>
<td>------------</td>
<td>----------------</td>
<td>-------------------------------------------</td>
<td>------------------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>Jake</td>
<td>Fall 2011</td>
<td>Yes</td>
<td>I don’t think they would</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Engineers made it and it uses energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>Interviewer did not ask</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall 2012</td>
<td>Yeah</td>
<td></td>
<td>I don’t think so</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>I don’t know, they could probably make little notes on it or something.</td>
</tr>
<tr>
<td>Spring 2013</td>
<td>Yes</td>
<td>Because it’s a man-made thing</td>
<td>Maybe</td>
<td></td>
</tr>
<tr>
<td>Mike</td>
<td>Fall 2011</td>
<td>Yes</td>
<td>Yes</td>
<td>They could just like put a layer in the middle and two things on the bottom and the side and the will just paint the whole thing to make it look like a phone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>It’s because people use it to call somebody and text with it and if they want to talk to somebody on the speaker they could just press a button and it says speaker</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2012</td>
<td>Yes</td>
<td>No</td>
<td>Because they don’t always call the people</td>
</tr>
<tr>
<td></td>
<td></td>
<td>It uses electricity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall 2012</td>
<td>Yes</td>
<td>Because cell phones help you talk to people and it could help you text someone like if you’re lost you could call the police.</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spring 2013</td>
<td>Yes</td>
<td>Yes</td>
<td>If they can’t figure out the problem by ourselves or if they have it they can use the calculator to check it</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Because it helps you figure out math problems if you can’t</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5.6 Student Responses to a Cellular Telephone as an Example of Technology, Continued

<table>
<thead>
<tr>
<th>Date</th>
<th>Is technology?</th>
<th>Why?</th>
<th>Engineer use?</th>
<th>How?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beth</td>
<td>Fall 2011</td>
<td>Yes</td>
<td>Yes</td>
<td>They design the buttons</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Because you can call people if you needed to in an emergency or something</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring 2012</td>
<td>Yes</td>
<td>You can use it as a GPS and if you get lost you can use it for GPS</td>
<td>Yes</td>
<td>They create it</td>
</tr>
<tr>
<td>Fall 2012</td>
<td>Yes</td>
<td>It’s manmade but it’s just technology because it has-for instance, a toothbrush isn’t technology because it doesn’t do anything, you operate it yourself, but a phone operates itself kind of.</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Spring 2013</td>
<td>Yes</td>
<td>Because an engineer created it to make someone’s life easier</td>
<td>Yes</td>
<td>Creating it and making it better. Making it a better phone than others.</td>
</tr>
</tbody>
</table>
### Table 5.6 Student Responses to a Cellular Telephone as an Example of Technology, Continued

<table>
<thead>
<tr>
<th>Date</th>
<th>Is technology?</th>
<th>Why?</th>
<th>Engineer use?</th>
<th>How?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elena</td>
<td>Fall 2011</td>
<td>Yeah</td>
<td>Yes</td>
<td>Um he would work on it because people need phones and engineers fix things so he’s going to fix the phone for somebody like it like the energy broke down and um, so he’ll fix it up and put the new batteries in and make it work.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Because it uses batteries and it takes energy and it needs energy for it to work.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring 2012</td>
<td>Yes</td>
<td>Because it uses electricity and it helps people.</td>
<td>Yes</td>
<td>Because sometimes phone give off light when they need to work under a car maybe and um and like they’ll helps it by if you look on the internet it helps engineers know where other things are.</td>
</tr>
<tr>
<td>Fall 2012</td>
<td>Yes</td>
<td>Because engineers had to- if they made it, they had to use technology because it’s electronical, and test it out a lot to make sure the buttons will work and design new, lots of them</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring 2013</td>
<td>Yes</td>
<td>Because you can use it to, like, call people and you can use it, like, since it’s technology you can see that if you touch the screen it automatically, like, goes to that place.</td>
<td>Yes</td>
<td>Well they can use the camera to, like, go in and see closer and they can go on the internet and look up things about it.</td>
</tr>
</tbody>
</table>
5.5 Students’ Attitudes toward Engineering

The students profiled in this case study rarely showed interest in engineering as a career on the Engineering Identity Development Scale, though nearly all of them rated engineering as highly interesting during the interview as seen in Table 5.7. Students were only asked to rate their interest in engineering during the final three interviews so there are no ratings for the first three. They enjoyed taking part in engineering activities but did not want to be engineers themselves as a primary career choice. In every interview, students described a different career or multiple careers that they were interested in instead of, or in addition to, engineering.

Table 5.7 Interest in engineering across instruments

<table>
<thead>
<tr>
<th></th>
<th>Instrument</th>
<th>Fall 2010</th>
<th>Spring 2011</th>
<th>Fall 2011</th>
<th>Spring 2012</th>
<th>Fall 2012</th>
<th>Spring 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashleigh</td>
<td>Interview</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>EIDS</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Rating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Sofia</td>
<td>Interview</td>
<td>Yes</td>
<td>Yes</td>
<td>Unsure</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>EIDS</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Rating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Marcos</td>
<td>Interview</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Unsure</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>EIDS</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Rating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Jake</td>
<td>Interview</td>
<td>Unsure</td>
<td>Unsure</td>
<td>Unsure</td>
<td>Unsure</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>EIDS</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Rating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Mike</td>
<td>Interview</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>EIDS</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Rating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Beth</td>
<td>Interview</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Unsure</td>
<td>Unsure</td>
</tr>
<tr>
<td></td>
<td>EIDS</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Rating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Elena</td>
<td>Interview</td>
<td>No</td>
<td>Yes</td>
<td>Unsure</td>
<td>Unsure</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>EIDS</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Rating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>
Students were much more likely to say that they were interested in engineering as a career when talking to an interviewer than to agree with the statement, “When I grow up I want to be an engineer.” Students rarely told the interviewer they did not want to be an engineer after responding that they would like to on the EIDS as seen in Table 5.1. This may have been because students knew that some of the interviewers were engineers and did not want to disappoint them or because they were able to describe that they might be interested in engineering but had other primary career interests. Frequencies of student interest as reported during the interview and on the EIDS are shown in Figure 5.1.

![Figure 5.1 Frequency of student responses to interest in engineering as a career during interviews and on the EIDS](image)

5.6 Students’ Reported Experiences

Throughout the study, certain engineering experiences were described by the students during the interviews or were seen in students’ DAETs (see Table 5.2). Of the Engineering is Elementary units, the second grade unit, A Work in Process: Improving a Play Dough Process, was the most frequently recalled and the fourth grade unit, A Stick in the Mud: Evaluating a Landscape, was not mentioned as an engineering activity. Two students characterized this lesson as a science activity when discussing the core soil
samples during the interview, but did not consider it engineering. Videos seemed to be memorable interactions; two female students, Ashleigh and Sofia, recalled watching *Design Squad* and one male, Marcos, recalled a potato chip factory video.

Student conceptions of engineers and engineering were drawn from the DAET with supporting evidence from interviews. Five of the seven students, all but Sofia and Elena, drew engineers engaging in engineering similar to what they had seen in classroom engineering activities. Marcos, Mike, and Beth drew engineers engaging in activities seen during the EiE unit *A Work in Process: Improving a Play Dough Process*. Marcos drew engineers engaging in an assembly line similar to what was presented in *Marvelous Machines: Making Work Easier*. Ashleigh drew an engineer she saw in the *Design Squad* video, while Jake drew an engineer building a chair as he had done in the *Gumdrop People and Chairs* activity. Students’ drawings were most commonly based on their experiences during their second-grade post-test; all five drew engineers engaging in activities they had taken part in that year while Marcos is the only student whose drawings directly reflected reported classroom experiences in later years of the study.
<table>
<thead>
<tr>
<th>Student</th>
<th>Spring 2011</th>
<th>Fall 2011</th>
<th>Spring 2012</th>
<th>Fall 2012</th>
<th>Spring 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashleigh</td>
<td><em>DAET: Design Squad</em>, she drew Kim from Design Squad as seen in Figure 4.3</td>
<td><em>Interview: Design Squad</em>, she recalls watching the video</td>
<td><em>Interview: Gumdrop People and Chairs</em>, she recalls making gumdrop structures as an engineering activity</td>
<td><em>Interview: Gumdrop People and Chairs</em>, she recalls making gumdrop structures as an engineering activity</td>
<td><em>Interview: Design Squad</em>, she recalls watching the video</td>
</tr>
<tr>
<td>Sofia</td>
<td><em>Interview: Design Squad</em>, she recalls watching the video</td>
<td><em>Interview: GT Pyramids</em>, she recalls making a board game as an engineering activity</td>
<td><em>Interview: GT Pyramids</em>, she recalls making a board game as an engineering activity</td>
<td><em>Interview: Design Squad</em>, she recalls watching the video</td>
<td></td>
</tr>
</tbody>
</table>
Table 5.8 Students’ Memorable Experiences, Continued

<table>
<thead>
<tr>
<th>Name</th>
<th>Spring 2011</th>
<th>Fall 2011</th>
<th>Spring 2012</th>
<th>Fall 2012</th>
<th>Spring 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marcos</td>
<td><em>DAET: Play Dough</em>, he drew an engineer making play dough as seen in Figure 4.15</td>
<td><em>DAET: Play Dough</em>, he drew an engineer making play dough as seen in Figure 4.16</td>
<td><em>DAET: Marvelous Machines</em>, he drew a potato chip factory as seen in Figure 4.17</td>
<td><em>DAET: Marvelous Machines</em>, he drew a potato chip factory as seen in Figure 4.18</td>
<td><em>Interview: Potato Chip Video</em>, he recalls watching a video about a potato chip factory</td>
</tr>
<tr>
<td></td>
<td><em>Interview: Play Dough</em>, he recalls making play dough as an engineering activity</td>
<td></td>
<td><em>Interview: Marvelous Machines</em>, he recalls designing a project with simple machines</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Interview: Gumdrop People and Chairs</em>, he recalls making gumdrop structures as an engineering activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5.8 Students’ Memorable Experiences, Continued

<table>
<thead>
<tr>
<th></th>
<th>Spring 2011</th>
<th>Fall 2011</th>
<th>Spring 2012</th>
<th>Fall 2012</th>
<th>Spring 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jake</td>
<td>DAET: Gumdrop People and Chairs, he drew an</td>
<td>Interview: Windmills, he recalls making</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>engineer building a chair as seen in Figure 4.22</td>
<td>windmills as an engineering activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interview: Play Dough, he recalls making play</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>dough as an engineering activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interview: Windmills, he recalls making windmills</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>as an engineering activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mike</td>
<td>DAET: Play Dough, he drew an engineer making</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>play dough as seen in Figure 4.29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beth</td>
<td>DAET: Play Dough, she drew an engineer making</td>
<td>Interview: Play Dough, she recalls making</td>
<td>Interview: Play Dough, she recalls making</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>play dough as seen in Figure 4.35</td>
<td>play dough as an engineering activity</td>
<td>play dough as an engineering activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elena</td>
<td>Interview: Play Dough, she recalls making play</td>
<td>Interview: Marvelous Machines, she recalls</td>
<td>Interview: Marvelous Machines, she recalls</td>
<td></td>
<td>Interview: Marvelous Machines, she recalls</td>
</tr>
<tr>
<td></td>
<td>dough as an engineering activity</td>
<td>designing a project with simple machines</td>
<td>designing a project with simple machines</td>
<td></td>
<td>designing a project with simple machines</td>
</tr>
</tbody>
</table>
5.7 Teacher Professional Development

During the teacher interviews, teachers’ understanding of engineers, engineering, design, and technology was not explored. Some teachers described their conceptions of these areas their experiences in teaching engineering. One example pointing to the need for high quality teacher professional development to ensure fidelity of implementation was found in this study. In the interview described in section 4.6.3, one of the teachers described an understanding of engineering that did not align with the complex understanding of engineers as designers; instead, she focused on the creation of a prototype as the role of an engineer. This was her second year teaching engineering and she had attended both required Summer Academies, yet she appeared to hold an incomplete conception about engineers and engineering.

This observation can be further substantiated by one of the teacher’s students and his understanding of engineering. Mike described his engineer as “a person who does stuff but doesn’t do it for a living.” He uses language similar to the language used by his teacher described what she taught the class, “With me questioning them, more questioning, they would realize, okay, a lot of them know he doesn’t make those [Igloo coolers] for a living, and I said, ‘So how many would he make?’ and it was a chorus response of, ‘One.’” Mike repeats what he has been taught, though this does not align with what was presented at the Academies.
CHAPTER 6. DISCUSSION

In this chapter, the results of this study are considered in a developmental context, using the work of Piaget and Vygotsky. The students’ drawings and tentative understandings of the work of an engineer and the role of technology are compared to existing literature to further explore the meaning of student responses.

6.1 A Developmental Perspective

Developmentally, the participants in this study align well with Piaget’s stages of intellectual development as seen in Table 6.1. In these stages, all ages are approximate but generally align to when children acquire different ways of considering the world and solving problems. In this study, students begin at the end of the preoperational stage in second grade and progress to the concrete operational stage in grades three and four. They are not followed into the formal operational stage past approximately age twelve.

Table 6.1 Piaget’s Stages of Intellectual Development (reproduced from Salkind, 2004, p. 243)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Age</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensorimotor</td>
<td>Birth – 2 years</td>
<td>Intelligence based on perceptual experiences</td>
</tr>
<tr>
<td>Preoperational</td>
<td>2 – 7 or 8</td>
<td>Onset of sophisticated language system; egocentric reasoning; perception-bound thinking</td>
</tr>
<tr>
<td>Concrete operational</td>
<td>7 – 12</td>
<td>Development of reversible thought, logical operations, conservation, ability to solve concrete problems, experience-based thinking</td>
</tr>
<tr>
<td>Formal Operational</td>
<td>12 – adulthood</td>
<td>Formulation and testing of hypotheses, abstract thought</td>
</tr>
</tbody>
</table>
In second grade, the students are in the preoperational stage, highlighted by their egocentric understanding of engineering. All seven students drew themselves, or someone they knew, or an example of engineer who they had seen during the school year in second grade. Students in this stage tend to connect themselves personally to concepts they are learning, including engineering (Salkind, 2004).

In the third and fourth grade years, students tend to focus on the concrete aspects of engineering. When probed for what “design” means, Sofía described design as “fixing” at the end of her third grade year and “making and testing plastic items” at the beginning of fourth grade. Marcos had a complex understanding of design, and described the sketches and drawings his engineer makes as design, focusing on the concrete outcomes of engineering design work during the first data collection period in fourth grade. Jake also showed a complex understanding of engineering and included engineering drawings as part of his drawings of an engineer in third and fourth grade.

This evidence suggests that when students described a complex understanding of engineering as design, they focus on concrete engineering outcomes. Students who did not seem to have a complex understanding of design focused on concrete actions such as making, testing, or fixing. All students connect engineering to concrete actions in grades three and four, as is expected in Piaget’s concrete operational stage.

This study explored children’s understanding of engineering design. Engineering design is a difficult concept to define. In this study, it has been defined as a process that engineers use to create technology and described as distinct from artistic design. The abstract nature of engineering design requires the ability to understand design in a decontextualized way. It is possible to describe what engineers do in a concrete manner,
but understanding engineering design as a whole is an abstract thought. *Engineering in K-12 Education* (2009) attempts to make the concept of engineering design more concrete by providing a description of the outputs of engineering work, “Usually, engineers do not literally construct artifacts. They develop plans and directions for how artifacts are to be constructed. Some artifacts are small – a hand calculator, for example, or a computer chip – and some are large – a bridge, for example, or an aircraft carrier. Engineers also design processes, ranging from the manufacturing processes used in the chemical and pharmaceutical industries to create chemicals and drugs to procedures for putting components together on an assembly line” (p. 27). Engineering design can be connected to the concrete outputs of engineering work, but engineering design itself is an abstract concept.

Vygotsky (as reprinted in Van der Veer & Valsiner, 1994) posits “specific investigations show that only after the age of 12, i.e. only at the beginning of the pubescent period and after the end of the primary school age, do the processes which lead to the formation of concepts and abstract thinking begin to develop in children” (p. 202). This aligns with Piaget’s abstract stage, beginning at approximately the same age. It is not until this age that children are likely to be able to navigate a linguistically-based reality, using language as mediators for abstract concepts. A full understanding of engineering design requires the ability to negotiate abstract concepts and ideas to know what engineering design is beyond concrete connections (e.g. engineers design a plan for a bridge, drawing the trusses and calculating their sizes, or engineers design an industrial process, creating instructions and drawings for how the process will work). Children in elementary grades may be unable to understand the abstract idea of engineers designing
something like an industrial process without connecting this concept to the concrete output of engineering work.

In this study, Beth and Marcos understood that the work of engineers might be connected to industrial processes in factories, but their understanding is connected to the concrete example of the assembly line they had practiced and discussed in class. Based on the *Engineering is Elementary* curriculum, they should have been told that engineers design industrial processes like assembly lines. Without knowing the concrete output of an engineer, such as written instructions or a diagram of the process, both Beth and Marcos have associated their drawings of an engineer with the concrete example of human work in an assembly line they are aware of, indicating they are assembly line workers.

During their interviews, the students often described what their engineers do as “design”. When probed for further descriptions of what design means, Sofia attributed “fixing and building” as aspects of design, while Jake attributed drawing plans. The participants do not describe the abstract concepts of the engineering design process or describe design using other abstract ideas, rather, they focus on concrete examples of what they believe to be engineering work, describing the actions an engineer might take. This evidence suggests that the elementary school students in this study are at a concrete stage of understanding, as characterized by Piaget and Vygotsky.

6.2 Students’ Understanding of Technology

The most difficult concept for students in this study to fully understand and apply was technology. This finding is not surprising, considering the common cultural understanding of what technology is. Educational technology is the study of integrating
iPads and SMART Boards into classrooms, not pencils and paper. Alan Kay famously encapsulated the cultural understanding of technology, “Technology is anything that wasn’t around when you were born.” (as cited by Greelish, 2013). We tend to consider new high-tech advances as technology, not appreciating the full extent of human advancement. As Beth stated, a toothbrush is “not literally technology,” because even though it is something that has been designed to help people, the classroom definition of technology, it does did not meet the popular definition of technology. The broader cultural understanding of what technology is can be difficult to overcome. Ashleigh stated a common understanding of technology at the end of her third grade year, even though she participated in lessons about technology during the school year. A comprehensive understanding of engineering and design requires a foundational understanding of technology, content that is not adequately found in typical pre-service or in-service teacher training (Hsu et al., 2011).

The results of this study are similar to those seen in other studies (Cunningham, Lachapelle, & Lindgren-Streicher, 2005; Firat, 2015; Lachapelle, Hertel, Jocz, & Cunningham, 2013). Artifacts found in nature are the easiest to categorize; one student incorrectly categorized the flower, an example of something that is not technology. Items found in nature are not generally considered by elementary-aged students as examples of technology (Cunningham et al., 2005; Firat, 2015; Lachapelle et al., 2013). On the other end of the spectrum, cellular telephones were considered to be technology in all cases in this study. Elementary school students recognize cellular telephones and other high-tech artifacts like computers as examples of technology. In their study, Lachapelle and colleagues (2013) found that over 95% of students chose electrical examples of...
technology as examples of technology, while non-electrical technologies ranged from 10% of students choosing a bonnet as an example of technology to just under 60% of students choosing that a windmill was technology. After instruction, these numbers increased to 60% - 80%, while the belief that electrical technologies were examples of technology remained consistent. Students in Turkey have similar conceptions, with 98% of students choosing a television and cellular telephone as examples of technology, and under 30% choosing book, scissors, house, or shoe as examples (Firat, 2015). Culturally, technology seems to be something that requires electricity, a misconception that persists for Ashleigh, Sofia, Elena, and Mike in this study.

6.3 Chapter Summary

The work of Vygotsky and Piaget has been used as a developmental lens to understand and explore students’ responses throughout this study. The students have constructed their conceptions of engineers, engineering design, and technology in developmentally-appropriate ways. While in the preoperational stage, students are egocentric, often drawing themselves or engineers they have seen when asked to draw an engineer. During the years of the study, the participants are not yet in a stage where they can navigate a decontextualized world according to Vygotsky, and focus on the concrete aspects of engineering. An understanding of technology as defined in this study is at odds with the common cultural depiction of technology as “high-tech” electronics. This conflict is seen in other studies of student understanding of technology and in this study, where three of the seven students (Marcos, Jake, and Beth) have achieved the desired understanding of technology while four (Ashleigh, Sofia, Mike, and Elena) have not.
Engineering instruction has helped all seven students to construct their knowledge about, attitudes toward, and conceptions of engineers, engineering design, and technology.
CHAPTER 7. CONCLUSIONS

The purpose of this study was to understand changes in students’ knowledge of, attitudes toward, and conceptions of engineers and engineering. Based on the analysis of data, there are three significant assertions to be made. The first assertion is that none of the students in this particular study developed a complex understanding of engineering as design-based during one year of engineering instruction, even when the teacher introduced engineering through multiple activities. The second assertion is that all the students in this study attained some level of understanding of engineers as designers. All students were also exposed to the idea that technology is anything man-made; this concept, despite repeated lessons, was not understood by many students, possibly due to strong cultural connotations. The third and final assertion is that, for the majority of students in this study, their understandings of engineers as designers did not shift until fourth grade. This seems to suggest that engineering does not have a strong impact in the second or third grade years; however, the second and third grade level engineering activities were recognized by students as engineering activities while the activities students experienced in their fourth grade school year were not. All students recognized at least one activity from their second or third grade year as an engineering activity, yet, no student recognized activities completed during their fourth grade school year as engineering activities.
It is clear that there is no clear or consistent path students take when developing their understanding of engineering as design. Equally important is the claim that students’ conceptions are often malleable as well as dynamic.

7.1 Implications of this Study

For educators, part of the allure of engineering curricula like *Engineering is Elementary* is that it is integrated into other subjects, allowing teachers to teach or reinforce science and literacy concepts while attempting to build engineering and technology literacy. Due to the *Next Generation Science Standards*, engineering is now considered an aspect of science education for many states and is expected to be integrated into the science classroom throughout a student’s K-12 experience. For students, this may create confusion as to what engineering is, especially if they hold strong schemas regarding engineering that align with cultural stereotypes. They may be able to assimilate the facts they are presented in the science classroom as part of their science schemas without accommodating their underlying conceptions of engineers, engineering, technology, or design. Students in this study did not recognize the fourth grade EiE unit, *A Stick in the Mud: Evaluating a Landscape*, as an engineering activity, but two students did recall working with soil core samples as part of their science class, describing the activities involved in the EiE unit. One possible explanation is how the activity is introduced and implemented in the context of the science classroom.

All of the students focused on the hands-on aspects of the Engineering Design Process as partial understandings of engineering, including building, testing, and fixing or improving. These align with common concepts of engineers as builders, mechanics, and technicians or tradespeople. Students at this age are still in the concrete operations stage
of development, able to solve problems that apply to concrete objects but not abstract concepts or hypothetical tasks (Pulaski, 1971).

In the fields of teacher development and curriculum design, engineering should be introduced in a developmentally appropriate way. For elementary students, this may mean focusing on concrete representations of design, including instructions and blueprints, rather than abstract concepts associated with an adult understanding of the term “design.” If students are not presented with developmentally appropriate, concrete representations of engineering, they run the risk of harboring misconceptions of engineers as builders and mechanics.

7.2 Future Research

Future research is needed to understand the impact of engineering activities on student learning, motivation, and interest. There are fifteen different engineering lessons or activities that were presented by teachers in this study. Each student participated in at least three during each year of the study, including an EiE unit that extended across four different lessons. Few of these respective lessons were recognized or discussed by students as engineering activities during the end-of-year interviews. Memorable activities need to be studied further to understand what made these activities stand out to students, what students learned from them, and how to design better engineering activities in the future to help students understand and make connections among the complex concepts of engineers, engineering, design, and technology. Additional longitudinal work is needed to explore the ramifications of introducing engineering to students in their elementary years, such as follow-up surveys to see what major students choose if they attend college. A
greater focus on teacher’s technology and engineering content knowledge would support their efforts to instruct students in these areas.

For elementary students to reach a complex understanding of engineers, engineering, design, and technology, teacher education, both pre-service and in-service, needs to be a priority. Repeated interactions with the concepts of engineering seem to be required for complete understanding and accommodation of engineering concepts. Improvement in student understanding has been seen across three years of engineering instruction, but the long-term effects of this instruction and whether constant reinforcement is needed are questions that remain unanswered. Over time, elementary students can understand what engineers do and may be able to achieve a complete understanding of engineering design and technology, but each students’ path to this understanding may be unique.

7.3 Limitations

This study follows seven individual students across three years of elementary engineering instruction. The case study method can be used to inform research and practice, but as it focuses on a small number of participants, is not widely generalizable. These students learned engineering in diverse school districts in the south central United States; this context cannot be divorced from the results.

Observations of the classroom were not a part of this study. Teacher fidelity of implementation, peer interactions, and other in-school exposure that could have an impact on participants’ conceptions of, knowledge about, and attitudes toward engineering are not known. All teachers were trained through the Summer Academies and had resources available for instruction. Teacher attitudes varied and their
understanding of engineering and implementation of the units were not studied. Students may have been exposed to ideas about engineering, design, and technology at home or through media they consumed; these and similar variables that could have contributed to their responses is unknown.

Data was not initially collected with these specific research questions in mind. The interview questions were not developed for this study and were inconsistent across years and interviewers. Multiple interviewers spoke to participants in this study. While all received training, different interviewing styles and rapport with students may have created inconsistencies across interviews. The instruments retained many of the same questions across data collection periods, and this may have influenced student responses as well.
REFERENCES


APPENDICES
Appendix A  Draw an Engineer Task

Name: ________________________________  Grade ______
Teacher’s Name: ________________________________  DATE

DRAW AN ENGINEER TASK

In the space below, draw an engineer doing engineering work.

What is the engineer doing? ________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Prepared by Brenda Capobianco, Purdue University 8/1/07
Appendix B  Engineering Identity Development Scale, 2\textsuperscript{nd} Grade

Name: __________________________

1. I do my school work as well as my classmates.

2. I am good at solving problems in mathematics.

3. I am good at solving problems in science.

4. I use computers as well as my classmates.

5. I am good at working with others in small groups.
6. I like being a student at my school. 

7. Being a student at my school is important to me. 

8. I make friends easy at my school. 

9. The teachers at my school want me to do well in my school work.
10. Engineers solve problems that help people. 😕 😕 😊

11. Engineers work in teams. 😕 😕 😊

12. Engineers design everything around us. 😕 😕 😊

13. There is more than one type of engineer. 😕 😕 😊

14. Engineers use mathematics. 😕 😕 😊
15. Engineers use science.

16. Engineers are creative.

When I grow up...

17. I want to be an engineer.

18. I want to solve problems that help people.

19. I want to design different things.

20. I want to work on a team with engineers.
Appendix C  Engineering Identity Development Scale, 3rd and 4th Grade

Name: ___________________________  Date: ___________________________

Directions: Read each statement carefully. Select one of the three answers that best describes how you feel about the statement. For example, if you agree with the statement, "I like recess time," you would rate the statement Yes by circling the number 3.

<table>
<thead>
<tr>
<th>Statement</th>
<th>No</th>
<th>Not Sure</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I do my school work as well as my classmates.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2. I am good at solving problems in mathematics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3. I am good at solving problems in science.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4. I use computers as well as my classmates.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>5. I am good at working with others in small groups.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6. I like being a student at my school.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7. Being a student at my school is important to me.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>8. I make friends easy at my school.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>9. The teachers at my school want me to do well in my school work.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>10. Engineers solve problems that help people.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>11. Engineers work in teams.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>12. Engineers design everything around us.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>13. There is more than one type of engineer.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>14. Engineers use mathematics.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>15. Engineers use science.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>16. Engineers are creative.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>17. When I grow up I want to be an engineer.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>18. When I grow up I want to solve problems that help people.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>19. When I grow up I want to design different things.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>20. When I grow up I want to work on a team with engineers.</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

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Appendix D  Student Knowledge Tests

Name: ___________________________________________  Grade 2
Teacher’s Name ___________________________________  Fall 2010 (Pre)

Hello! Researchers at Purdue University would like to understand what you know about science and engineering!
They have some questions for you. I will not grade your answers. Just do your best.

Thank you for giving Purdue your best effort.

Directions: For each of the questions below, choose the BEST answer and circle the letter.
Choose only one answer for each question.

1) Jack left a cup of ice in a hot car while his family went inside a store to shop for a long time. What will be in the cup when he gets back to the car?

   A. solid
   B. liquid
   C. gas

2) Malcolm brought something to school to show his classmates. It had a cube shape. It was rough. It could be broken into pieces. The item Malcolm brought to class was a

   A. solid.
   B. liquid.
   C. gas.

3) What tool do you need to use to measure an amount of orange juice?

   A. ruler
   B. watch
   C. measuring cup
4. Salt is a
   A. solid.
   B. liquid.
   C. gas.

5. Sarah has made a mixture of flour, water and salt. When she adds more flour to the mixture, the mixture will become more like a
   A. solid.
   B. liquid.
   C. gas.

6. Sam bought a balloon at the fair. What was inside the balloon?
   A. solid
   B. liquid
   C. gas
   D. nothing

7. Gillian has a carton of milk. The milk is a liquid because
   A. it is white and cannot be seen through.
   B. it can be held in her hand.
   C. it changes shape when it is poured.
8) If a city were hit by a flood, what would a role of engineers be?
   A. create a system to prevent future floods
   B. replace roofs on damaged buildings
   C. clean up damage and debris
   D. contact the families of the victims

9) Play dough is considered technology because
   A. it is human made.
   B. it can be cut with a knife.
   C. it is made of more than one ingredient.
   D. it can be made into different shapes.

10) Which of the following is an example of a task that an engineer would perform?
    A. build a house for a family
    B. drive a train engine
    C. fix a car for a customer
    D. design a quiet vacuum cleaner
1) Sam is a chemical engineer. In his job, he is likely to
   A. change the oil in cars.
   B. create a new toothpaste
   C. drive a dump truck.
   D. clean bathrooms.

12) When an engineer is told to design a new technology, the first thing an engineer does is
    A. test.
    B. improve.
    C. ask.
    D. create.

13) Which is an example of technology?
    A. lightning
    B. rabbit
    C. scissors
    D. river
Answer the next two questions based on the following paragraph:

14) Monique and Ben were talking about how to mix ingredients together to make healthy cookies. Ben suggested using wheat flour in the recipe. Monique suggested using both oats and flour in the recipe because it is healthier. They continued to think of more ideas. What step of the engineering design process were they working on?

A. ask
B. imagine
C. plan
D. create

15) Ben and Monique have selected all of their ingredients and listed the steps that they will follow to make the cookies. Which step in the engineering design process will Monique and Ben most likely work on next?

A. ask
B. imagine
C. plan
D. create
Hello! Researchers at Purdue University would like to understand what you know about science and engineering! They have some questions for you. I will not grade your answers. Just do your best.

Thank you for giving Purdue your best effort.

Directions: For each of the questions below, choose the BEST answer and circle the letter. Choose only one answer for each question.

1) Which is an example of technology?
   A. river
   B. scissors
   C. lightning
   D. rabbit

2) What tool do you need to use to measure an amount of orange juice?
   A. measuring cup
   B. watch
   C. ruler

3) Gabe bought a balloon at the fair. What was inside the balloon?
   A. liquid
   B. gas
   C. solid
   D. nothing
4. Aaron left a cup of ice in a hot car while his family went inside a store to shop for a long time. What will be in the cup when he gets back to the car?
   A. liquid
   B. gas
   C. solid

Answer the next two questions based on the following paragraph:

5. Karli and Sam were talking about how to mix ingredients together to make healthy cookies. Sam suggested using wheat flour in the recipe. Karli suggested using both oats and flour in the recipe because it is healthier. They continued to think of more ideas. What step of the engineering design process were they working on?
   A. ask
   B. imagine
   C. plan
   D. create

6. Sam and Karli have selected all of their ingredients and listed the steps that they will follow to make the cookies. Which step in the engineering design process will Karli and Sam most likely work on next?
   A. ask
   B. imagine
   C. plan
   D. create
7. Mark is a chemical engineer. In his job, he is likely to
   A. clean bathrooms.
   B. change the oil in cars.
   C. create a new toothpaste.
   D. drive a dump truck.

8. Sonia has made a mixture of flour, water and salt. When she adds more flour to the mixture, the mixture will become more like a
   A. liquid.
   B. gas.
   C. solid.

9. Play dough is considered technology because
   A. it is made of more than one ingredient.
   B. it is human made.
   C. it can be cut with a knife.
   D. it can be made into different shapes.
10) If a city were hit by a flood, what would a role of engineers be?
   A. contact the families of the victims
   B. replace roofs on damaged buildings
   C. clean up damage and debris
   D. create a system to prevent future floods

11) Which of the following is an example of a task that an engineer would perform?
   A. design a quiet vacuum cleaner
   B. drive a train engine
   C. build a house for a family
   D. fix a car for a customer

12) Terrance brought something to school to show his classmates. It had a cube shape. It was rough. It could be broken into pieces. The item Terrance brought to class was a
   A. liquid.
   B. gas.
   C. solid.
13) When an engineer is told to design a new technology, the first thing an engineer does is
   
   A. test. 
   B. improve. 
   C. create. 
   D. ask. 

14) Salt is a
   
   A. liquid. 
   B. gas. 
   C. solid. 

15) Lisa has a carton of milk. The milk is a liquid because
   
   A. it can be held in her hand. 
   B. it changes shape when it is poured. 
   C. it is white and cannot be seen through.
Hello! Researchers at Purdue University would like to understand what you know about science and engineering! They have some questions for you. I will not grade your answers. Just do your best.

Thank you for giving Purdue your best effort.

Directions: For each of the questions below, choose the BEST answer and circle the letter. Choose only one answer for each question.

1) Salt is a
   A. gas.
   B. solid.
   C. liquid.

2) Daniela has made a mixture of flour, water and salt. When she adds more flour to the mixture, the mixture will become more like a
   A. gas.
   B. solid.
   C. liquid.

3) Play dough is considered technology because
   A. it can be made into different shapes.
   B. it can be cut with a knife.
   C. it is made of more than one ingredient.
   D. it is human made.
4. Ryan is a chemical engineer. In his job, he is likely to
   A. drive a dump truck.
   B. change the oil in cars.
   C. clean bathrooms.
   D. create a new toothpaste.

5. Brandon bought a balloon at the fair. What was inside the balloon?
   A. gas
   B. solid
   C. liquid
   D. nothing

6. Alyssa has a carton of milk. The milk is a liquid because
   A. it changes shape when it is poured.
   B. it can be held in her hand.
   C. it is white and cannot be seen through.
Answer the next two questions based on the following paragraph:

7) Hailey and Lucas were talking about how to mix ingredients together to make healthy cookies. Lucas suggested using wheat flour in the recipe. Hailey suggested using both oats and flour in the recipe because it is healthier. They continued to think of more ideas. What step of the engineering design process were they working on?

A. ask  
B. imagine  
C. plan  
D. create

8) Lucas and Hailey have selected all of their ingredients and listed the steps that they will follow to make the cookies. Which step in the engineering design process will Hailey and Lucas most likely work on next?

A. ask  
B. imagine  
C. plan  
D. create
9. When an engineer is told to design a new technology, the first thing an engineer does is
   A. improve.
   B. ask.
   C. test.
   D. create.

10. Which of the following is an example of a task that an engineer would perform?
   A. fix a car for a customer
   B. build a house for a family
   C. design a quiet vacuum cleaner
   D. drive a train engine

11. What tool do you need to use to measure an amount of orange juice?
   A. watch
   B. measuring cup
   C. ruler

12. Which is an example of technology?
   A. scissors
   B. lightning
   C. rabbit
   D. river
13) Peter left a cup of ice in a hot car while his family went inside a store to shop for a long time. What will be in the cup when he gets back to the car?
   A. gas
   B. solid
   C. liquid

14) Willis brought something to school to show his classmates. It had a cube shape. It was rough. It could be broken into pieces. The item Willis brought to class was a
   A. gas.
   B. solid.
   C. liquid.

15) If a city were hit by a flood, what would a role of engineers be?
   A. clean up damage and debris
   B. replace roofs on damaged buildings
   C. create a system to prevent future floods
   D. contact the families of the victims
Hello! Researchers at Purdue University would like to understand what you know about science and engineering! They have some questions for you. I will not grade your answers. Just do your best.

Thank you for giving Purdue your best effort.

Directions: For each of the questions below, choose the BEST answer and circle the letter. Choose only one answer for each question.

1) In the picture below, Rich is using a rope and pulley to lift a weight. Which of the arrows shows the direction which Rich is applying force to the rope?

A. \[ \downarrow \]  
B. \[ \rightarrow \]  
C. \[ \uparrow \]  
D. \[ \leftarrow \]  

2) If a city were hit by a flood, what would a role of engineers be?

A. create a system to prevent future floods  
B. replace roofs on damaged buildings  
C. clean up damage and debris  
D. contact the families of the victims

3) A simple machine…

A. makes energy  
B. has many moving parts  
C. does not involve energy  
D. uses energy to complete a task
4) Sherri is an industrial engineer who studies ergonomics. Ergonomics is the study of
   A. money and spending.
   B. work spaces and systems.
   C. plants and animals.
   D. chemical reactions.

5) Juan is an industrial engineer. For his job, Juan might
   A. design the recipe for a really strong cleaning solution.
   B. clean offices.
   C. build new cars.
   D. design assembly lines.

6) Look at the picture to the right. Michael and Ann are playing on a seesaw. Michael
   weighs more than Ann. What must happen for Michael to be lifted up and for Ann to be
   set down?
   A. Ann moves closer to the center of the seesaw
   B. Michael moves closer to the center of the seesaw
   C. Ann jumps off the seesaw
   D. Michael jumps off the seesaw

7) Simple machines are considered technology because they
   A. are made of metal.
   B. are designed to solve a problem.
   C. have many parts.
   D. use electricity.
8) All of the following describe an assembly line EXCEPT
   A. used in a factory to make work easier
   B. is a process
   C. requires electricity
   D. is a technology

9) Aisha is cutting out cookies using her Mom’s cookie cutter. What kind of simple machine is a cookie cutter?
   A. pulley
   B. inclined plane
   C. wedge
   D. A cookie cutter is not a simple machine.

10) Which of the following is an example of a task that an engineer would perform?
    A. build a house for a family
    B. design a quiet vacuum cleaner
    C. fix a car for a customer
    D. drive a train engine

11) Which is an example of technology?
    A. lightning
    B. rabbit
    C. scissors
    D. river
Answer the next two questions based on the following paragraph:
Workers on an assembly line make chairs. They complain that the work is very hard because they must move and lift heavy materials. Devin and Riley are designing a new assembly line that must make work easier for the workers. Devin and Riley think of many ways to use simple machines to make work easier on the new assembly line.

12) What part of the engineering design process are Devin and Riley working on?
   A. imagine
   B. plan
   C. create
   D. ask

13) Devin and Riley select three simple machines and create the assembly line. What will they most likely do next?
   A. improve
   B. create
   C. test
   D. plan

14) When an engineer is told to design a new technology, the first thing an engineer does is
   A. test.
   B. improve.
   C. ask.
   D. create.

15) What kind of simple machine do you see in this picture?
   A. pulley
   B. inclined plane
   C. wheel and axle
   D. There is no simple machine in the picture.
Hello! Researchers at Purdue University would like to understand what you know about science and engineering! They have some questions for you. I will not grade your answers. Just do your best.

Thank you for giving Purdue your best effort.

Directions: For each of the questions below, choose the BEST answer and circle the letter. Choose only one answer for each question.

1) Which is an example of technology?
   A. rabbit
   B. scissors
   C. river
   D. lightning

Answer the next two questions based on the following paragraph:
Workers on an assembly line make chairs. They complain that the work is very hard because they must move and lift heavy materials. Kasey and Ben are designing a new assembly line that must make work easier for the workers. Kasey and Ben think of many ways to use simple machines to make work easier on the new assembly line.

2) What part of the engineering design process are Kasey and Ben working on?
   A. create
   B. ask
   C. imagine
   D. plan

3) Kasey and Ben select three simple machines and create the assembly line. What will they most likely do next?
   A. plan
   B. test
   C. improve
   D. create
4) In the picture below, Malcolm is using a rope and pulley to lift a weight. Which of the arrows shows the direction which Malcolm is applying force to the rope?

A. \[\uparrow\]  
B. \[\rightarrow\]  
C. \[\downarrow\]  
D. \[\leftarrow\]

5) What kind of simple machine do you see in this picture?
A. inclined plane  
B. wheel and axle  
C. pulley  
D. There is no simple machine in the picture.

6) Which of the following is an example of a task that an engineer would perform?
A. drive a train engine  
B. fix a car for a customer  
C. design a quiet vacuum cleaner  
D. build a house for a family

7) Marcos is an industrial engineer. For his job, Marcos might
A. build new cars.  
B. design assembly lines.  
C. clean offices.  
D. design the recipe for a really strong cleaning solution.
8) All of the following describe an assembly line EXCEPT
A. is a process
B. is a technology
C. used in a factory to make work easier
D. requires electricity

9) Look at the picture to the right. Jack and Beth are playing on a seesaw. Jack weighs more than Beth. What must happen for Jack to be lifted up and for Beth to be set down?
A. Jack jumps off the seesaw
B. Beth jumps off the seesaw
C. Jack moves closer to the center of the seesaw
D. Beth moves closer to the center of the seesaw

10) A simple machine…
A. uses energy to complete a task.
B. makes energy.
C. does not involve energy.
D. has many moving parts.

11) Sadie is cutting out cookies using her Mom’s cookie cutter. What kind of simple machine is a cookie cutter?
A. inclined plane
B. wedge
C. pulley
D. A cookie cutter is not a simple machine.
12) When an engineer is told to design a new technology, the first thing an engineer does is
   A. improve.
   B. ask.
   C. create.
   D. test.

13) Simple machines are considered technology because they
   A. have many parts.
   B. use electricity.
   C. are made of metal.
   D. are designed to solve a problem.

14) If a city were hit by a flood, what would a role of engineers be?
   A. replace roofs on damaged buildings
   B. contact the families of the victims
   C. create a system to prevent future floods
   D. clean up damage and debris

15) Jade is an industrial engineer who studies ergonomics. Ergonomics is the study of
   A. work spaces and systems.
   B. plants and animals.
   C. chemical reactions.
   D. money and spending.
Hello! Researchers at Purdue University would like to understand what you know about science and engineering! They have some questions for you. I will not grade your answers. Just do your best.

Thank you for giving Purdue your best effort.

**Directions:** For each of the questions below, choose the BEST answer and circle the letter. Choose only one answer for each question.

1) When an engineer is told to design a new technology, the first thing an engineer does is
   A. create.
   B. improve.
   C. test.
   D. ask.

2) Roman is an industrial engineer. For his job, Roman might
   A. clean offices.
   B. design the recipe for a really strong cleaning solution.
   C. design assembly lines.
   D. build new cars.

3) Heidi is an industrial engineer who studies ergonomics. Ergonomics is the study of
   A. money and spending.
   B. plants and animals.
   C. chemical reactions.
   D. work spaces and systems.

4) A simple machine...
   A. makes energy.
   B. has many moving parts.
   C. uses energy to complete a task.
   D. does not involve energy.
5) Zara is cutting out cookies using her Mom’s cookie cutter. What kind of simple machine is a cookie cutter?
   A. wedge
   B. pulley
   C. inclined plane
   D. A cookie cutter is not a simple machine.

6) Look at the picture to the right. Ryan and Olivia are playing on a seesaw. Ryan weighs more than Olivia. What must happen for Ryan to be lifted up and for Olivia to be set down?
   A. Olivia jumps off the seesaw
   B. Olivia moves closer to the center of the seesaw
   C. Ryan jumps off the seesaw
   D. Ryan moves closer to the center of the seesaw

7) All of the following describe an assembly line EXCEPT
   A. requires electricity
   B. is a technology
   C. used in a factory to make work easier
   D. is a process

8) Simple machines are considered technology because they
   A. are designed to solve a problem.
   B. use electricity.
   C. have many parts.
   D. are made of metal.
Answer the next two questions based on the following paragraph:
Workers on an assembly line make chairs. They complain that the work is very hard because they must move and lift heavy materials. Aaron and Samuel are designing a new assembly line that must make work easier for the workers. Aaron and Samuel think of many ways to use simple machines to make work easier on the new assembly line.

9) What part of the engineering design process are Aaron and Samuel working on?
   A. ask
   B. imagine
   C. plan
   D. create

10) Aaron and Samuel select three simple machines and create the assembly line. What will they most likely do next?
    A. plan
    B. create
    C. improve
    D. test

11) If a city were hit by a flood, what would a role of engineers be?
    A. clean up damage and debris
    B. create a system to prevent future floods
    C. contact the families of the victims
    D. replace roofs on damaged buildings
12) Which of the following is an example of a task that an engineer would perform?
   A. drive a train engine
   B. fix a car for a customer
   C. build a house for a family
   D. design a quiet vacuum cleaner

13) What kind of simple machine do you see in this picture?
   A. pulley
   B. wheel and axle
   C. inclined plane
   D. There is no simple machine in the picture.

14) In the picture below, Rich is using a rope and pulley to lift a weight. Which of the arrows shows the direction which Rich is applying force to the rope?
   A.  
   B.  
   C.  
   D.  

15) Which is an example of technology?
   A. scissors
   B. rabbit
   C. lightning
   D. river
Hello! Researchers at Purdue University would like to understand what you know about science and engineering!

They have some questions for you. I will not grade your answers. Just do your best.

Thank you for giving Purdue your best effort.

Directions: For each of the questions below, choose the BEST answer and circle the letter.

Choose only one answer for each question.

1) Making soil more compact before building on it is considered technology because it is
   A. a source of pollution.
   B. a process designed to solve a problem.
   C. work that takes many people.
   D. done by nature.

2) Samantha is a geotechnical engineer. In her job, she is likely to do all of the following EXCEPT
   A. talk with others about what they need and want.
   B. test properties of soils in a project area.
   C. run a machine that digs up soil and rock.
   D. plan a process to reduce erosion.

3) A geotechnical engineer has designed a treatment to prevent soil erosion on sloping ground. The engineer now needs to test the erosion control treatment. Which test would be MOST appropriate?
   A. compare the erosion that occurs on a treated slope and an untreated slope
   B. plant grass in different kinds of soil to see if it will grow
   C. determine the cost of the erosion prevention system
   D. ask people to predict whether the system will prevent erosion
4) A core sample of soil is taken to
   A. examine properties of soil layers.
   B. measure nutrients in topsoil.
   C. stop soil erosion.
   D. reduce slope in the land.

5) Topsoil will usually contain all of the following EXCEPT
   A. air space.
   B. roots and twigs.
   C. dead insect parts.
   D. packed clay.

6) Soil can be improved to support a structure better by adding
   A. gravel or crushed rock.
   B. fertilizer and mulch.
   C. water and oil.
   D. plant roots and seeds.

7) Mana is trying to design a way to make the ground strong enough to sink a pole to hold a basketball hoop. Mana thinks of several different ideas and sketches them. Then, she chooses one of the ideas and writes out a list of materials. She then constructs a model of her idea. What will she most likely do next?
   A. improve
   B. plan
   C. create
   D. test
8) If a city were hit by a flood, what would a role of engineers be?
   A. replace roofs on damaged buildings
   B. clean up damage and debris
   C. contact the families of the victims
   D. create a system to prevent future floods

9) Which is an example of technology?
   A. lightning
   B. scissors
   C. rabbit
   D. river

10) A geotechnical engineer is helping the city park department find ways to use plants as part of a system to prevent erosion on hillsides in city parks. The engineer takes samples from the hillside to find out about soil layers. What property of the soil samples is most important for plant growth?
    A. the ability to retain water
    B. the temperature of the soil
    C. the color of the soil
    D. the ability of the soil to form clumps

11) When an engineer is told to design a new technology, the first thing an engineer does is
    A. test.
    B. ask.
    C. improve.
    D. create.
12) Matt is designing a new bicycle. He wants to make the handlebars and bike seat light up when someone rides the bike at night. Matt uses his best drawing to make a list of materials and tools he will need to build his test bicycle. Which step of the engineering design process is Matt working on?
   A. plan
   B. ask
   C. create
   D. imagine

13) Which of the following is an example of a task that an engineer would perform?
   A. fix a car for a customer
   B. drive a train engine
   C. design a quiet vacuum cleaner
   D. build a house for a family

14) Erosion along a river bank will be the GREATEST problem for
   A. campers staying overnight.
   B. people building cabins close to a river.
   C. boaters following a river.
   D. hikers and backpackers.

15) What changes happen along ALL rivers over time?
   A. Rivers become polluted.
   B. Animals leave the river area.
   C. Average water temperature becomes colder each year.
   D. Erosion along a river’s banks changes the river’s shape.
Hello! Researchers at Purdue University would like to understand what you know about science and engineering!

They have some questions for you. I will not grade your answers. Just do your best.

Thank you for giving Purdue your best effort.

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   B. measure nutrients in topsoil.
   C. stop soil erosion.
   D. reduce slope in the land.

2) Topsoil will usually contain all of the following EXCEPT
   A. air space.
   B. roots and twigs.
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   D. packed clay

3) Which is an example of technology?
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   A. test.
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   D. create.

6) Making soil more compact before building on it is considered technology because it is
   A. a source of pollution.
   B. a process designed to solve a problem.
   C. work that takes many people.
   D. done by nature.
7) Soil can be improved to support a structure better by adding
   A. gravel or crushed rock
   B. fertilizer and mulch
   C. water and oil
   D. plant roots and seeds

8) Which of the following is an example of a task that an engineer would perform?
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   D. hikers and backpackers.

10) If a city were hit by a flood, what would a role of engineers be?
    A. replace roofs on damaged buildings
    B. clean up damage and debris
    C. contact the families of the victims
    D. create a system to prevent future floods
11) Matt is designing a new bicycle. He wants to make the handlebars and bike seat light up when someone rides the bike at night. Matt uses his best drawing to make a list of materials and tools he will need to build his test bicycle. Which step of the engineering design process is Matt working on?
   A. plan  
   B. ask  
   C. create  
   D. imagine

12) What changes happen along ALL rivers over time?
   A. Rivers become polluted.  
   B. Animals leave the river area.  
   C. Average water temperature becomes colder each year.  
   D. Erosion along a river’s banks changes the river’s shape.

13) Samantha is a geotechnical engineer. In her job, she is likely to do all of the following EXCEPT
   A. talk with others about what they need and want.  
   B. test properties of soils in a project area.  
   C. run a machine that digs up soil and rock.  
   D. plan a process to reduce erosion.
14) A geotechnical engineer has designed a treatment to prevent soil erosion on sloping ground. The engineer now needs to test the erosion control treatment. Which test would be MOST appropriate?
   A. compare the erosion that occurs on a treated slope and an untreated slope
   B. plant grass in different kinds of soil to see if it will grow
   C. determine the cost of the erosion prevention system
   D. ask people to predict whether the system will prevent erosion

15) Maria is trying to design a way to make the ground strong enough to sink a pole to hold a basketball hoop. Maria thinks of several different ideas and sketches them. Then, she chooses one of the ideas and writes out a list of materials. She then constructs a model of her idea. What will she most likely do next?
   A. improve
   B. plan
   C. create
   D. test
Hello! Researchers at Purdue University would like to understand what you know about science and engineering!

They have some questions for you. I will not grade your answers. Just do your best.

Thank you for giving Purdue your best effort.

Directions: For each of the questions below, choose the BEST answer and circle the letter. Choose only one answer for each question.

1) Which of the following is an example of a task that an engineer would perform?
   A. fix a car for a customer
   B. drive a train engine
   C. design a quiet vacuum cleaner
   D. build a house for a family

2) Erosion along a river bank will be the GREATEST problem for
   A. campers staying overnight.
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5) Topsoil will usually contain all of the following EXCEPT
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   B. roots and twigs.
   C. dead insect parts.
   D. packed clay.

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   A. gravel or crushed rock
   B. fertilizer and mulch.
   C. water and oil.
   D. plant roots and seeds.

7) When an engineer is told to design a new technology, the first thing an engineer does is
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   B. a process designed to solve a problem.
   C. work that takes many people.
   D. done by nature.

9) Samantha is a geotechnical engineer. In her job, she is likely to do all of the following EXCEPT
   A. talk with others about what they need and want.
   B. test properties of soils in a project area.
   C. run a machine that digs up soil and rock.
   D. plan a process to reduce erosion.

10) Maria is trying to design a way to make the ground strong enough to hold a basketball hoop. Maria thinks of several different ideas and sketches them. Then, she chooses one of the ideas and writes out a list of materials. She then constructs a model of her idea. What will she most likely do next?
    A. improve
    B. plan
    C. create
    D. test

11) Which is an example of technology?
    A. lightning
    B. scissors
    C. rabbit
    D. river
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   B. plant grass in different kinds of soil to see if it will grow
   C. determine the cost of the erosion prevention system
   D. ask people to predict whether the system will prevent erosion

13) Matt is designing a new bicycle. He wants to make the handlebars and bike seat light up when someone rides the bike at night. Matt uses his best drawing to make a list of materials and tools he will need to build his test bicycle. Which step of the engineering design process is Matt working on?
   A. plan
   B. ask
   C. create
   D. imagine

14) A geotechnical engineer is helping the city park department find ways to use plants as part of a system to prevent erosion on hillside slopes in city parks. The engineer takes samples from the hillside to find out about soil layers. What property of the soil samples is most important for plant growth?
   A. the ability to retain water
   B. the temperature of the soil
   C. the color of the soil
   D. the ability of the soil to form clumps

15) If a city were hit by a flood, what would the role of engineers be?
   A. replace roofs on damaged buildings
   B. clean up damage and debris
   C. contact the families of the victims
   D. create a system to prevent future floods
**Appendix E  Student Interview Protocols**

Student Interview August 2010

**STUDENT INTERVIEW PROTOCOL**

The purpose of this interview is to learn about what you think engineering is and what kind of work engineers do. I will ask you some questions about the topic of the engineering and what you are learning at school about engineering. Please answer the questions as best you can and any answer is okay. If you do not know, it is okay to say "I don't know." If you need time to think, please let me know and I will give you time. If you want to stop, that is okay; I will stop and you can return to class. Do you have any questions before we begin?

**Section I – Reflecting on Drawing**

Let us take a look at your drawing (drawing of engineer).

1. I am going to ask you a few questions about your drawing. This may sound a little strange, but pretend you are telling your friend about your drawing over the phone. Your friend cannot see the drawing, so just let them know what you have drawn.

<table>
<thead>
<tr>
<th><strong>Engineer Drawn</strong> (human or non-human)</th>
<th>Can you point to the engineer in your drawing?</th>
<th>Who is the engineer in your drawing? □ <em>me</em> _________ (e code)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Probe: What can you tell me about your engineer?</td>
<td>Who are the other figures in your drawing? (if 2 or more figures drawn)</td>
</tr>
<tr>
<td></td>
<td>How does your engineer feel?</td>
<td>What is your engineer wearing?</td>
</tr>
<tr>
<td></td>
<td>Can you describe what your engineer looks like?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Tools, Artifacts, or Other Objects Are Present</strong></th>
<th>What is (are) your engineer(s) doing?</th>
<th>Does your engineer do anything else?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Probe: What does design/fabricate (use word student uses) mean?</td>
<td>What is “stuff”?</td>
</tr>
<tr>
<td></td>
<td>Why is your engineer doing this for someone or something?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>What does your engineer use in their work?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>What tools is your engineer using? (if tools are drawn)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Probe: How are these tools used?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>What other objects are in your picture? (if other objects are drawn)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>What are the steps that your engineer uses to fix/repair/design/use word student uses?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Environmental Component Present</strong> (clouds, plants, animals)</th>
<th>Where is your engineer working?</th>
<th>Probe: Is it indoors or outdoors?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>What can you tell me about this location (place)?</td>
<td></td>
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<tr>
<td></td>
<td>Are there any animals or plants drawn in your picture? (if any drawn)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Probe: What is the animal?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Does the animal help your engineer or do anything for your engineer?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>How did you show this in your drawing?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Probe: Does your engineer work any place else? (ex. – fire fighter)</td>
<td></td>
</tr>
</tbody>
</table>

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Student Interview: August 2010

<table>
<thead>
<tr>
<th>BUILDING, STRUCTURE, AND/OR MACHINE PRESENT</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>What is the thing (structure) in your picture? (if any drawn)</td>
</tr>
<tr>
<td></td>
<td>Who helped make the thing (structure)? Did anyone else help?</td>
</tr>
<tr>
<td></td>
<td>Did your engineer help make it?</td>
</tr>
<tr>
<td></td>
<td>[Probe:] What is drawn on your structure? (ex. flag/cross)</td>
</tr>
<tr>
<td></td>
<td>What is this (machine) in your picture?</td>
</tr>
<tr>
<td></td>
<td>[Probe:] Is it a vehicle? What kind of vehicle?</td>
</tr>
<tr>
<td></td>
<td>What is your engineer doing with the vehicle?</td>
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2. If you had more time to draw, what else would you add?

Section II – Engineering
Now we are going to talk about engineers and engineering.

3. When you hear the word "engineer", what comes to your mind?

4. Please complete the following sentence: An engineer is someone who ...

5. What type of engineer is your engineer (in your drawing)?

6. Where did you learn about engineers?

Section III – Learning Engineering at School
Now we will talk about the activities you have done in your class.

7. Have you done some engineering activities in your class? What kinds of activities have you done? (Note: Be sure the student is describing activities that are engineering-related. Sometimes students talk about everyday classroom activities OR school science and mathematics activities and consider these as "engineering activities". If so, then ask: What make these activities "engineering"? OR What make these activities different from what you have done before in class? How did you use science? How did you use math?)

8. What did you like about this activity?

9. What did you not like about this activity?

10. What is something new you learned about engineering or engineers that you did not know before?

11. What can you do with what you learned? (Probe: In other words, how will you use what you learned?)

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Student Interview August 2010

Section IV – Engineering Work

12. Can you give me an example of one type of engineer?

If a specific type is given: What kind of work does this engineer do?
If no specific type is given: What do engineers do?

13. Can you give me an example of another type of engineer?

If a specific type is given: What kind of work does this engineer do?
If no specific type is given: What do engineers do?

14. Have you heard of the engineering design process? What can you tell me about it?
   (Probe: If the student remembers the terms then continue to ask how the student used these concepts in their engineering lessons. For example: “Did you ASK questions? What kind of questions did you ASK? What kinds of things did you first IMAGINE? Did you and your team members make a PLAN? What did your PLAN look like? Or How did you PLAN? What did your team CREATE? In what ways did you and your team members IMPROVE your product?”

15. INSERT DESIGN PROCESS KNOWLEDGE QUESTIONS HERE

16. Would you like to be an engineer when you grow up? Why or why not?
   (Probe: If the why seems like something an engineer would also do, ask whether the student thinks this is something an engineer does. Example: Doctor – help people. Do you think engineers help people? If yes, how?)

17. Is there anything else about your drawing or engineering that you want to tell me?
Student Interview May 2011

STUDENT INTERVIEW PROTOCOL

The purpose of this interview is to learn about what you think engineering is and what kind of work engineers do. I will ask you some questions about the topic of the engineering and what you are learning at school about engineering. Please answer the questions as best you can and any answer is okay. If you do not know, it is okay to say "I don't know." If you need time to think, please let me know and I will give you time. If you want to stop, that is okay; I will stop and you can return to class. Do you have any questions before we begin?

Section I – Reflecting on Drawing

Let us take a look at your drawing (drawing of engineer).

1. I am going to ask you a few questions about your drawing. This may sound a little strange, but pretend you are telling your friend about your drawing over the phone. Your friend cannot see the drawing, so just let them know what you have drawn.

   a. Can you point to the engineer in your drawing?
      Who is the engineer in your drawing? □ it's me! ______________ (e code)
      Probe: What can you tell me about your engineer? (Follow-up: If the student does not mention gender, ask, "Is your engineer a person?" "Is your engineer a boy or a girl?
      Then, ask, "What did you draw to make your engineer look like a girl?
      Probe: Can you describe what your engineer looks like? (Only ask this if it's not redundant for the student to answer).
    b. GROUP (if 2 or more figures drawn): Who are the others in your drawing?
    c. How does your engineer feel?
    d. Can you tell me about the colors you chose to use in your drawing?
    e. CLOTHES: What is your engineer wearing? (Follow-up: If student mentions clothing not in the drawing, ask, "Can you show me (or point to it) in your drawing?"

   a. What is (are) your engineer(s) doing?
      Outside Realm – “What is (are) your engineer(s) doing here?”
      Probe: What does design/do make (use word student uses) mean?
      What is “stuff”?
      b. Why is your engineer doing (this) ______?
      c. Is your engineer doing this for someone or something?
      d. What does your engineer use in their work?
    e. TOOLS (if office/physical labor tools drawn): What tool(s) is your engineer using?
       If unsure - "Can you show me (or point to it) in your drawing?"
       Probe: If no office tools included - "What is this in your drawing?"
       Probe: How are these tools used?
      f. What other objects are in your picture? (if other objects/artifacts are drawn)
      g. What are the steps that your engineer uses to fix/repair/design (use word student uses) ______?
Student Interview May 2011

1. Environmental
   a. Where is your engineer working?
   b. What can you tell me about this location (place)?
   (Follow-up: What did you draw that makes it look like it’s indoors?)
   c. ANIMALS/PLANTS/ETC. (If drawn): Are there any animals or plants drawn in
      your picture?
   d. Does your engineer work anywhere else? (e.g. - fire station)

2. If you had more time to draw, what else would you add?

Section II – Engineering
Now we are going to talk about engineers and engineering.

3. When you hear the word “engineer”, what comes to your mind?

4. Please complete the following sentence. An engineer is someone who...

5. What type of engineer is your engineer (in your drawing)?

6. Where did you learn about engineers?

Section III – Learning Engineering at School
Now we will talk about the activities you have done in your class.

7. Have you done some engineering activities in your class? What kinds of activities have you done?
   (Note: Be sure the student is describing activities that are engineering-related. Sometimes
   students talk about every day classroom activities OR school science and mathematics
   activities and consider these as “engineering activities”. If so, then ask: What makes these
   activities “engineering”? OR What make these activities different from what you have done
   before in class? How did you use science? How did you use math?)

   (Note: If the student cannot recall doing engineering… give them some reminders.
   Remember making… play dough (Gr 1), an assembly line or using pulleys (Gr 3), a package (Gr 4)?
   You may also have a list of other activities the teacher completed to use.)

8. What did you like about this activity?

9. What did you not like about this activity?

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Student Interview May 2011

10. What is something new you learned about engineering or engineers that you did not know before?

11. What can you do with what you learned? (Probe: In other words, how will you use what you learned?)

Section IV – Engineering Work

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15. INSERT DESIGN PROCESS KNOWLEDGE QUESTIONS HERE

16. Would you like to be an engineer when you grow up? Why or why not?
   If no: "What would you like to be when you grow up? Why?"
   (Probe: If the why seems like something an engineer would also do, ask the student. So you think this is something an engineer does? Example: Doctor – help people. Do you think engineers help people? If yes, how?)

17. Is there anything else about your drawing or engineering that you want to tell me?

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Student Interview Aug-Sept 2011

STUDENT INTERVIEW PROTOCOL

The purpose of this interview is to learn about what you think engineering is and what kind of work engineers do. I will ask you some questions about the topic of the engineering and what you are learning at school about engineering. Please answer the questions as best you can and any answer is okay. If you do not know, it is okay to say “I don’t know.” If you need time to think, please let me know and I will give you time. If you want to stop, that is okay, I will stop and you can return to class. Do you have any questions before we begin?

Section I – Reflecting on Drawing

Let us take a look at your drawing (drawing of engineer).

1. I am going to ask you a few questions about your drawing. This may sound a little strange, but, pretend you are telling your friend about your drawing over the phone. Your friend cannot see the drawing, so just let them know what you have drawn.

   a. Can you point to the engineer in your drawing?
      Who is the engineer in your drawing? 
      ![Code]
      Probe: What can you tell me about your engineer? (Follow-up: If the student does not mention gender, ask, “Is your engineer a person?” “Is your engineer a boy or a girl?”
      Then, ask, “What did you draw to make your engineer look like a girl?”
      Probe: Can you describe what your engineer looks like? (Only ask this if it’s not redundant for the student to answer).

   b. GROUP (if 2 or more figures drawn): Who are the others in your drawing?

   c. How does your engineer feel?

   d. Can you tell me about the colors you chose to use in your drawing?

   e. CLOTHES: What is your engineer wearing? (Follow-up: If student mentions clothing not in the drawing, ask, “Can you show me (or point to it) in your drawing?”

2. What is (are) your engineer(s) doing?
   Outside Realm – “What is (are) your engineer(s) doing here?”
   Probe: What does design/fix/make (use word student uses) mean?
   What is “stuff”?

3. Why is your engineer doing (this _______)?

4. Is your engineer doing this for someone or something?

5. What does your engineer use in their work?

6. TOOLS (if office/physical labor tools drawn): What tool(s) is your engineer using?
   If unsure - “Can you show me (or point to it) in your drawing?”
   Probe: If no office tools included – “What is this in your drawing?”
   Probe: How are these tools used?

7. What other objects are in your picture? (if other objects/artifacts are drawn)

8. What are the steps that your engineer uses to fix/repair/design (use word student uses) ________?
Student Interview: Aug.-Sept. 2011

a. Where is your engineer working?  
   Probe: Is it indoors or outdoors?  
   (Follow-up: What did you draw that makes it look like it’s indoors?)

b. What can you tell me about this location (place)?  
   Outside Realms: “Can you show me (or point to it) in your drawing?”

c. ANIMALS/PLANTS/ETC. (if drawn): Are there any animals or plants drawn in your picture?  
   Probe: What is this (animal/plant/cloud/river/moon)?

d. Does your engineer work anywhere else? (ex. – fire station)

2. If you had more time to draw, what else would you add?

Section II – Engineering  
Now we are going to talk about engineers and engineering.

3. When you hear the word “engineer”, what comes to your mind?

4. Please complete the following sentence: An engineer is someone who ...

5. What type of engineer is your engineer (in your drawing)?

6. Where did you learn about engineers?

Section III – Technology and Engineering  
Now I am going to show you 4 objects one at a time and we are going to talk about each one.

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<th>Grade 4</th>
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<td>Flower</td>
<td>Pulley</td>
<td>Flower or Pulley</td>
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<tr>
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<td>Pulley</td>
<td>Flower</td>
<td>Core Soil Sample</td>
</tr>
<tr>
<td>4</td>
<td>Cell Phone</td>
<td>Cell Phone</td>
<td>Cell Phone</td>
</tr>
</tbody>
</table>

Interview Note: The flower is fake, but need to tell the student to pretend that it is real.

Interview Note: Repeat interview items 7-9 for each item.

7. Can you tell me what this object is?

8. Do you think this object is an example of technology? (Give time to respond. If long wait, ask the child what he/she thinks the word technology means and then try again.)

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Probe: If yes, Why do you think this is an example of technology 
   If no, why not?

9. Do you think this object has something to do with the work of an engineer?
   Probe: How would an engineer use this object as part of their work?
   Probe: How would an engineer work on this object as part of their work?
   Probe (if student seems to be able to relate object to a class activity):
     + Does this object remind you of an engineering activity you did at school?
     + Can you tell me about that activity? Did you use science? How? Did you use math? How?
     + Was this activity different than others you do in school? How?
     + What did you like about this activity?
     + What did you not like about this activity?
     + What is something new you learned about engineering or engineers that you did not know before?
     + What can you do with what you learned? (In other words, how will you use what you learned?)

Section IV – Engineering Work

10. Can you give me an example of one type of engineer?
    If a specific type is given: What kind of work does this engineer do?
    If no specific type is given: What do engineers do?

11. Can you give me an example of another type of engineer?
    If a specific type is given: What kind of work does this engineer do?
    If no specific type is given: What do engineers do?

12. Have you heard of the engineering design process? What can you tell me about it?
    (Probe: If the student remembers the terms then continue to ask how the student used these concepts in their engineering lessons. For example: “Did you ASK questions? What kind of questions did you ASK? What kinds of things did you first IMAGINE? Did you and your team members make a PLAN? What did you PLAN look like? Or How did you PLAN? What did your team CREATE? In what ways did you and your team members IMPROVE your product?”)

13. INSERT DESIGN PROCESS KNOWLEDGE QUESTIONS HERE

14. Would you like to be an engineer when you grow up? Why or why not?
    If no: What would you like to be when you grow up? Why?
    (Probe: If the why seems like something an engineer would also do, ask the student. So you think this is something an engineer does? Example: Doctor – help people. Do you think engineers help people? If yes, how?)

15. Is there anything else you know about engineering that you want to tell me?

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Student Interview May 2012

STUDENT INTERVIEW PROTOCOL

The purpose of this interview is to learn about what you think engineering is and what kind of work engineers do. I will ask you some questions about the topic of engineering and what you are learning at school about engineering. Please answer the questions as best you can and any answer is okay. If you do not know, it is okay to say "I don’t know." If you need time to think, please let me know and I will give you time. If you want to stop, that is okay; I will stop and you can return to class. Do you have any questions before we begin?

Section I – Reflecting on Drawing

Let us take a look at your drawing (drawing of engineer).
1. I am going to ask you a few questions about your drawing. This may sound a little strange, but, pretend you are telling your friend about your drawing over the phone. Your friend cannot see the drawing, so just let them know what you have drawn.

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<th>ENGINEER DRAWN</th>
<th>TOOLS, ARTIFACTS, OTHER OBJECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Can you point to the engineer in your drawing?</td>
<td>a. What is (are) your engineer(s) doing?</td>
</tr>
<tr>
<td>Who is the engineer in your drawing?</td>
<td>Probe: What does design/fix/make the word student use mean?</td>
</tr>
<tr>
<td>b. GROUP (if 2 or more figures drawn): Who are the others in your drawing? (Only ask this if it’s not redundant for the student to answer)</td>
<td>What is “stuff”?</td>
</tr>
<tr>
<td>c. What can you tell me about your engineer(s)?</td>
<td>b. Can you tell me a little bit more about why your engineer is use phrase student uses?</td>
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<td>Follow-up: If student does not mention gender, ask, Is your engineer a person? Is your engineer a boy or a girl?</td>
<td>c. Is your engineer use phrase student uses to help someone?</td>
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<td>Probe: Can you describe what your engineer looks like? (Only ask this if it’s not redundant for the student to answer)</td>
<td>d. What does your engineer use in his or her work?</td>
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<td>Then, ask: What did you draw to make your engineer look like a girl?</td>
<td>e. TOOLS (if office/physical labor tools drawn): What tool(s) is your engineer using?</td>
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<td>d. How does (do) your engineer(s) feel?</td>
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Student Interview May 2012

<table>
<thead>
<tr>
<th>ENVIRONMENTAL</th>
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| a. Where is your engineer working?
  Is it indoors or outdoors?
  Follow-up: What did you draw that makes it look like it is indoors/outdoors?
| b. What can you tell me about this location (place)?
| Outside Realm: Can you show me (or point to) it in your drawing?
| c. ANIMALS/PLANTS/ETC. (if drawn): Are there any animals or plants drawn in
  your picture?
  Probe: What is this (animal/plant/cloud/river/moon)?
| d. Does your engineer work anywhere else? (e.g. – fire station)

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| a. STRUCTURE (if drawn): What is this (structure) in your picture?
  Probe: What is drawn on your structure? (e.g. flag/cross etc.)
| b. VEHICLE/MACHINE (if drawn): What is this (vehicle/machine) in your picture?
  Probe: What is your engineer doing with the vehicle?

2. (If any other objects/artifacts are drawn) Point to object in drawing and ask, What is this?

3. If you had more time to draw, what else would you add?

Section II – Engineering

Now we are going to talk about engineers and engineering.

4. When you hear the word “engineer”, what comes to your mind?

5. Please complete the following sentence: An engineer is someone who ...

6. What type of engineer is your engineer (in your drawing)?

7. Where did you learn about engineers?
   If student talks about in school: Have you learned anything about engineering outside of
   school?
   If yes, What did you learn?
   If student talks about outside of school: Have you learned anything about engineering inside
   of school?
   If yes, What did you learn?

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Student Interview May 2012

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8. Can you tell me what this object is?

9. Do you think this object is an example of technology? (Give time to respond. If long wait, ask the child what she thinks the word technology means and then try again.)
   Probe: If yes, Why do you think this is an example of technology
   If no, why not?

10. Do you think this object has something to do with the work of an engineer?
    Probe: How would an engineer use this object as part of their work?
    Probe: How would an engineer work on this object as part of their work?
    If yes, continue with:
    * Does this object remind you of an engineering activity you did at school?
    * Can you tell me about that activity? Did you use science? How? Did you use math? How?
    * Was this activity different than others you do in school? How?
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Student Interview May 2012

13. Have you heard of the engineering design process? What can you tell me about it?
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15. Would you like to be an engineer when you grow up? Why or why not?
   If no: What would you like to be when you grow up? Why?
   (Probe: If the why seems like something an engineer would also do, ask the student. So you think this is something an engineer does? Example: Doctor — help people. Do you think engineers help people? If yes, how?)

16. What are you the most interested in, either in school or out of school?

17. What are you least interested in, either in school or out of school?
   Place the number line in front of the student.

18. (While pointing to number line) If you rate (answer to 16) as a 10 for high interest and (answer to 17) as a 1 for low interest, how would you rate your interest in engineering?
   Count number of line (1-10) and say into recorder

19. Why did you rate engineering that way? (point to their rating).

20. What was interesting about engineering?

21. What was not interesting about engineering?

22. IF RATE 1-5 on number line: What would make engineering more interesting?

23. IF RATE 6-10 on number line: What would make engineering even more interesting?

24. Do you think engineering could be related to Answer from 16?
   (Probe: How can they be related? How can engineering affect your interest in Answer from 16?)

25. Is there anything else you know about engineering that you want to tell me?

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Student Interview September 2012

STUDENT INTERVIEW PROTOCOL

The purpose of this interview is to learn about what you think engineering is and what kind of work engineers do. I will ask you some questions about the topic of engineering and what you are learning at school about engineering. Please answer the questions as best you can and any answer is okay. If you do not know, it is okay to say "I don't know." If you need time to think, please let me know and I will give you time. If you want to stop, that is okay; I will stop and you can return to class. Do you have any questions before we begin?

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Who is the engineer in your drawing? | a. What is (are) your engineer(s) doing?  
Probe: What does design mean?/what does engineering mean?  |
| b. GROUP (if 2 or more figures drawn): Who are the others in your drawing? (Only ask this if it's not redundant for the student to answer) | b. Can you tell me a little bit more about why your engineer is use phrase student uses?  |
| c. What can you tell me about your engineer(s)?  
Follow-up: If student does not mention gender, ask, Is your engineer a person? Is your engineer a boy or a girl?  
Probe: Can you describe what your engineer looks like? (Only ask this if it's not redundant for the student to answer)  
Then, ask: What did you draw to make your engineer look like a girl? | c. Is your engineer use phrase student uses to help someone?  |
| d. How does (do) your engineer(s) feel? | d. What does your engineer use in his or her work?  |
| e. CLOTHES (if clothing is drawn): What is your engineer wearing?  
Follow-up: If student mentions clothing not in the drawing, ask, Can you show me (or point to it) in your drawing?" | e. TOOLS (if office/physical labor tools drawn): What tool(s) is your engineer using?  
Follow-up: Can you show me (or point to it) in your drawing?  |
| f. What are the steps that your engineer uses to use phrase student uses? | Probe: What is this in your drawing?  |

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Student Interview September 2012

Environmental

a. Where is your engineer working?
   Follow-up: What did you draw that makes it look like it is indoors/outdoors?
b. What can you tell me about this location (place)?
   Outside Realm- Can you show me (or point to) it in your drawing?
c. ANIMALS/PLANTS/ETC. (if drawn): Are there any animals or plants drawn in
   your picture?
   Probe: What is this (animal/plant/cloud/river/moon)?
d. Does your engineer work anywhere else? (ex. fire station)

Building/Structure/Machine

a. STRUCTURE (if drawn): What is this (structure) in your picture?
   Probe: What is drawn on your structure? (ex. flag/cross etc.)
b. VEHICLE/MACHINE (if drawn): What is this (vehicle/machine) in your picture?
   Probe: What is your engineer doing with the vehicle?

2. (If any other objects/artifacts are drawn) Point to object in drawing and ask, What is this?

3. If you had more time to draw, what else would you add?

Section II – Engineering

Now we are going to talk about engineers and engineering.

4. When you hear the word "engineer", what comes to your mind?

5. Please complete the following sentence: An engineer is someone who ...

6. What type of engineer is your engineer (in your drawing)?

7. Where did you learn about engineers?
   If student talks about in school: Have you learned anything about engineering outside of
   school?
   If yes, What did you learn?
   If student talks about outside of school: Have you learned anything about engineering inside
   of school?
   If yes, What did you learn?

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Student Interview September 2012

Section III – Technology and Engineering

Now I am going to show you 4 objects one at a time and we are going to talk about each one.

<table>
<thead>
<tr>
<th>Object Order</th>
<th>Grade 2</th>
<th>Grade 3</th>
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<tbody>
<tr>
<td>1</td>
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</tr>
<tr>
<td>4</td>
<td>Cell Phone</td>
<td>Cell Phone</td>
<td>Cell Phone</td>
</tr>
</tbody>
</table>

Interview Note: The Flower is fake, but need to tell the student to pretend that it is real.

8. Can you tell me what this object is?

9. Do you think this object is an example of technology? (Give time to respond. If long wait, ask the child what he thinks the word technology means and then try again.)
   Probe: If yes, Why do you think this is an example of technology if not, why not?

10. Do you think this object has something to do with the work of an engineer?
    Probe: How would an engineer use this object as part of their work?
    Probe: How would an engineer work on this object as part of their work?
    Probe: Did you see this object in one of our class activities this year?
    If yes, continue with:
    + Does this object remind you of an engineering activity you did at school?
    + Can you tell me about that activity? Did you use science? How? Did you use math? How?
    + Was this activity different than others you do in school? How?
    + What did you like about this activity?
    + What did you not like about this activity?
    + What is something new you learned about engineering or engineers that you did not know before?
    + What can you do with what you learned? (In other words, how will you use what you learned?)

Section IV – Engineering Work

11. Can you give me an example of one type of engineer?
    If a specific type is given: What kind of work does this engineer do?
    If no specific type is given: What do engineers do?

12. Can you give me an example of another type of engineer?
    If a specific type is given: What kind of work does this engineer do?
    If no specific type is given: What do engineers do?
Student Interview September 2012

13. Have you heard of the engineering design process? What can you tell me about it?
   (Probe: If the student remembers the terms then continue to ask how the student used these
   concepts in their engineering lessons. For example: "Did you ASK questions? What kind of
   questions did you ASK? What kind of things did you first IMAGINE? Did you and your
   team members make a PLAN? What did you PLAN look like? Or How did you PLAN?
   What did your team CREATE? In what ways did you and your team members IMPROVE
   your product?")

14. INSERT DESIGN PROCESS KNOWLEDGE QUESTIONS HERE

15. Would you like to be an engineer when you grow up? Why or why not?
   If yes: What would you like to be when you grow up? Why?
   (Probe: If the why seems like something an engineer would also do, ask the student. So you
   think this is something an engineer does? Example: Doctor – help people. Do you think
   engineers help people? If yes, how?)

16. What are you the most interested in, either in school or out of school?

17. What are you least interested in, either in school or out of school?

   Place the number line in front of the student.

18. (While pointing to number line) If you rate (answer to 16) as a 10 for high interest and
   (answer to 17) as a 1 for low interest, how would you rate your interest in engineering?

   Count number of line (1-10) and say into recorder

19. Why did you rate engineering that way? (point to their rating).

20. What was interesting about engineering?

21. What was not interesting about engineering?

22. IF RATE 1-5 on number line: What would make engineering more interesting?

23. IF RATE 6-10 on number line: What would make engineering even more interesting?

24. Do you think engineering could be related to Answer from 16?
   (Probe: How can they be related? How can engineering affect your interest in Answer from
   16?)

25. Is there anything else you know about engineering that you want to tell me?

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STUDENT INTERVIEW PROTOCOL

The purpose of this interview is to learn about what you think engineering is and what kind of work engineers do. I will ask you some questions about the topic of engineering and what you are learning at school about engineering. Please answer the questions as best you can and any answer is okay. If you do not know, it is okay to say "I don't know." If you need time to think, please let me know and I will give you time. If you want to stop, that is okay; I will stop and you can return to class. Do you have any questions before we begin?

Section I – Reflecting on Drawing

Let us take a look at your drawing (drawing of engineer).
1. I am going to ask you a few questions about your drawing. This may sound a little strange, but pretend you are talking to your friend about your drawing over the phone. Your friend cannot see the drawing, so just let them know what you have drawn.

<table>
<thead>
<tr>
<th>ENGINEER DRAW</th>
<th>TOOLS, AFFECTS, OTHER OBJECTS</th>
</tr>
</thead>
</table>
| a. Can you point to the engineer in your drawing? Yes or no? Then, ask if it is not redundant for the student to answer. | a. What is (are) your engineer(s) doing? What does design
data make the word student use mean? What is "stuff"? |
| b. GROUP (If 2 or more figures drawn): Who are the others in your drawing? (Only ask this if it is not redundant for the student to answer) | b. Can you tell me a little bit more about why your engineer is use phrase student uses? |
| c. What can you tell me about your engineer(s)? Follow-up: If student does not mention gender, ask, Is your engineer a person? Is your engineer a boy or a girl? Probe: Can you describe what your engineer looks like? (Only ask this if it is not redundant for the student to answer) Then, ask: What did you draw to make your engineer look like a girl? | c. Is your engineer use phrase student uses to help someone? |
| d. How does (do) your engineer(s) feel? | d. What does your engineer use in his or her work? |
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| f. What are the steps that your engineer uses to use phrase student uses? | f. What are the steps that your engineer uses to use phrase student uses? |
Student Interview May 2013

Environmental
a. Where is your engineer working?
   Follow-up: What did you draw that makes it look like it is indoors or outdoors?
b. What can you tell me about this location (place)?
   Outside Realm: Can you show me (or point to it) in your drawing?
c. ANIMALS/PLANTS/ETC. (if drawn): Are there any animals or plants drawn in your picture?
   Probe: What is this (animal/plant/cloud/river/moon)?
d. Does your engineer work anywhere else? (ex. – fire station)

Vehicle/Machine
a. STRUCTURE (if drawn): What is this (structure) in your picture?
   Probe: What is drawn on your structure? (ex. flag/cross etc.)
b. VEHICLE/MACHINE (if drawn): What is this (vehicle/machine) in your picture?
   Probe: What is your engineer doing with the vehicle?

2. (If any other objects/artifacts are drawn) Point to object in drawing and ask, What is this?

3. If you had more time to draw, what else would you add?

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Now we are going to talk about engineers and engineering.

4. When you hear the word “engineer”, what comes to your mind?

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6. What type of engineer is your engineer (in your drawing)?

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Student Interview May 2013

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Interview Note: The Flower is fake, but need to tell the student to pretend that it is real.

Interview Note: Repeat interview items 8-10 for each item.

8. Can you tell me what this object is?

9. Do you think this object is an example of technology? (Give time to respond. If long wait, ask the child what she thinks the word technology means and then try again.)
   Probe: If yes, Why do you think this is an example of technology? If no, why not?

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   Probe: How would an engineer use this object as part of their work?
   Probe: How would an engineer work on this object as part of their work?
   Probe: Did you see this object in one of our class activities this year?
   If yes, continue with:
   * Does this object remind you of an engineering activity you did at school?
   * Can you tell me about that activity? Did you use science? How? Did you use math? How?
   * Was this activity different than others you do in school? How?
   * What did you like about this activity?
   * What did you not like about this activity?
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Student Interview May 2013

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16. What are you the most interested in, either in school or out of school?

17. What are you least interested in, either in school or out of school?
   Place the number line in front of the student.

18. (While pointing to number line) If you rate \(\text{answer to 16}\) as a 10 for high interest and \(\text{answer to 17}\) as a 1 for low interest, how would you rate your interest in engineering?
   Count number of line (1-10) and say into recorder

19. Why did you rate engineering that way? (point to their rating).

20. What was interesting about engineering?

21. What was not interesting about engineering?

22. IF RATE 1-5 on number line: What would make engineering more interesting?

23. IF RATE 6-10 on number line: What would make engineering even more interesting?

24. Do you think engineering could be related to \text{Answer from 16}?
   Probe: How can they be related? How can engineering affect your interest in \text{Answer from 16}?

25. Is there anything else you know about engineering that you want to tell me?

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Interview Number Line used Fall 2011, Spring 2012, Fall 2012, and Spring 2013
# Teacher Information Sheet

## Personal Information

<table>
<thead>
<tr>
<th>Name:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Year of birth:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Ethnicity:</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐ African American, not Hispanic</td>
</tr>
<tr>
<td>☐ American Indian or Alaskan Native</td>
</tr>
<tr>
<td>☐ Hispanic/Latino</td>
</tr>
<tr>
<td>☐ Asian or Pacific Islander</td>
</tr>
<tr>
<td>☐ White, not Hispanic</td>
</tr>
<tr>
<td>☐ Other</td>
</tr>
</tbody>
</table>

## Teaching Experience

**Check all that apply.**

### Teaching Assignment for 2011-2012:

**Grade Level**
- ☐ First
- ☐ Second
- ☐ Third
- ☐ Fourth
- ☐ Fifth
- ☐ Sixth
- ☐ Seventh-Eighth
- ☐ Ninth - Twelfth

**Subject**
- ☐ Science
- ☐ Mathematics
- ☐ English/Language Arts
- ☐ Social Studies/History
- ☐ Technology
- ☐ Other – Explain:

**Average number of students in your class:**

**Check all that apply.**

### ANTICIPATED Teaching Assignment for 2012-2013:

**Grade Level**
- ☐ First
- ☐ Second
- ☐ Third
- ☐ Fourth
- ☐ Fifth
- ☐ Sixth
- ☐ Seventh-Eighth
- ☐ Ninth - Twelfth

**Subject**
- ☐ Science
- ☐ Mathematics
- ☐ English/Language Arts
- ☐ Social Studies/History
- ☐ Technology
- ☐ Other – Explain:

**ANTICIPATED number of students in your class:**

# Teacher Information Sheet

How would you describe your teaching philosophy in the context of teaching math and science? Check all that apply.

**LEARNING STYLE**
- [ ] cooperative learning — small teams of students, each member is responsible for learning what is taught, but also for helping his or her teammates learn, so the group becomes a supportive learning environment; work face-to-face and learn to work as a team
- [ ] traditional learning — focus is on students individually mastering content to be prepared for the next grade level, lessons are designed to run through the various steps in the learning process to meet the needs of the class as a whole
- [ ] project-based learning — focus is on the centrality of the curriculum, driving questions that lead students to encounter central concepts, investigations that involve inquiry and knowledge building, processes that are student-driven, authentic problems that people care about in the real world; complete tasks that result in a realistic product or presentation to an audience
- [ ] discovery learning — takes place in problem solving situations where the learner draws on his or her own experience and prior knowledge; students interact with their environment by exploring and manipulating objects, wrestling with questions and controversies or performing experiments
- [ ] design-based learning — build on the belief that children learn deeply when they create products that require understanding and application of knowledge; involves stages of revisions as students create, assess, and redesign their products; work often requires collaboration and specific roles for individual students, enabling them to become experts in a particular area
- [ ] inquiry-based learning — students are taught how to ask good questions; learning is then driven by learners’ questions, you help students identify and refine their “real” questions into learning projects or opportunities, you then guide the subsequent research, inquiry, and reporting processes

**TEACHING STYLE**
- [ ] lecture based model — focus is on content, teacher-centered, where you feel responsible for providing and controlling the flow of the content and the student is expected to receive the content
- [ ] demonstrator or personal model — run teacher-centered classes with an emphasis on demonstration and modeling, act as role model by demonstrating skills and processes and then as a coach/guide in helping students develop and apply these skills and knowledge
- [ ] facilitator model — focus on activities, student-centered learning, responsibility placed on students to take the initiative for meeting the demands of various learning tasks
- [ ] delegator model — place much of the control and responsibility for learning on individuals or groups of students
Appendix G  Teacher Interview Protocols

AISD Teacher Interview May 2011

Teacher ID: ___________________________  Cohort: _____

School: ______________________________  Recorder & Track: ____________

Interviewer: ___________________________  Date: ________________

Interviewer Read: This interview has two parts, with the first being focused on collecting information related to your experience of implementation, and the second part being focused on your perspective of the integration of engineering into elementary education more generally.

**Part 1**

1. Which of the following best describes your approach to preparing your students for the EiE unit you taught?

<table>
<thead>
<tr>
<th>Item</th>
<th>Did not do that</th>
<th>Did it, but very little</th>
<th>Did a pretty solid job on this</th>
<th>This was a real focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is engineering?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What is technology?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transforming about technology</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical vocabulary</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Engineering design process</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Model-eliciting activities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (fill in)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Can you verify my record of what engineering lessons you have taught this year? (Note: Lessons taught are listed in an Excel file for each teacher. For some teachers, there are clarifications that need to be made. MAKE NOTES HERE.)
AISD Teacher Interview May 2011

3. Which of the following best describes your overall experience?

<table>
<thead>
<tr>
<th>Item</th>
<th>This did not go well at all</th>
<th>This was just OK</th>
<th>This went pretty well</th>
<th>This went extremely well</th>
</tr>
</thead>
<tbody>
<tr>
<td>How long the unit took compared to how long you thought it was going to take</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Managing student teams</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Overall student engagement</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Overall student attitudes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessing student work</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ Check if created any</td>
<td></td>
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</tr>
<tr>
<td>Teacher created materials</td>
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</tr>
<tr>
<td>□ Check if created any</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall student learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Which of the following best describes your approach AFTER having taught the EiE lessons? Did you use some of the INSPIRE strategies in other areas?

<table>
<thead>
<tr>
<th>Item</th>
<th>Have not done that since doing the EiE unit</th>
<th>Have done that, but very little</th>
<th>We continue to do a pretty solid job on this</th>
<th>This continues to be a real focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model-eliciting activities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is this engineering?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering design process (short activity)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Another EiE (fill in)</td>
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<tr>
<td>Other (fill in)</td>
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</table>

Part 2

<table>
<thead>
<tr>
<th>Item</th>
<th>Teacher Choice</th>
<th>Item</th>
<th>Teacher Choice</th>
<th>Item</th>
<th>Teacher Choice</th>
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<td>2</td>
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<td>5</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td></td>
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AISD Teacher Interview May 2011

Part 1 and 2

Instructions to interviewer: Follow-Up Questions (to be used as necessary)

Elaborations:
- Would you tell me more about that?
- That’s helpful. I’d appreciate it if you’d give me more detail.
- I’m intrigued by what you’re telling me, but I’m not sure I get the whole picture yet.

Open-Ended Clarifications:
- I want to be sure I understand. Could you go over that once again?
- I think I see what you mean, but I’m not sure I understand fully.
- Why do you suppose it worked that way?

Detailed Elaborations:
- Who else was involved?
- When (when, how, etc.) did all this happen?
- How did you fit in? What was your role?
- Can you describe the process in more detail?
- What would be a good example of that?

Part 2

Instructions to interviewer: The interviewee and you will each have his/her own copy of the following questions. As the interviewee reads through the statements and makes choices, record a single final choice for each item. Ask the interviewee about his/her thinking, including asking for clarifications, examples, etc. Use follow-up questions such as “which ones” and “how” to allow the interviewee an opportunity to explain his/her thinking.

Interviewer Read: This part of the interview is about your thoughts regarding the integration of engineering into elementary education more generally. Please take a moment to read through each statement out loud, express your thinking as you go, and then choose the one that is closest to your thinking.

Instructions to interviewer: Work through questions 1-7. Then ask the questions below as appropriate.

COHORT 1 and 2 Teachers:
8. How was your teaching with engineering the same or different than last year?

COHORT 3 Teachers:
8. How was your teaching with engineering the same or different than you anticipated?

ALL Teachers:
9. How do you anticipate teaching with engineering being different next year?
1. Which of the following best describes your thinking about the relationship between engineering lessons and other subject matter in your curriculum? Why?
   A. Engineering takes away from other subject matter the students need to learn.
   B. Engineering is good but it is not as important as other subject matter like math, language arts, and science.
   C. Engineering is good but it is quite separate from other subject matter students are learning.
   D. Engineering is a good way to reinforce a few subjects the students are learning.
      *Follow-up: Which subject areas can it reinforce?*
   E. Engineering is a good way to reinforce all subjects the students are learning.
      *Follow-up: So, math, science, language arts, and social studies? Are some subjects better reinforced than others?*
   F. Engineering is a good way to introduce new concepts from other subject matter.
      *Follow-up: Which concepts?*

2. Which of the following best describes your thinking about the integration of engineering knowledge and skills and other content? Why?
   A. Engineering is a good way to introduce ideas that will be more fully developed elsewhere such as in math or science.
   B. Engineering is a good way to practice ideas first learned in other subject areas, like math or science.
      *Follow-up to A & B: Which ideas?*
   C. Engineering is best done distinct from other lessons, as stand-alone projects.
   D. Engineering is a good way to practice process skills needed in other subject areas.
      *Follow-up: What kind of process skills?*
   E. Engineering examples are useful when teaching other subject matter.
      *Follow-up: Which subjects?*
   F. Engineering examples are useful but difficult to connect to other subject matter.
   G. Engineering examples does not connect well to other subject matter.
AISD Teacher Interview May 2011

3. Which of the following best describes your thinking about student benefits related to engineering education? Why?

A. Students benefit most from the opportunity to engage in creative problem solving.
B. Students benefit most from learning and engaging in the engineering design process.
C. Students benefit most from engaging in team work.
D. Student learning benefits received from engineering education do not justify the time and effort required to teach engineering.
E. Students benefit most from subject matter (math and science) connections to engineering.
F. Students benefit most from activities in which it is OK to fail.

4. Which of the following best describes your thinking about the time needed to teach engineering in your class(es)? Why?

A. There is more than enough time to do all the engineering we choose.
B. There is plenty of time for engineering, but it does take some juggling.
C. There is adequate time for engineering, but we need to spread it out over more than a week.
D. There is adequate time for engineering, but we need to spend a significant amount of time preparing for engineering lessons compared to other lessons.
E. There is barely time for engineering and we struggle to fit it in.
F. There is barely time for engineering and it often means taking time away from other areas that we need to cover.
AISD Teacher Interview May 2011

5. Which of the following best describes your thinking about engineering and state curriculum standards? Why?
   A. Engineering is the best way to prepare students for meeting our state curriculum standards.
   B. Engineering is helpful for preparing students for meeting our state curriculum standards, but it takes a lot of time.
   C. Engineering is helpful for preparing students for meeting our state curriculum standards, but only once the other subject matter has been thoroughly covered.
   D. Engineering is OK for addressing our state curriculum standards, but our current curriculum and approach are sufficient for preparing students.
   E. Engineering is OK for addressing our state curriculum standards, but the focus at our school is different.
      Follow-up: What is the focus at your school?
   F. Engineering is not really a very good match for our state curriculum standards.

6. Which of the following best describes your thinking about assessment and engineering? Why?
   A. Assessment of student learning around the engineering activities is not really necessary.
   B. Assessment of student learning around the engineering activities is best done informally.
   C. Assessment of student learning around the engineering activities is best done with a traditional test.
   D. Assessment of student learning around the engineering activities is best done using a portfolio-type assessment with a rubric.

      Follow-up for B-D: What should be assessed?
7. Which of the following best describes your thinking about teaching engineering when other changes are going on in your school? Why?

A. There is nothing going on at our school that gets in the way of integrating engineering.
B. We have one other big change under way and we need to juggle this with engineering.
C. We have one other big change under way and this really creates problems with doing engineering.
   Follow-up for B & C: What is the one big change?
D. We have two or more other changes under way, but these don’t really affect doing engineering.
E. We have two or more changes under way and this makes doing engineering a real problem.
F. We have some changes going on, but these actually support a stronger integration of engineering.
   Follow-up for D-E: What are the big changes?
Teacher Interview May 2012

Teacher ID: ________________  Cohort: _____
School: ________________  Recorder & Track: _______
Interviewer: ________________  Date: __________

### Teaching with Engineering 2011-2012

**Check all that apply.**

When I prepared to teach engineering, there were instances where

- I prepared alone
- I prepared with my entire grade level team
- I prepared with at least one other INSPIRE teacher
  Teacher Name(s):

- I prepared with at least one other NON-INSPIRE teacher
  Teacher Name(s):

- Other - Explain:

**Check all that apply.**

The students to whom I taught engineering were

- ONLY my students in my grade level class
- ALL students across my grade level, one class at a time
- Students in at least one other class at the same grade level, ONE class at a time
  Teacher Name(s):

- Students in at least one other class at the same grade level, by COMBINING classes
  Teacher Name(s):

- Other - Explain:

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Teacher Interview May 2012

**Check all that apply.**

I taught the engineering lessons  
☐ alone, there was no other teacher in the room  
☐ WITH at least one other teacher in SEPARATE rooms, we rotated students, I taught some engineering content and the other teacher(s) taught additional engineering content  
  Teacher Name(s):

☐ WITH another teacher in the SAME room (shared engineering teaching responsibilities)  
  Teacher Name(s):

☐ WITH another teacher in the room, BUT I was responsible for the engineering content  
  Teacher Name(s):

☐ while another teacher observed  
  Teacher Name(s):

☐ Other - Explain:

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Teacher Interview May 2012

Interviewer Read: This interview has two parts, with the first being focused on collecting information related to your experience of implementation, and the second part being focused on your perspective of the integration of engineering into elementary education more generally.

Part 1
1. Which of the following best describes your approach to preparing your students for the Engineering is Elementary (EiE) unit you taught?

<table>
<thead>
<tr>
<th>Item</th>
<th>Did not do that</th>
<th>Did it, but very little</th>
<th>Did a pretty solid job on this</th>
<th>This was a real focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is engineering?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What is technology?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brainstorming about technology</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical vocabulary</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering design process</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model-eliciting activities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (fill in)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Can you verify my record of what engineering lessons you have taught this year? (Note: Lessons taught are listed in an Excel file for each teacher. For some teachers, there are clarifications that need to be made. MAKE NOTES HERE.)

Before Thanksgiving

After Thanksgiving, before Winter Break

After Winter Break, before Spring Break

After Spring Break, before INSPIRE Assessments

After INSPIRE Assessments

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Teacher Interview May 2012

3. Which of the following best describes your overall experience?

<table>
<thead>
<tr>
<th>Item</th>
<th>This did not go well at all</th>
<th>This was just OK</th>
<th>This went pretty well</th>
<th>This went extremely well</th>
</tr>
</thead>
<tbody>
<tr>
<td>How long the unit took compared to how long you thought it was going to take Resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Managing student teams</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall student engagement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall student attitudes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessing student work</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ Check if created any</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher created materials</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ Check if created any</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall student learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Which of the following best describes your approach AFTER having taught the EiE lessons?
   Did you use some of the INSPIRE strategies in other areas?

<table>
<thead>
<tr>
<th>Item</th>
<th>Have not done that since doing the EiE unit</th>
<th>Have done that, but very little</th>
<th>We continue to do a pretty solid job on this</th>
<th>This continues to be a real focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model-eliciting activities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is this engineering?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering design process (short activity)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Another EiE (fill in)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (fill in)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Part 2

<table>
<thead>
<tr>
<th>Item</th>
<th>Teacher Choice</th>
<th>Item</th>
<th>Teacher Choice</th>
<th>Item</th>
<th>Teacher Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>4</td>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>5</td>
<td></td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Teacher Interview May 2012

Part 1 and 2
Instructions to interviewer: Follow-Up Questions (to be used as necessary)

Elaborations:
- Would you tell me more about that?
- That’s helpful. I’d appreciate it if you’d give me more detail.
- I’m intrigued by what you’re telling me, but I’m not sure I get the whole picture yet.

Open-Ended Clarifications:
- I want to be sure I understand. Could you go over that once again?
- I think I see what you mean, but I’m not sure I understand fully.
- Why do you suppose it worked that way?

Detailed Elaborations:
- Who else was involved?
- When (when, how, etc.) did all this happen?
- How did you fit in? What was your role?
- Can you describe the process in more detail?
- What would be a good example of that?

Part 2

Instructions to interviewer: The interviewee and you will each have his/her own copy of the following questions. As the interviewee reads through the statements and makes choices, record a single final choice for each item. Ask the interviewee about his/her thinking, including asking for clarifications, examples, etc. Use follow-up questions such as “which ones” and “how” to allow the interviewee an opportunity to explain his/her thinking.

Interviewer Read: This part of the interview is about your thoughts regarding the integration of engineering into elementary education more generally. Please take a moment to read through each statement out loud, express your thinking as you go, and then choose the one that is closest to your thinking.

Instructions to interviewer: Work through questions 1-7. Then ask the questions below as appropriate.

COHORT 1, 2 and 3 Teachers:
8. How was your teaching with engineering the same or different than last year?

COHORT 4 Teachers:
8. How was your teaching with engineering the same or different than you anticipated?

ALL Teachers:
9. How do you anticipate teaching with engineering being different next year?

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Teacher Interview May 2012

1. Which of the following best describes your thinking about the relationship between engineering lessons and other subject matter in your curriculum? Why?
   A. Engineering takes away from other subject matter the students need to learn.
   B. Engineering is good but it is not as important as other subject matter like math, language arts, and science.
   C. Engineering is good but it is quite separate from other subject matter students are learning.
   D. Engineering is a good way to reinforce a few subjects the students are learning.
      *Follow-up: Which subject areas can it reinforce?*
   E. Engineering is a good way to reinforce all subjects the students are learning.
      *Follow-up: So, math, science, language arts, and social studies? Are some subjects better reinforced than others?*
   F. Engineering is a good way to introduce new concepts from other subject matter.
      *Follow-up: Which concepts?*

2. Which of the following best describes your thinking about the integration of engineering knowledge and skills and other content? Why?
   A. Engineering is a good way to introduce ideas that will be more fully developed elsewhere such as in math or science.
   B. Engineering is a good way to practice ideas first learned in other subject areas, like math or science.
      *Follow-up to A & B: Which ideas?*
   C. Engineering is best done distinct from other lessons, as stand-alone projects.
   D. Engineering is a good way to practice process skills needed in other subject areas.
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   E. Engineering examples are useful when teaching other subject matter.
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©2012 Heidi A. Diekemper, Purdue University
3. Which of the following best describes your thinking about student benefits related to engineering education? Why?

A. Students benefit most from the opportunity to engage in creative problem solving.
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C. Students benefit most from engaging in team work.
D. Student learning benefits received from engineering education do not justify the time and effort required to teach engineering.
E. Students benefit most from subject matter (math and science) connections to engineering.
F. Students benefit most from activities in which it is OK to fail.

4. Which of the following best describes your thinking about the time needed to teach engineering in your class(es)? Why?

A. There is more than enough time to do all the engineering we choose.
B. There is plenty of time for engineering, but it does take some juggling.
C. There is adequate time for engineering, but we need to spread it out over more than a week.
D. There is adequate time for engineering, but we need to spend a significant amount of time preparing for engineering lessons compared to other lessons.
E. There is barely time for engineering and we struggle to fit it in.
F. There is barely time for engineering and it often means taking time away from other areas that we need to cover.

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Teacher Interview May 2012

5. Which of the following best describes your thinking about engineering and state curriculum standards? Why?
   A. Engineering is the best way to prepare students for meeting our state curriculum standards.
   B. Engineering is helpful for preparing students for meeting our state curriculum standards, but it takes a lot of time.
   C. Engineering is helpful for preparing students for meeting our state curriculum standards, but only once the other subject matter has been thoroughly covered.
   D. Engineering is OK for addressing our state curriculum standards, but our current curriculum and approach are sufficient for preparing students.
   E. Engineering is OK for addressing our state curriculum standards, but the focus at our school is different.
      Follow-up: What is the focus at your school?
   F. Engineering is not really a very good match for our state curriculum standards.

6. Which of the following best describes your thinking about assessment and engineering? Why?
   A. Assessment of student learning around the engineering activities is not really necessary.
   B. Assessment of student learning around the engineering activities is best done informally.
   C. Assessment of student learning around the engineering activities is best done with a traditional test.
   D. Assessment of student learning around the engineering activities is best done using a portfolio-type assessment with a rubric.
      Follow-up for B-D: What should be assessed?

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Teacher Interview May 2012

7. Which of the following best describes your thinking about teaching engineering when other changes are going on in your school? Why?

A. There is nothing going on at our school that gets in the way of integrating engineering.
B. We have one other big change under way and we need to juggle this with engineering.
C. We have one other big change under way and this really creates problems with doing engineering.

*Follow-up for B & C: What is the one big change?*

D. We have two or more other changes under way, but these don’t really affect doing engineering.
E. We have two or more changes under way and this makes doing engineering a real problem.
F. We have some changes going on, but these actually support a stronger integration of engineering.

*Follow-up for D-E: What are the big changes?*
Teacher Interview May 2013

Part 1

Engineering activities expected:
- What is technology? (e.g., brainstorming, image sort, timeline)
- What is engineering? (focused on the work of engineers & relation to technology)
- Introduction to the engineering design process
- Engineering is Elementary: FALL 2011 - PRESENT

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Grade 2</th>
<th>Grade 3</th>
<th>Grade 4 (current)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Book</td>
<td>Mariana Becomes a Butterfly</td>
<td>Aisha Makes Work Easier</td>
<td>Summer Crosses the Kamal River</td>
</tr>
<tr>
<td>2 - Engineer</td>
<td>ALE: Integrated Post Management Play</td>
<td>IE: Assembly Line</td>
<td>Geotech E: Core soil samples</td>
</tr>
<tr>
<td>3 - Science</td>
<td>Test Materials</td>
<td>Simple Machines</td>
<td>Soil Compaction</td>
</tr>
<tr>
<td>4 - Design</td>
<td>Design Hand Pollinator</td>
<td>Design a Subsystem</td>
<td>Evaluate a Site for Tarp</td>
</tr>
</tbody>
</table>

PRIOR to FALL 2011

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Grade 2</th>
<th>Grade 3</th>
<th>Grade 4 (current)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Book</td>
<td>Michelle's MVP Award</td>
<td>Same as above</td>
<td>A Gift from Fadil</td>
</tr>
<tr>
<td>2 - Engineer</td>
<td>Chemical E. Product Research</td>
<td>Package E. Functions of Packages</td>
<td></td>
</tr>
<tr>
<td>3 - Science</td>
<td>Solids &amp; Liquids</td>
<td>Plants</td>
<td></td>
</tr>
<tr>
<td>4 - Design</td>
<td>Design a Process to make good Playdough</td>
<td>Design a Plant Package</td>
<td></td>
</tr>
</tbody>
</table>

- MEAs Possible: Recycle (Button Sort), Potato Chip Factory, Windmill,

Questions 1-3: Use the following codes for “When done?”
1. Before Thanksgiving
2. After Thanksgiving, before Winter Break
3. After Winter Break, before Spring Break
4. After Spring Break, before INSPIRE Assessments
5. After INSPIRE Assessments

Question 4: Add up the minutes and confirm that the number of hours is a good estimate.

Part 1 and 2

Instructions to interviewer: Follow-Up Questions (to be used as necessary)

Elaborations:
- Would you tell me more about that?
  That’s helpful. I’d appreciate it if you’d give me more detail.
  I’m intrigued by what you’re telling me, but I’m not sure I get the whole picture yet.

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Detailed Elaborations:
- Who else was involved? Can you describe the process in more detail?
- When (when, how, etc.) did all this happen? What would be a good example of that?
- How did you fit in? What was your role?

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Teacher Interview May 2013

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Teacher Interview May 2013

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   A. Students benefit most from the opportunity to engage in creative problem solving.
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   Follow-up: What is the focus at your school?

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Teacher Interview May 2013

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   B. We have one other big change under way and we need to juggle this with engineering.
   C. We have one other big change under way and this really creates problems with doing engineering.
      Follow-up for B & C. What is the one big change?
   D. We have two or more other changes under way, but these don’t really affect doing engineering.
   E. We have two or more changes under way and this makes doing engineering a real problem.
   F. We have some changes going on, but these actually support a stronger integration of engineering.
      Follow-up for D-E: What are the big changes?

8. How was your teaching with engineering the same or different than last year?

9. How do you anticipate teaching with engineering being different next year?
VITA
VITA

EDUCATION
Doctor of Philosophy, Engineering Education, Expected August 2016
Purdue University – Lafayette, IN
Dissertation: From mechanic to designer: Evolving perceptions of elementary students over three years of engineering instruction
Committee: Dr. Heidi Diefes-Dux (Co-Chair), Dr. Brenda Capobianco (Co-Chair), Dr. Şenay Purzer, Dr. Allison Godwin, Dr. K. Anna Douglas
Master of Engineering, Mechanical Engineering (Dual Degree BS/MEng), May 2008
Rochester Institute of Technology – Rochester, NY
Bachelor of Science, Mechanical Engineering (Dual Degree BS/MEng), May 2008
Rochester Institute of Technology – Rochester, NY

PRINCIPLE AREAS of INTEREST
K-12 STEM identity formation, policies and evaluation, extracurricular programs

HONORS and AWARDS
2012-2016 Purdue Doctoral Fellowship ($53,661.80)
2015-2016 Purdue Bilsland Dissertation Fellowship ($18,500)
2016 Making Academic Change Happen Emerging Engineering Scholar Support ($1000)
2015 College of Engineering Outstanding Service Scholarship ($2000)
2015 PGSG General Research Grant ($400)
2015, 2015 PGSG Travel Grant ($1000, $900)
2015 Applied Management Principles Attendance Scholarship ($1400)
2015 STEM Think Tank and Conference 2015 Scholarship ($250)
2015 NextProf Conference, competitive selection
2015 Communicating Science Convention (ComSciCon), competitive selection
2014, 2015 PGSG Professional Grant ($500, $775)
2014 PGSG Graduate Student Organization Grant Allocation ($1000)
2013 Purdue Service Learning Grant ($500)
RESEARCH EXPERIENCE

Institute for P-12 Engineering Research and Learning (INSPIRE)
Lafayette, IN
Purdue Doctoral Fellow 6/2012-7/2016
Developed research questions and worked in teams and independently to research and analyze data. Conducted teacher interviews. Analyzed multi-year teacher interviews for expected and emergent themes, worked with a post-doctoral scholar to train oversee undergraduates in coding interviews using Dedoose software. Developed a coding scheme for Draw an Engineer Tests, then trained and oversaw undergraduates in its use.

PictureSTEM K-5 Engineering Curriculum
Lafayette, IN
Research Assistant 1/2015-7/2016
Developed and refined K-5 STEM curricula integrating engineering and literacy with standards-based science and mathematics. Trained teachers in using the curricula, observed classroom implementation, improved curriculum based on teacher feedback, and analyzed video data for conference presentations and journal articles.

University of Delaware Center for Composite Materials
Newark, DE
Independently completed research project involving vibrational analysis of composite armor for the purpose of structural health monitoring. Fabricated composite panels and analyzed structure of panels using ultrasonic sensors with OROS25 vibrational analysis system using the SIDER method for damage detection.

PEER REVIEWED PUBLICATIONS


PEER REVIEWED CONFERENCE PUBLICATIONS


PRESENTATIONS & CONFERENCE PUBLICATIONS


TEACHING EXPERIENCE

Purdue University
Lafayette, IN

Future Faculty Fellow 5/2014–5/2015

Instructor of Record for first-year engineering courses ENGR131/132 Fall and Spring semesters. Developed materials and exercises for use in a flipped classroom environment Summer 2014. As instructor, developed and presented materials in flipped classroom format, provided guidance and feedback for students through modeling and design projects, revised teaching practices from mid-semester feedback, and collaborated with graduate and undergraduate TAs. Evaluations: 4.0 and 3.8 on 5.0 scale.

Early K-12 Engineering Teacher Professional Development Course
Lafayette, IN

Course Designer 11/2012–6/2013

Collaborated in an interdisciplinary team to design four online courses introducing engineering concepts, projects, and pedagogy to early K-12 pre-service and in-service teachers. Designed course and led the team in final course design and implementation.

Kanazawa Technical College
Kanazawa, Japan

Assistant Professor of Mechanical Engineering 10/2008–4/2012

Presented engineering content to Japanese students aged 15 – 20 in English. Co-taught hands-on courses with Japanese professors including an introductory machine shop course and a team-centered design-build project. Independently taught lecture-based courses including robotics, materials science, mechanics of materials, and technical English. Created materials for classes and course textbooks. Wrote and presented papers
and posters at various conferences and symposia. Contributed to efforts to adapt KTC’s curriculum to CDIO Standards by providing evaluations of and feedback for courses as well as assisting with translations of CDIO materials.

Rochester Institute of Technology, Dean’s Office
Rochester, NY
Assisted mechanical engineering students with concepts, homework problems, and test preparation during open office hours. Concurrently tutored several students studying different subjects.

SERVICE

Purdue University Peer Ombuds
Attended training through The International Ombudsman Association, represented Ombuds services at new graduate student orientations, university Health Fair, and other events, met with graduate students individually to share available resources and options.

Journal of Pre-College Engineering Education Research (J-PEER)
Editorial Assistant 6/2013 – 8/2015
Acted as point of contact for reviewers and authors, facilitated typesetting and editing process, solicited journal submissions, and represented the Journal at conferences.

Purdue Discipline Based Education Research Graduate Student Organization
Member 12/2012 –present
Planned and executed a one-day symposium to study and strengthen the DBER community at Purdue University. Presented and led discussions on Next Generation Science Standards and educational research methods.

Reviewer
International Journal for Engineering Education 2015
ASEE Conference & Exposition, ERM, NEE, K-12, & Student Div. 2010-2016
FIE Conference 2015, 2106

American Society for Engineering Education, Student Division, National Membership Chair 6/2014 – 6/2015
Oversaw Mentorship Program and Facebook page, created survey to understand Student Division members’ needs, and worked with E-Board to make decisions.

Purdue Educational Policies Committee (EPC)
Graduate Student Representative 9/2013 – 5/2015
Represented the graduate student perspective as a voting member in monthly committee meetings. Assisted with creating inclusive language in
policy updates for Purdue University. Surveyed the graduate student body on pieces of university policy as needed. During tenure, transfer credit, military absence, and evening exam policies were updated.

**Purdue Graduate Student Government (PGSG)**

*Webmaster*  
Filled position after two year gap. Updated website, added important information, streamlined updating for sustainability, participated in E-Board meetings and decisions.

*Student Trustee Search Committee*  
2/2015 – 5/2015  
Represented graduate students in the interview process for Purdue’s Student Trustee.

*Grant Review and Allocation Committee (GRAC) Member*  
9/2012 – 5/2014  
Review and discuss grants. Revised, unified, and streamlined documents.

*GRAC Vice-Chair for Travel Grants*  
Point of contact for Travel Grant applicants and campus offices. Sent applications to reviewers, normalized and analyzed results, and notified applicants of application status.

*Engineering Education Senator*  
Voting member representing the Engineering Education student body. Updated ENE student body via e-mail and surveyed members to fully represent them when voting.

**ASEE, Purdue Student Chapter**

*President & Research and Scholarship Chair*  
Revived Student Chapter after 1.5 year dormancy. Planned one research-related event per month, coordinated meeting with Drs. Richard Felder and Rebecca Brent, assisted with successful GSOGA grant application ($1000), and mentored future E-Board members.

**Purdue Engineering Education Graduate Student Association**

*Treasurer & Finance Chair*  
Oversaw funding including reimbursement and budgeting for events, planned and implemented fundraising events, and assisted with general event planning and facilitation.
OUTREACH

Purdue Women in Engineering Program Introduce a Girl to Engineering Day

Activity Co-Lead 1/2015 – 2/2015
Collaborated with Dr. Sean Brophy to enhance the civil engineering activity with a shaker table. Updated an environmental engineering outreach activity for 9th and 10th grade girls incorporating research-based messages to be presented in February.

Activity Co-Lead 1/2014 – 2/2014
Updated a civil engineering outreach activity for 9th and 10th grade girls incorporating research-based messages. Trained 4 assistants.

Activity Leader 1/2013 – 2/2013
Designed an electrical and computer engineering outreach activity for 9th and 10th grade girls incorporating research-based messages. Trained 4 assistants, presented to 90+ girls.

Purdue GK-12 Program
Lafayette, IN
Volunteer Graduate Teaching Fellow 9/2013–11/2013
Observed, co-taught, and designed and implementing an engineering lesson plan in a 7th grade science classroom.

Purdue Women in Engineering Program Access Engineering
Lafayette, IN
Leadership Team Member 5/2013–8/2013
Worked as part of a team to provide engineering activities at various summer camps to children ages 5 – 12. Introduced activities, monitored children during activities and provided assistance, support, and clarification of the project as necessary.

Center for Science Teaching & Learning
Worldwide, Online
Clean Tech Competition Judge 2014, 2015
Judged and provided feedback for a world-wide K-12 research and design competition.

Pre-Kindergarten Outreach
Lafayette, IN
Assistant 10/2012, 6/2013
Designed and presented two engineering experiences for 3-5 year old students involving an engineering video, a book related to engineering, and a hands-on building project.
INDUSTRY EXPERIENCE
ATSI Engineering, Inc.
Amherst, NY
Performed thermal, fluid, and static stress calculations on components of steel plants and created standard ISO 9000 reports to present the results of calculations. Worked independently and collaboratively to implement design changes based on calculations.

Garlock Sealing Technologies
Palmyra, NY
Designed fork lift attachment to lift new 400 lb. packaging materials. Performed repeatability and reliability tests on various equipment. Tested gasket samples and used data to determine required changes in formula for gaskets. Reviewed rejected material and determined cause of failure in weekly quality control meetings.

Clough, Harbour and Associates, LLP
Albany, NY
Organized and entered job files into a Microsoft Access database, wrote reports using gINT Logs and AutoCAD, visited job sites. Began as a part-time job, was asked to remain over the summer and become a full-time employee.

PROFESSIONAL DEVELOPMENT AND CERTIFICATIONS
2016 Graduate Teaching Certificate, Center for Instructional Excellence, Purdue University
2015 Effective College Teaching Workshop
2008 Engineer in Training - Fundamentals of Engineering (FE) Exam, New York State

PROFESSIONAL MEMBERSHIPS
American Society for Engineering Education (ASEE), 2010 - present
Girl Scouts (Lifetime Member), Gold Award Recipient