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USING CONCEPT MAPPING TO COMPARE INTENTIONALLY TAUGHT OUTCOMES WITH ACTUAL OUTCOMES OF A PREKINDERGARTEN ROBOTICS AND PROBLEM SOLVING CURRICULUM

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Abstract: The purpose of this paper is to share knowledge gained using a comparison of a master concept map of lessons in which the children participated to concept maps created from children's interviews asking about their learning during the lessons. The lessons were part of the Robotics and Programming for Prekindergarten (RAPP) project, designed to teach 4- and 5-year old children about robotics, programming, and problem solving. The RAPP implementation that is reported in this paper occurred in five classrooms located in two childcare centers. One piece of the evaluation of the project was interviewing children near the beginning and end of implementation to assess their knowledge of both robotics and problem solving. Researchers transcribed the interviews and created concept maps from each transcription. These interview concept maps were compared to a master concept map of RAPP instruction. Comparisons showed that the teachers used the robot with their children independently of RAPP researchers and introduced some concepts earlier than the researchers. Comparisons demonstrated areas of strength in the lessons (vocabulary cards and songs), and identified areas which needed improvement (last two steps of the problem solving process). Researchers will use the findings to strengthen the RAPP curriculum, and will continue using this process of using concept maps to compare what we are teaching to what children are actually learning in future research projects.

1 Introduction

The purpose of this paper is to report on the use of the concept maps formed from transcriptions of children's interviews to document student learning from the first three lessons of the Robotics and Programming for Prekindergarten (RAPP) project. A comparison is made between the maps of the children's interviews and the master concept map of the first three lessons of the RAPP curriculum. RAPP is a series of instructional lessons designed to introduce 4- to 5-year-old children to robotics, programming, and problem solving. As part of the evaluation of the project, the children were interviewed both near the beginning and again at the end of implementation to assess knowledge gained during the lessons. RAPP researchers concept mapped the interview transcripts. The focus of this paper is the first round of interviews which occurred after the first three RAPP lessons. As the paper is about a robotics, programming, and problem solving curriculum, we first more fully describe RAPP and the rationale for developing engineering lessons for prekindergarten children.

1.1 Prekindergarten Robotics, Programming, and Problem Solving

Because many jobs require proficiency in science, technology, engineering, and mathematics (STEM) skills, the National Science Board advised President Obama in 2009 to make STEM education a priority in early childhood education (National Science Board, 2009). Promoting science in prekindergarten prepares children for later science learning and is a developmentally appropriate practice that builds upon young children's natural desire to explore new things (Bers, 2008). However, children's natural curiosity concerning technology and engineering are rarely nurtured in prekindergarten classrooms. Furthermore, the introduction of engineering and programming coupled with the use of robots helps children learn about abstract mathematics and science concepts in concrete ways and promotes the development of children's technological fluency (Cejka, Rogers, & Portsmore, 2006; Rogers & Portsmore, 2004; Weyth, 2008). Children as young as 4-years old can understand programming rules and create commands for robots to follow. While promoting children's engineering skills, programming also strengthens many foundational concepts including patterning, sequencing, modularity, and the understanding of cause-and-effect relationships.

The purpose of RAPP was to develop and implement innovative STEM lessons for children in prekindergarten classrooms. After reviewing commercially available robots designed for use with young children, the RAPP research team selected KIBO for this project. KIBO is a robot developed at DevTech, Tufts University (Boston, Massachusetts, USA) and commercially available at KinderLab. KIBO is interactive, designed specifically for use with 4- to 7-year old children, and uses programming blocks containing words for readers, pictures for nonreaders, and bar codes. After building their programs with the blocks, children can u the program using KIBO's embedded scanner so that no screen time is required. Three RAPP researchers designed and implemented 12 robotics and programming lessons introducing children to engineering, programming, and problem solving using the KIBO robot. The pilot was implemented over a 3-month period in the participating classrooms and concluded with a concept-map-assisted review of the lessons. Figure 1 presents an overview of the RAPP project. (See McLemore & Wehry, 2016 for more complete RAPP details and results from other evaluations.)

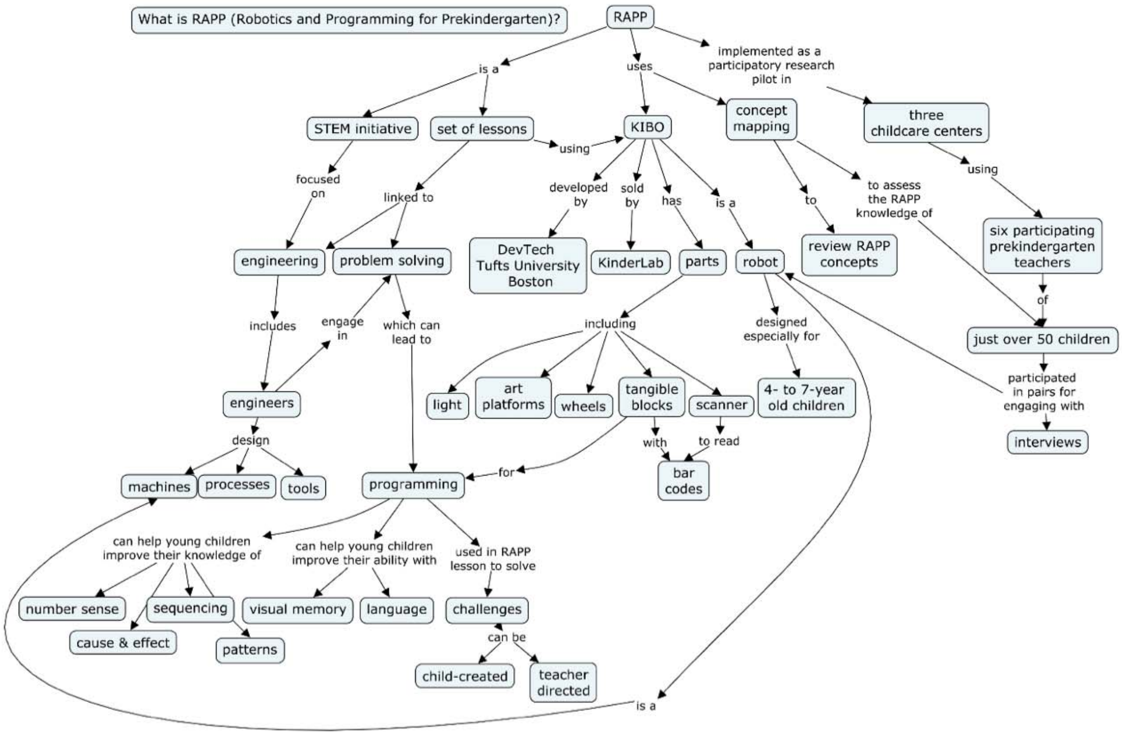

Figure 1: An overview of the robotics and programming project.

2 Participants, Data, and Methodology

2.1 Participants

The RAPP pilot project involved developing, iteratively refining, and evaluating RAPP using a partnership between a university research team and six experienced prekindergarten teachers from three childcare centers located in an American urban area. All three childcare centers enrolled children from low-income families. All of the teachers were women, and five of the six teachers were Black and the other was Asian. In this area, the typical non-public-school-based childcare center teacher has no more than an Associate's Degree. During February 2016, the teachers attended a 3-hour professional development workshop designed to teach about KIBO and programming. Each attending teacher received a KIBO kit to use in her classroom.

2.2 Data

One of the elements of the overall RAPP evaluation plan called for interviewing young children near the beginning and at the end of the project implementation. This paper is focused on the first set of interviews and the children from only two of the childcare centers, the five participating teachers, and the two researchers that worked with the teachers at these two childcare centers. The children at the remaining childcare center had participated in more than three lessons at the time they were first interviewed. The remainder of this section provides information about the RAPP interviews of the young children.

Roberts-Holmes (2014) suggested that young children can feel uncomfortable in one-to-one interviews when the interviewer is not very familiar to them. One way to make young children comfortable is to interview them in groups. Roberts-Holmes also stated that children enjoy the social aspect of the focus-group setting, are more relaxed, and encourage each other in articulating their thoughts. Based on these thoughts, each researcher interviewed the children that she taught.

Figure 2: The Solve It 4 poster.

The research team scheduled the first interviews during the first full week of March, after completing three lessons, to provide time for the children to become familiar with the researcher. We chose to interview two children at a time to accommodate the large number of children participating in RAPP lessons and to encourage less talkative children. When interacting with KIBO during the lessons, the children worked in pairs. The research team decided that pairing them for the interviews was an efficient and logical choice. Two focal questions shaped the interviews: What do you know about KIBO? What do you know about problem solving? Visual aids used during the interviews included the KIBO vocabulary card for the first question and the Solve It 4 (CSEFEL, 2013) poster for the second question (Figure 2). The children's interviews were transcribed and concept mapped.

Concept mapping is documented as a strategy for examining children's understanding of relationships among concepts (Novak & Gowin, 1984). Researchers at the Institute of Human and Machine Cognition summarized the uses of concept mapping in educational settings to include support for learning, assessment of learning, and for the organization and presentation of knowledge. Assessment applications of concept mapping included formative and summative assessments and to document changes in children's conceptual knowledge (Coffey et al, 2003). Many researchers have used concept maps to assess young children's knowledge (Cassata-Wildera, 2008; Monroe-Ossi, Wehry, Algina, & Hunter, 2008; Novak & Cañas, 2006).

RAPP researchers provided non-verbatim transcriptions of the interviews and concept mapped the transcripts. Final data included one master concept map depicting the learning objectives and activities of the first three RAPP lessons, Figure 3, and 30 concept maps from the children's interviews in the five classes.

2.3 Methodology

We visually compared the 30 concept maps to the master concept map in Figure 3. Points of comparisons involved the concepts linked to KIBO: has wheels, motor, scanner, brain; can move; and is held like a sandwich. Comparisons for problem solving came from the Solve It 4 and minimally included ask, think, try, and share. Concept maps that included those concepts indicated that the children could express in the interviews what the researchers' lessons included. However, all five teachers had KIBO kits and had attended the workshop on how to work with KIBO. Thus, teachers had opportunities to use KIBO with their students independently of the researchers. In fact, at one the childcare centers, all three teachers did not have the opportunity to see the researcher work with their children, while at the other childcare center, the teachers did have the opportunity to see the researcher work with their children. So some teachers were observing and extending RAPP lessons while others were working with KIBO totally on their own. Our assumption was that concepts beyond those presented in Figure 3 were the result of the prekindergarten teachers working with KIBO during their instructional time.

3 Results

The results of comparing the master concept map to the 30 interview maps are shown in Table 1. Four indicators are presented: The number of the children's interviews that indicated a teacher effect, the number of children who did not express all four of the Solve It 4 steps, the number of children who did not mention either scanning or scan, and a list of concepts that the class collectively expressed that could be attributed to the teacher rather than the researcher.

As can be seen, some of the children in all of the classes indicated that their RAPP knowledge was augmented by their classroom teacher. Knowledge of the Solve It 4 indicated that over half of the children in all classes could not name the four steps in the cycle even when the pictures on the poster in Figure 2 were available. The try step was the most frequently missing piece across the interviews when children spoke about the cycle. Some of the children did not talk about any of the steps and gave examples of problem solving instead. Likewise, with the exception of one class, at least 50% of the children did not express anything relative to KIBO about scanning. In one class, none of the children mentioned either scan or scanner. The list of new concepts, for the most part is a list of the functions of the programming blocks and the mechanisms that are visible when executing a program.

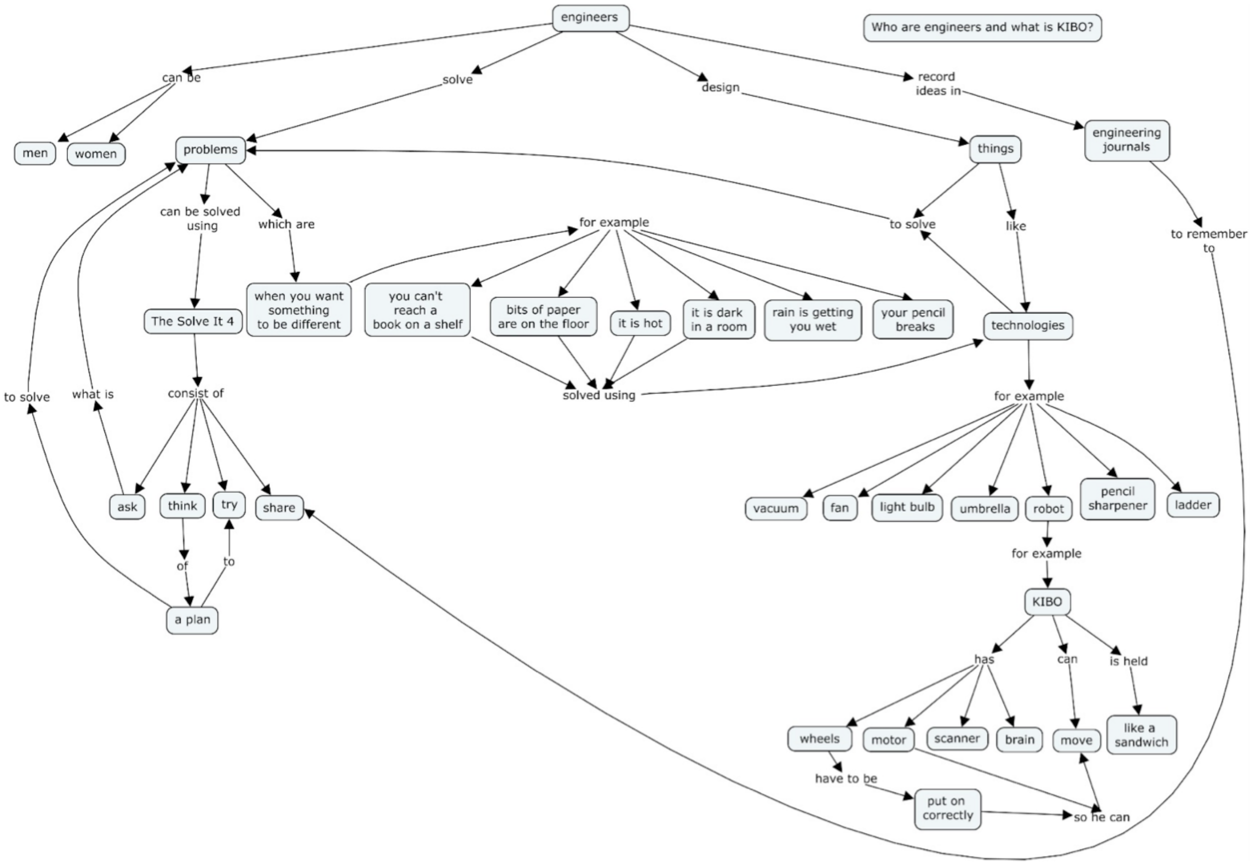

Figure 3: Master concept map of the first three RAPP lessons.

The concept maps in Figures 4-6 represent the variations in the children's interviews. The concept map in Figure 4 is as close as any to the minimal representation in Figure 3. The concept map in Figure 5 is the most expansive of the children's interviews about KIBO, and the concept map in Figure 6 is very representative of expansive concept maps of knowledge of problem solving.

The concept map in Figure 4 is representative of the children who minimally expressed the concepts of the first three RAPP lessons. The concepts with white backgrounds indicate that they are concepts in Figure 3, but not expressed by the children. None of the children's concept mapped interviews indicated the exact minimal concepts. If they knew more than what is on this concept map, they generally spoke using a lot more KIBO vocabulary and added examples of problems to solve or voiced problem solving as a cycle.

The concept map presented in Figure 5 is from an interview in which the children expresssed some of the vocabulary of the KIBO programming blocks. In three instances, the children could add a level beyond the first level, and they did add cross links including one that presents a causation. The children knew that KIBO has blocks (programming) to scan, but did not connect the *blocks* in the second level of the map to their corresponding functions in the first level (*sing*, *beep*, *spin*, play notes, and *go straight*).

Teacher	Summary of Concepts
C1T1 (7)	7 indicated concepts that are not from first three RAPP lessons 4 missed at least one step of the Solve It 4 cycle 3 did not say scanner or scan New concepts: has light, programming blocks (beginning and end) to tell it what to do, button to push to move, and sensor; can sing, play notes, beep, go straight, decorate, scans bar codes, spins & we take care of KIBO
C1T2 (7)	7 indicated concepts that are not from first three RAPP lessons 5 missed at least one step of the Solve It 4 cycle 4 did not say scanner or scan New concepts: has an ear to listen, a telescope, lightbulbs (3 that can come on), programming blocks (yellow, blue, & red: begin, left, right) and button to push to move; and can go straight, shake, decorate, and spin
C2T1 (5)	4 indicated concepts that are not from first three RAPP lessons 5 missed at least one step of the Solve It 4 cycle (*try* missing) 4 did not say scanner or scan New concepts: has chip, a light, and can push nose to move and can scan
C2T2 (6)	4 indicated concepts that are not from first three RAPP lessons 5 missed at least one step of the Solve It 4 cycle (*try* missing) 5 did not say scanner or scan New concepts: can go straight & turn, can spin & go in a circle, has blocks, can shake
C2T3 (5)	4 indicated concepts that are not from first three RAPP lessons 3 missed at least one step of the Solve It 4 cycle (*try* missing) 5 did not say scanner or scan New concepts: can sing, light, spin, shake, stop, & go

Note. Teacher C1T1 is teacher 1 at childcare center 1 and the number in parenthesis after C1T1 indicates the number of interviews from the class. Similarly, C2T2 is teacher 2 from childcare center 2.

Table 1: Results of Comparing the Children's Concept Maps and the Master Concept Map of the First Three Lessons

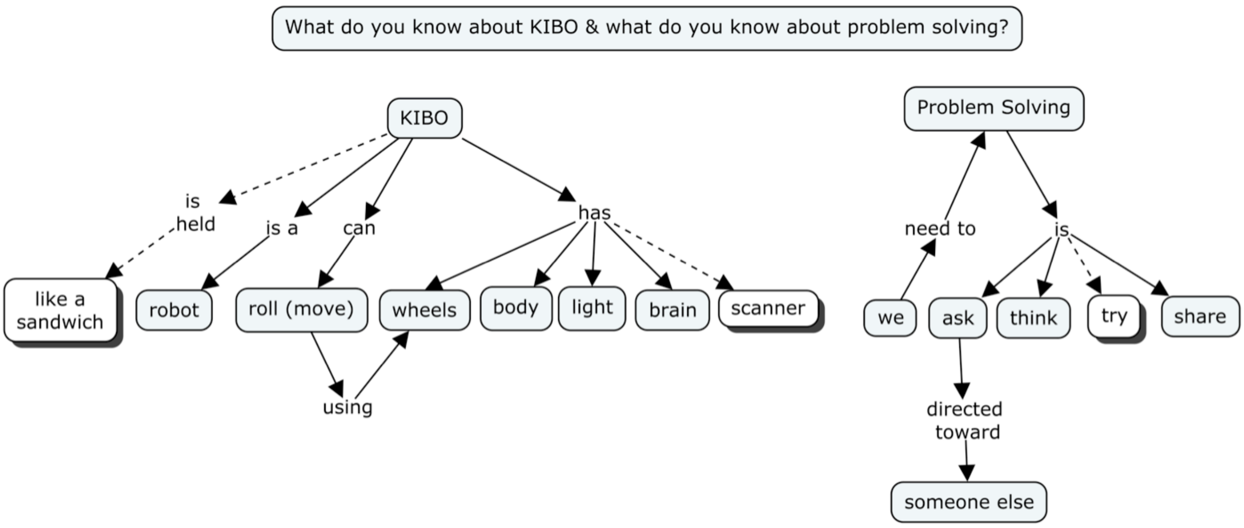

Figure 4: Concept map from an interview that almost replicates the minimally expressed concepts of the first three RAPP lessons.

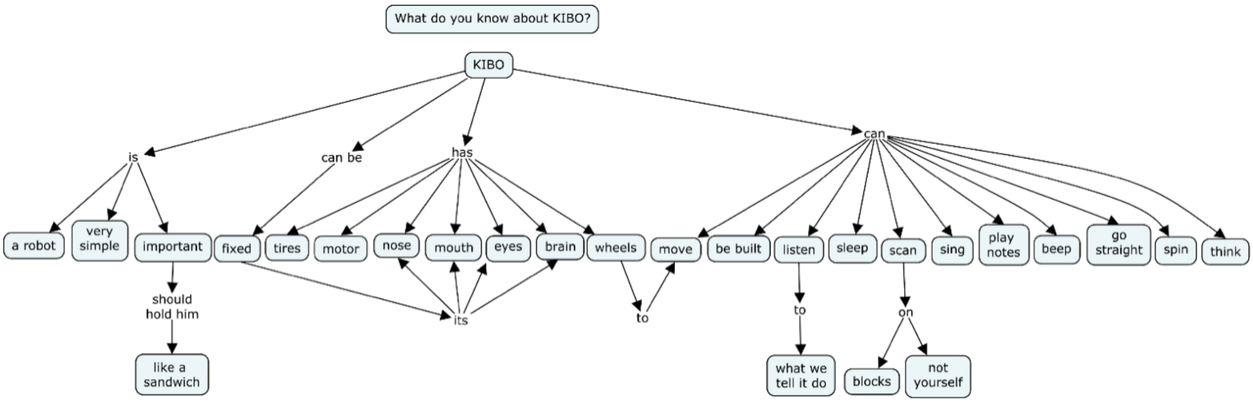

Figure 5: Concept map from an interview that greatly expands the KIBO concepts presented in the first three RAPP lessons.

The concept map presented in Figure 6 is from an interview in which the children speak of problem solving as a cycle. The children expressed all four steps of the Solve It 4 process as a cycle using an if-then statement and *try again*. They also identified *share* as talking rather than sharing toys and playing nice. The interview further connected problem solving to engineering and provided an example of a problem to solve from the lessons.

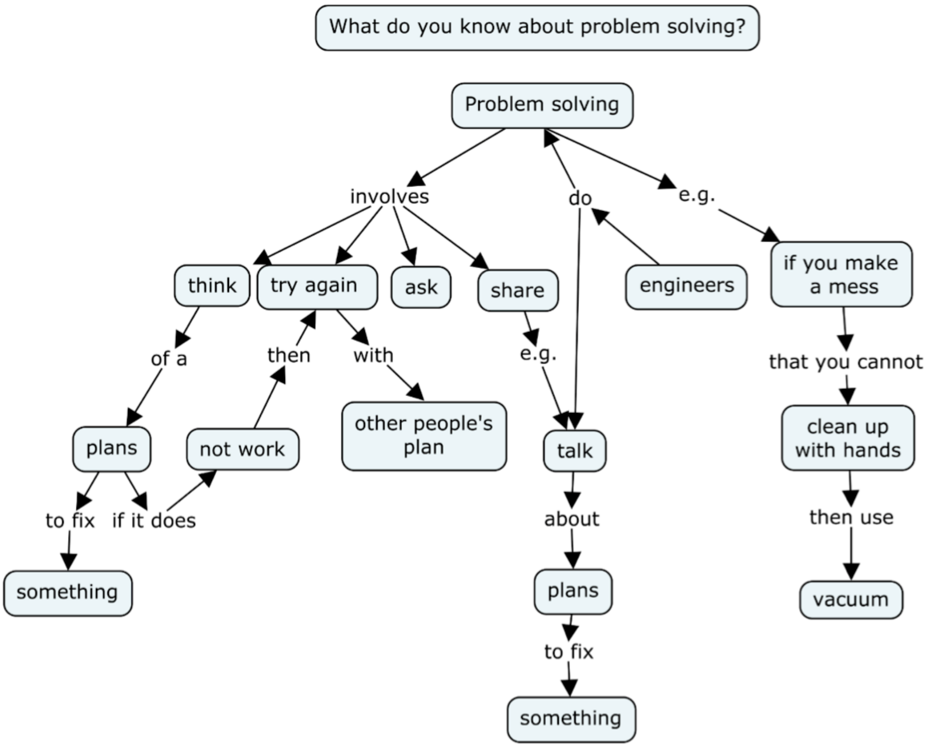

Figure 6: Concept map from an interview that exceeds the minimally stated problem solving concepts presented in the first three RAPP lessons.

4 Discussion

Comparing the concept maps of the children's interviews to the master concept map of the first three lessons documented that all five of the prekindergarten teachers were using KIBO in their classrooms independently of the researchers. The researchers did not have the opportunity to actually observe this, but knew through conversations with the teachers that this use of KIBO was happening. We believe that the information that the children discussed during their first interviews that had not yet been taught was the result of the teachers working with KIBO in their classrooms independently of the researchers. The lists of new concepts children named in the interviews presented in Table 1 suggest that the teachers had introduced many possibilities of KIBO and did so sufficiently enough for the children to voice this knowledge in their interviews. Thus, comparing the set of children's concept maps to the master concept map provided insight into how the teachers were allowing the children to interact with KIBO in addition to what was happening in the researcher-led lessons. Based upon the information that the children shared during the interviews that had not yet been taught during the RAPP lessons, the research team concluded that the teachers were adding value to the project.

The concept map comparisons also identify areas where the children either could not express or were uncomfortable expressing knowledge of KIBO or problem solving or both. Though children were taught the four steps of the solving problem process using a song during the first three lessons, they had only been introduced to the first two steps of the process using vocabulary cards and instructional activities and discussions. Therefore, we were not surprised that several children missed naming the final two steps during the initial interview. The research team was also not surprised that the children's knowledge of problem solving was not solid. Problem solving is a very abstract concept and young children are more comfortable talking about concrete ideas. To help children remember and connect to the abstract information about problem solving presented in the curriculum, the RAPP team developed the Solve It 4 poster, songs, and concrete examples from the children's daily lives. The children quickly learned the songs and sang them throughout the day, even when they were not engaged in RAPP activities. The teachers commented on how often students referred to the problem solving process that they learned with KIBO to solve problems on the playground and during learning center time.

In future implementations, the Solve It 4 poster will be revised relative to *try* and *share*. The picture used for try is of a child putting together three KIBO programming blocks to form a program. The children had not used programming blocks in class by the third lesson, so the picture was not a helpful visual reminder at this early stage in the project. Additionally, prekindergarten children typically understand the meaning of the word *share* as sharing toys with the other children. Teacher's comments usually center on having nice hands and taking turns so the research team plans to add more discussion of this concept. When using the term *share* in RAPP lessons, the children need to know that thoughts can also be shared by talking, drawing, and writing about them.

The findings from this project will be used to refine the RAPP lessons. The researchers did not expect the children to express so much of the new vocabulary and concepts in the lessons. The design of the RAPP lessons allows the new vocabulary to continually build and reinforces the concepts. All concepts have associated vocabulary cards for the children to use. A vocabulary card used in the first lesson is the engineer card pictured in Figure 7. The team plans to assure that vocabulary words are continually used and reviewed throughout the lessons to assure they are learned.

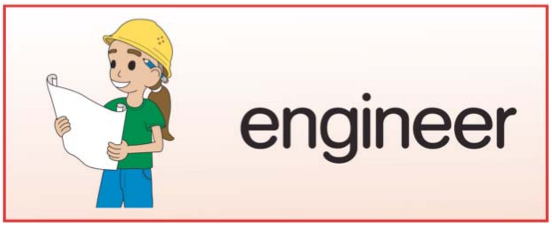

Figure 7: The engineer vocabulary card.

Pairing the children for the interviews most likely made them more comfortable, while also providing security for them to try out their newly minted knowledge. In the interviews, the children were obviously reacting and amplifying what each other were saying.

An area for future research is to use this process of concept mapping lessons and comparing them to children's interview concept maps more frequently to monitor and revise our instructional plan as we continue to build a 6-month curriculum. However, interviewing children, even in pairs, is very time intensive due to the need to transcribe the interviews and to then concept map the transcripts. For this purpose, perhaps a random sample of pairs to interview would be sufficient.

5 Acknowledgement

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