Chapter

Redcay's STEM-oscope Model: Connecting STEM Education, Social Robots, and Metacognition

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Abstract

A qualitative analysis of second grade students' responses to Science, Technology, Engineering, and Mathematics (STEM) Challenge demonstrated that young learners use metacognitive skills throughout challenges (beginning, middle, and end). Students work through Engineer by Design (EbD) loop: (1) define and research a problem (2) brainstorm and explore possible solutions (3) develop a prototype (4) test (5) reflect (6) redesign (7) re-test. Social robots can be used throughout STEM challenges to model think alouds. Educators prepare the environment for young learners. Specially, educators find meaningful ways for students to connect concrete and abstract ideas. Five themes emerged from students' responses to two STEM challenges. The theme with the highest frequency demonstrated that students were making real-world connections. The additional themes included metalinguistic awareness, problem solving strategies, social metacognitive thinking, and concrete to abstract thinking. The five themes were connected to metacognitive thinking, EbD loop, and 6 E's of Science Inquiry. The themes were arranged in a new model called Redcay's STEM-oscope Model used to describe the connection between STEM education, social robots, and metacognition. The research study adds to the existing body of research about STEM education by directly linking metacognitive skills, STEM education, social robots.

Keywords: STEM challenges, metacognition, design loop, engineering by design, qualitative research, problem-based learning, social robots, think alouds, 6 E's of Science Inquiry

1. Introduction

Visualize this…A teacher is co-teaching a group of second grade students with a social robot. The teacher has coded the robot to introduce the Science, Technology, Engineering, and Mathematics (STEM) Challenge to the class. The robot states: "We are going to complete a STEM challenge. Yesterday, we explored different bridges using our Virtual Reality Field Trip. Also, we read April Jones Prince's 'Twenty-One Elephants and Still Standing' about how elephants were used to test durability of the Brooklyn Bridge. Today you are going to start to think about how you will build a bridge that can hold as many plastic elephants (weights) as possible." The teacher shows the student materials that are available to use for the STEM challenge. Further, the teacher tells the students that they need to make sure that they create durable drawbridge that can open and close. The students examine the little baby-pool that was set-up in the classroom to see how the bridge will need to safely connect two different areas. Sophie, a girl in the class, starts to measure the area so she can consider this as he starts to create a plan. Davin, a boy in the class, goes to get his sketchpad so he can start to sketch a possible design. The students start to share ideas with their group members. The students are starting to work through the Engineer by Design (EbD) process.

The previous scenario is similar to what is occurring in a second-grade classroom in Pennsylvania, United States. Dr. Jessica D. Redcay codes Robon, the first female robot, from RoboKind® to co-teach lessons. Previously, teachers have not used robots as teaching assistants in the classroom so a limited amount of research is available. RoboKind® uses the platform of providing Robots4STEM. Therefore, the research study specifically focused-on the connection between using Robon during a STEM challenges with second grade students. Robon is a robot so the teacher can use a loop-code to repeat concepts to students who might benefit from repetition. Science topics include a lot of content-specific terms and concepts. Students can develop strong background knowledge about new content that will be covered throughout the unit. In addition, Robon is coded to model think alouds to students throughout STEM challenges. All of these types of activities should help foster metacognitive thinking. However, since this model for teaching was not previously utilized additional research was need to explore this model.

Science Technology Engineering Math (STEM) Challenges involve students using problem-based learning (PBL) [1]. Engineers are problem solvers who design or improve the design of different things in the world [2]. Designing is a process not a product so the word is used a verb not a noun [2]. Engineers use Engineer by Design (EbD) loop that include: (1) define and research a problem (2) brainstorm and explore possible solutions (3) develop a prototype (4) test (5) reflect (6) redesign (7) test [3]. The steps are centered around three main stages of the loop: beginning, middle, and end. The three main stages are connected to define, design, and optimize [4]. The beginning stage involves engineers defining the problem. This stage occurs during step one of the design loop. The middle stage involves designing. Steps two through four are included in the middle stage. The end stage involves optimizing or changing the new idea to address a problem. Steps five through seven occur during the end stage [4].

2. Literature review

STEM challenges are used in the classroom with students to help students have a chance to learn more about real-world problems [3]. A STEM challenge involves the teacher providing a real-world problem, and the teacher provides a question for the students to try to solve. The students work with a team, within specified parameters, to try to develop and test possible solutions [5]. A STEM challenge has theoretical underpinnings within a constructivist or inquiry approach [6]. Further STEM challenges utilize Bybee's 6 E's Instructional Model. The 6 E's include engage, explore, explain, elaborate, evaluate, and engineer [6]. Research studies have supported the use of STEM challenges with young children [5]. Prior to the current research study, social robots were not used in conjunction with STEM challenges.

2.1 Metacognition and STEM education and social robots

2.1.1 Metacognition and STEM challenges

Previous research studies have not directly linked STEM education and metacognition. However, STEM challenges have skills that have been linked to metacognition, Metacognitive thinking starts to occurs when a child is between the ages of 5 and 6 [7]. At this stage students start to think about their own process of thinking [7]. The research study involved students who are 7 and 8 years old. Students in second grade have only had a year or two to start developing metacognitive skills. Young children are naturally curious. As students work through a STEM challenges, children are using the inquiry model. Previous research studies have demonstrated that students show higher levels of metacognitive thinking when they become curious about task because students become more interested in activity seeking information to explain the unknown [8]. Additional research studies have demonstrated that students learn social metacognitive skills when working with groups [9].

2.1.2 Metacognition and social robots

Students demonstrate higher levels of metacognitive thinking when think-alouds are used by social robots [10]. Students need to be provided with guidance to encourage introspection. Vygotsky believed that students need to be provided with scaffolds or supports to help students understand that they can construct their own knowledge [7]. Additionally, students develop metalinguistic awareness when they are provided with models and time to reflect on experiences [7].

RoboKind® is a company that created a social, codable robot. The robot named Milo from RoboKind® has various facial expressions to encourage emotional awareness. Milo has a visual communicator on his chest. The pictures help make learning easier for students. Further, the robot can speak in different languages [11]. Originally, the robots were used to help children with Autism. Various teachers who have used Robots4Autism explained that social robots helped increase the engagement level of the students. Further, students develop better communication skills [12]. Social scripts are used with Milo to help increase students' ability to converse [13].

RoboKind® expanded Robots4Autism to Robots4STEM with Jett. Students learn visual programming as they work through different modules focused-on different key coding concepts. Students are able to code a personalized avatar, and students can sync the code with a robot [14]. Students are able to see concrete results of what they are coding. Jett has a sister robot who was released in 2019. Her name is Robon [14]. Robon, the first female Robots4STEM robot, was used as a part of this research study. The robot which was a part of the research study is used by a Girls Who Code Robots Club. In addition to the coding club, Robon is coded to act as a teaching assistant in the classroom. Robon was used in the research study to provide students with an introduction to different STEM topics. Since the idea of using social robots as a teacher assistant in the classroom is a new concept, research does not exist yet. Specially, previous research did not explore parallels between the use of STEM challenges and social robots to metacognitive skill development.

2.2 STEM education at an elementary level

2.2.1 Various STEM education formats

Some elementary schools have STEM specialists, and some elementary school teachers are responsible for teaching STEM lessons. Further, some schools have adopted STEM programs, and sometimes teachers are designing their own STEM lessons. STEM education at an elementary level can occur within a teacher's existing classroom or some schools have a STEM lab. The current research study involved a school that did not have a separate STEM lab area. Also, the school did not have a

STEM specialist. At the school of research study, classroom teachers were responsible for the STEM education of the students. The integration of STEM education at an elementary is rather natural because students are with the same teacher for most of the day [15].

2.2.2 Various materials

Teachers often find it challenging to obtain materials to use during a STEM challenge [16]. Recycled or free materials are a great option for STEM challenges. For example, teachers can use things like paper towel rolls, newspapers, cardboard boxes, and egg cartons. Additionally, teachers can purchase items that are versatile, and teachers can provide students with building materials that can be used in combination with other materials. Two examples of versatile materials include Creation Crate® TechCard® and SAM Labs®. The research study involved the use of recycled materials and versatile building materials.

Creation Crate® TechCard® are building materials designed for schools. The company provides kits that teachers can use with students to demonstrate different science concepts. Additionally, teachers can provide the students with materials to use to build freely. The materials are easy for students to use because the card contains punched holes that fit dowel rods. Further, the card sets are scored so students can fold it easily. The card kits are made from 100% recycled materials as well [17]. Young children benefit from using hands-on materials to understand abstract concepts [7]. The crane and drawbridge kits were used during the current research study. The students were encouraged expand or extend the original kit design.

SAM Labs® are wireless Bluetooth blocks that move, light-up, and make noises. The blocks pair with the coding app called SAM Blockly®. Students learn to code. The company provides lesson plans that teachers can use with students to teach coding skills [18]. Young learners need opportunities to see connections between concrete and abstract ideas [7]. Further, teachers can use the materials in other ways too. For example, during the current research study the SAM Labs® blocks were used in combination with the Creation Crate® TechCard® crane kit so the crane would move, light-up, and make a noise.

2.3 Time for reflections

2.3.1 Thinking time in the classroom

The most successful innovators find a balance between things they are doing with time to think and reflect [19]. In an era filled with technology and distractions, students are provided with a limited amount of time to stop, think, and reflect. Brain research has consistently demonstrated that students need enriched opportunities with time to reflect to help increase synaptic connections [7]. Neuroplasticity is the idea that the brain can improve for the better or for the worse. When students are overloaded with information without time to reflect then students are not able to find patterns within their own thinking [7]. Young students are processing a lot of information. The process of assimilating and accommodating information requires time for students to think [7]. The need for think time seems intuitive because every living being requires time. For example, if a Jade Plant is transplanted then it needs several weeks before it can be watered. The Jade Plant needed time to adjust to a new situation. In the classroom students are the same as Jade Plants and other living beings, they need time to reflect to foster metacognitive thinking skills.

2.3.2 The power of student voice

FlipGrid® is an online video discussion. A grid is a class or group of students. The teacher posts topics for the students to respond to with a video response. The students are able to view and respond to the video posts of their peers [20]. Students benefit from going into a privacy pod to think and record individual reflections. The research study involved the use of FlipGrid®. Students shared their reflections in privacy pods. The video responses were transcribed in FlipGrid®, and the transcriptions were exported.

Students need opportunities to hear their voice and the voices of their classmates. Learning occurs when students have the opportunities to express their ideas and opinions [21]. When students have opportunities to be heard in the classroom then students benefit from trying-out new thoughts and ideas [22]. Students develop metalinguistic awareness, or a better understanding of how they develop new words, when they have the chance to practice and try out new words [7].

3. Research question

A qualitative, explanatory research study was used to explore one central research question. Research question 1: What, if any, themes will emerge when exploring the responses of second grade students after complete two STEM challenges?

4. Research design

A second-grade class of 25 students completed two different STEM challenges that involved the use of a social robot. At the conclusion of the challenge the students reflected upon their experiences using FlipGrid®—a video discussion platform. The students were able to hold their physical projects that they constructed as they recorded their reflections. The responses of the students were transcribed, coded, and categorized to explore possible themes to describe students" thinking throughout STEM challenges.

The students were provided with a STEM challenge to create a drawbridge that would be strong enough to hold at least 21 plastic elephants. At the beginning of the challenge, the students were introduced to the vocabulary using Virtual Reality (VR) exploration of different real-world bridges. As the students progressed through Nearpod® VR the teacher and social robot, Robon from RoboKind®, provided a guided a think aloud and helped develop content-specific vocabulary. The students used Creation Crate® TechCard® Bridge Kits. Creation Crate® TechCard® are recycled materials that used by young students to create and design different things. Further, the teacher read aloud *Twenty-One Elephants and Still Standing* by April Jones Prince. The students were able to spend up to 5 minutes reflecting using a video recording.

Another STEM challenge involved building a working crane. The students were able to learn about cranes by exploring VR on Nearpod®. Robon from RoboKind®, was coded and used throughout the challenge to provide a think aloud to support the challenge. The students were provided with Creation Crate® TechCard® Crane Kit. The kit involves the use of air pistons to move the crane. The students added the Crane to SAM Labs® Kit. SAM Labs® include wireless Bluetooth blocks that connect to the app. The students were able to use the blocks to add lights, movement, and sound to the crane.

4.1 Research procedure

Fifty video responses recorded in FlipGrid® were transcribed to explore students experiences when completing two different STEM challenges. The transcriptions included 20 minutes of responses. Only two segments of data were removed the study because the student was unaware that they were continuing to record, and the recording did not connect to the topic.

5. Data analysis

Seventy-seven segments of data were coded. Five themes emerged. The following themes emerged: (1) metalinguistic awareness (2) curiosity and real-world connections (3) problem solving strategies (4) social metacognition strategies (5) concrete to abstract thinking. The themes and frequency are listed in **Table 1**.

Theme	Frequency of response
Metalinguistic	12 (16%)
Curiosity and real-world connections	26 (34%)
Problem solving	20 (26%)
Social metacognition	11 (14%)
Concrete to abstract thinking	8 (10%)

Table 1.
Themes and frequency.

6. Data results

6.1 Curiosity and real-world connections

The theme with the highest frequency of response was curiosity and real-world connections with 26 segments of data (34%). Responses were coded as curiosity and real-world connection when the response connected to real-world examples or the STEM challenge. Additionally, responses that demonstrated an interest in topic of the STEM challenge were coded within this category as well. An example of a response within this category included one student who stated: “Real cranes use lights and sounds when moving.” Another example of a response in this category included: “The Brooklyn Bridge took 14 years to build, and 21 elephants walked across it to see if was sturdy.” Some students identified the Golden Gate Bridge or other types of actual bridges that were observed during the Virtual Reality Tour.

6.2 Problem solving

The theme with the second highest frequency of response was problem solving with 20 segments of data (26%). Responses were included within this theme when students described how they worked through the problem or challenge. Further, the students described how they figured things out throughout the STEM challenge process. One example of a response that was included in this theme included a student who stated: “The air in the piston makes the crane move.” Another student explained: “We used the blue-tooth blocks that were connected to the iPad to make our crane move, light-up, and it made sound.” Other examples involved explaining how the drawstring bridge was created so it would be sturdy enough to hold a lot of plastic elephants but it still had the ability to move up and down.

6.3 Metalinguistic

The theme with the third highest frequency of response was metalinguistic with 12 responses (16%). Responses were included within this theme if the students responded focusing on the language. Sometimes students would describe new words, but the students could not remember the name of the word. For example, on student stated: "There was one thing under the toy crane. I forget what it was called, but it was the thing that we used with the iPad to control it." Another student stated: "We used a syringe as an air piston." The students were becoming aware of new words, and the students were learning how to apply the words to describe what they did.

6.4 Social metacognition

The theme with the second least amount of frequency of response was social metacognition with 11 responses (14%). Responses were included within this theme if the students reflected on the process involved with working and communicating with others. For example, one student stated: "We worked together as a team. I saw that people in my group were all doing a good job." Another student stated: "As a group we made a crane. We all had different things to do. I had was able to put the glue dots on the TechCard." Responses that involved group work and collaboration were coded in the Social Metacognition category.

6.5 Concrete to abstract thinking

The theme with the least amount of frequency of response involved concrete to abstract thinking with eight responses (10%). Responses within this category involved students using the concrete prototype to describe abstract concepts. When the students were reflecting on the experience then the student had the chance to hold the concrete object to help with the explanation. One student stated: "Let me show you how this works." Another student said, "Watch this!" Whenever a student referenced the concrete object when explaining abstract ideas then the response was categorized as concrete to abstract thinking.

7. Discussion

The research study results added to the existing body of knowledge in the area of STEM education. Previous research studies did not make a direct connection between STEM education, social robots, and metacognition. Different connections between STEM related skills were linked to metacognitive thinking, but it was not directly linked in a research study. FlipGrid® videos provide researchers an opportunity to explore students reflecting-upon their experiences.

Metacognitive thinking allows learners to transfer and adapt to different situations because learners have a strong understanding of their own knowledge [23]. Metacognition is similar to one looking into a toy kaleidoscope. As one turns or looks into the mirrors and reflections then the perspective changes. The word kaleidoscope is Greek, and the word means "beautiful form to see [24]." When a person is able to self-reflect then the thinking of the person transforms into a beautiful new understanding. The research study involved exploring the responses of students when using STEM challenges and social robots. The themes that emerged were connected the EbD loop and metacognition. When everything comes together then it can be explained by a new model called Redcay's STEM-oscope Model (RSM).

A triangle is located inside of a kaleidoscope. Therefore, RSM has a triangle with the three sides labeled to correspond with the three stages of a STEM challenge: (1) beginning-define, (2) middle-design, (3) end-optimize. The five themes that emerged from the research study fit within the three stages of STEM education. The curiosity and real-world connection theme is connected to the beginning-define stage. The social metacognition and concrete to abstract themes are connected to the middle-design stage. The problem-solving theme is connected to the end-optimize stage (see **Figure 1**).

7.1 Beginning-define stage

Two themes that emerged fall within the beginning-define stage of the EbD loop: (1) curiosity and real-world connections and (2) metalinguistic awareness. Within the beginning stage students are identifying the problem. Further, the engage phase of 6 E's of Science Inquiry is connected to the beginning stage as well [6]. The engage phase involves making connections between old and new knowledge. The two STEM challenges included in the research study included Virtual Reality Tour with Nearpod®, an introduction from Robon from RoboKind®, and read aloud. The purpose of the activities that occur during the beginning-define stage involve developing vocabulary and providing an authentic, real-word connection to the challenge.

7.1.1 Curiosity and real-world connections

Curiosity and real-world connections theme had the highest frequency of response. The engage stage of the 6 E's instructional method occurs at the beginning of a STEM challenge [6]. In the STEM challenge, Virtual Reality with Nearpod®

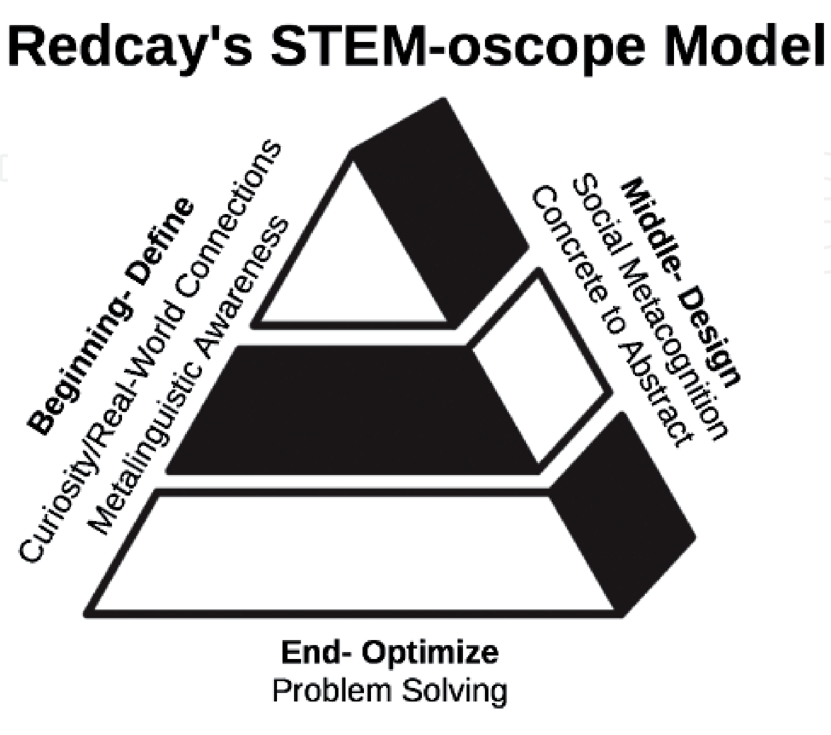

Figure 1.
A picture depicting Redcay's STEM-oscope Model that combines STEM education, social robots, and metacognition.

were used to help students see real-world examples. Further, students were provided with read alouds about the topic. Robon from RoboKind® was coded to give an introduction, and provide the students with background knowledge. Previous research studies have demonstrated that students learn the most when they are curious about the content area of focus [8]. When students are curious then they are able to learn more about something news. Further, when students show neuroplasticity-ability to make synaptic connections in the brain due to an enhanced learning opportunity—then students' ability to learn increases [8]. Students learn best when concepts are linked to real-world examples [11].

7.1.2 Metalinguistic

Metalinguistic was the theme with the third highest frequency. Students were able to use and apply new terms through the design process. Previous research studies have demonstrated that students' metalinguistic skills increased after students had an opportunity to observe and try-out new words within a group [7]. Robon from RoboKind® was coded to provide students with think alouds through the STEM challenges. Previous research studies have demonstrated that students benefited from think alouds provided by social robots [10]. Further, students had the opportunity to try out the new words using FlipGrid®. Students could listen to their own reflections, and the students could listen to the reflections of their peers. These different opportunities helped the students further develop their own knowledge about how they are using and applying new words.

7.2 Middle-design

Two themes were connected to the middle-design phase of the EbD loop: (1) problem solving and (2) concrete to abstract. During the design phase students brainstorm ideas, create a prototype, and test the prototype. The purpose of this phase is to try-out different hands-on activities. Students are working through the explore, explain, and engineer phases of 6 E's of Science Inquiry [6]. As students manipulate concrete objects then it helps students understand and explain abstract concepts. Further, students are working-on learning how to explain and properly communicate their ideas to others. Students need opportunities to collaborate and socialize.

7.2.1 Social metacognition

Social metacognition had the second to least frequency of response. Students were reflecting upon how they worked together in teams. Previous research studies have demonstrated that students benefit from working collaboratively, and this helps develop social metacognitive thinking [9]. Students reflected upon the negative and positive aspects of working within a group. Students were able to organize their thinking into patterns then the patterns or ideas can be applied or used in the future [25].

7.2.2 Concrete to abstract thinking

The category with the least amount of frequency was concrete to abstract thinking. Materials like Creation Crate® TechCard® allow students to construct, build, and re-build an unlimited number of proto-types that can help students better understand the connection between the concrete object and the abstract idea. Further, another versatile material is SAM Labs® students are able to connect different circuits in the app, but the abstract concept is applied to motion in an actual concrete object. Young students learn best when concrete objects are linked to abstract concepts [7]. Some students might have already internalized abstract ideas so they did not need to rely on concrete objects.

7.3 End-redesign

One theme connected to the end-redesign phase: problem solving. During the end-redesign phase the students are re-designing and re-testing. The redefine phase align with the elaborate and evaluate phase of the 6 E's of Science Inquiry [6]. Students are able to expand with new experiences to discover more about the topic. Students self-evaluate and reflect on the STEM challenge to make decisions about how to improve and change their initial ideas.

7.3.1 Problem solving

Problem solving was the theme with the second highest frequency. STEM challenges start with real-world problems [3]. Further, throughout the STEM challenge, students solve problems and students demonstrate flexible and creative thinking. Previous research has demonstrated that students benefit when they think through problems [3]. Students are able to reflect upon the process, and students can organize their thinking around patterns that can be used in future situations [11].

8. Future research

The research study was limited because it only included one group of students in one grade level. Additional research is needed to examine and explore the effectiveness of using social robots as teacher assistants when completing STEM challenges in the classroom. Further, additional research is needed to test the new STEM-oscope Model with students in differing grades and places. The current research had students reflect on the STEM challenges at the end. Future researchers might consider having students share reflections after the individual EbD loop phases. After exploring additional data per phase then possible subthemes might emerge. Quantitative research is needed to further explore the effectiveness of new educational models and methods.

9. Conclusion

The research study added to existing body of STEM Education Research because it connected STEM education, social robots, and metacognitive thinking in a new model called Redcay's STEM-oscope Model. The qualitative, explanatory research study involved the exploration of 100 student responses after completing two STEM challenges. The students responded to the STEM challenges using FlipGrid®. The data were transcribed, coded, and analyzed to answer the research question: What, if any, themes will emerge when exploring the responses of second grade students after complete two STEM challenges?

Five themes emerged: (1) metalinguistic awareness (2) curiosity and real-world connections (3) problem solving strategies (4) social metacognition strategies (5) concrete to abstract thinking. The five themes connected to the three main stages of the EbD loop: (1) Beginning-Define (2) Middle-Design (3) End-Optimize. Further, the 6 E's of Science Inquiry were embedded and connected to the themes as well. The model is arranged in the shape of triangle because kaleidoscopes use a triangle shape with mirrors. When STEM education is connected to metacognition then an experience similar to looking through a kaleidoscope occurs. As one turns and reflects then perspectives and understandings increase. STEM-oscope Model involves students self-reflecting throughout the STEM process to gain better self-awareness.

Metalinguistic awareness was promoted as a social robot, Robon from RoboKind® provided Think Alouds. Students were able to listen to their own recording, and students were able to listen to the recording of their peers. Students benefited from using versatile materials like Creation Crate® TechCard® and SAM Labs® that further allowed students to make connections between concrete objects and abstract ideas. Additionally, students benefited from having the opportunity to make real-world connections using Virtual Reality from Nearpod®. Students benefited from interacting within groups, and students learned more as they solved problems. These themes were previously recognized separately as benefiting students to think metacognitively. However, a STEM challenge allows the students to have an enhanced experience because it fosters metacognition by developing various skillsets.

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References

[1] Asunda PA, Weitlauf J. STEM habits of mind: Enhancing a PBL design challenge—Integrated STEM instruction approach. Technology & Engineering Teacher. 2018;**78**(3):34-38

[2] Radcliffe DF, Fosmire M. Integrating Information into the Engineering Design Process. Purdue University Press; 2014

[3] Jolly A. The Search for Real-World STEM Problems [Internet]. 2017. Available from: https://www.edweek.org/tm/articles/2017/07/17/the-search-for-real-world-stem-problems.html

[4] Turner KL, Kirby M, Bober S. Engineering design for engineering design: Benefits, models, and examples from practice. 2016;**8**(2):1-12 Available from: https://digitalcommons.nl.edu/ie/vol8/iss2/5

[5] Cox J. STEM Education in the Elementary Classroom [Internet]. 2019. Available from: https://www.teachhub.com/stem-education-elementary-classroom

[6] Duran LB, Duran E. The 5E instructional model: A learning cycle approach for inquiry-based science techniques. The Science Education Review. 2004;**3**(2):49-58 Available from: https://files.eric.ed.gov/fulltext/EJ1058007.pdf

[7] Biddle KA, Garcia-Nevarez A, Henderson WJ, Valero-Kerrick A. Early Childhood Education: Becoming a Professional. Sage; 2014

[8] Litman JA. Curiosity and metacognition. In: Larson CB, editor. Metacognition: A New Research Development. 2009. Available from: http://eds.a.ebscohost.com/eds/ebookviewer/ebook/bmxlYmtfXzQxMDIyNl9fQU41?sid=bc2b71ba-9f81-42be-8246-6668fe5f62eb@sdc-v-sessmgr02&vid=1&format=EB&rid=2

[9] Chiu MM, Kuo SW. Social metacognition in groups: Benefits, difficulties, learning, and teaching. In: Larson CB, editor. Metacognition: A New Research Development. 2009. Available from: http://eds.a.ebscohost.com/eds/ebookviewer/ebook/bmxlYmtfXzQxMDIyNl9fQU41?sid=bc2b71ba-9f81-42be-8246-6668fe5f62eb@sdc-v-sessmgr02&vid=1&format=EB&rid=2

[10] Ramachandran A, Huang C, Gurtland E, Scassellati B. Thinking Aloud with a Tutoring Robot to Enhance Learning [Internet]. 2018. Available from: http://eds.a.ebscohost.com/eds/pdfviewer/pdfviewer?vid=4&sid=bc2b71ba-9f81-42be-8246-6668fe5f62eb%40sdc-v-sessmgr02

[11] Robots4Autism. Manor ISD Uses Robots4STEM with Special Needs Students [Internet]. 2017. Available from: https://blog.robokind.com/success-stories/manor-isd-uses-robots4stem-with-special-needs-students

[12] Easton R. Success Story: West Vancouver, Canada, Six Weeks with Milo [Internet]. 2017. Available from: https://blog.robokind.com/success-stories/success-story-west-vancouver-canada-six-weeks-with-milo

[13] Goodman J. Education from Reactive to Proactive: The Blairsville-Saltsburg School District Story [Internet]. 2019. Available from: https://blog.robokind.com/success-stories/taking-autism-education-from-reactive-to-proactive-the-blairsville-saltsburg-school-district-story

[14] Robots4STEM. The Next Generation Coding and Programming Experience [Internet]. Available from: https://www.robokind.com/robots4stem/what-is-robots4stem

[15] Roberts A. A Justification for Stem Education [Internet]. Available from: https://www.iteea.org/File.aspx?id=86478&v=5409fe8e

[16] Wulfenstein J. Teaching STEM with Little or Not Budget [Internet]. Available from: http://www.classroomscience.org/teaching-stem-with-little-to-no-budget

[17] TechCard. What is Techcard? [Internet]. 2019. Available from: http://techcard.co.uk/about/

[18] SAM Labs. Why Use Sam Labs? [Internet]. 2019. Available from: https://samlabs.com

[19] Woodward M. Why Think Time is so Important in a Distracted World [Internet]. 2018. Available from: https://www.psychologytoday.com/us/blog/spotting-opportunity/201802/why-think-time-is-so-important-in-distracted-world

[20] FlipGrid. User Guides [Internet]. 2019. Available from: https://flipgrid.com

[21] Microsoft. Budget-Friendly Devices for Every Classroom [Internet] 2019. Available from: https://educationblog.microsoft.com/en-ca/2018/10/empowering-student-voice-with-flipgrid/

[22] Palmer B. Including Student Voice [Internet]. 2013. Available from: https://www.edutopia.org/blog/sammamish-2-including-student-voice-bill-palmer

[23] Chick N. Metacognition [Internet]. 2019. Available from: https://cft.vanderbilt.edu/guides-sub-pages/metacognition/

[24] Sciencing. How Does a Kaleidoscope Work? [Internet] 2018. Available from: https://sciencing.com/a-kaleidoscope-work-4564059.html

[25] Marzano RJ, Pickering DJ. Dimensions of Learning. ASCD; 1997