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STEM LEARNING AND LOOSE PARTS IN EARLY ELEMENTARY CLASSROOMS: A SCOPING REVIEW

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Abstract

When elementary students learn STEM topics (especially science) early in their educational journey, they have the opportunity to develop a passion to promote their future academic, personal, and professional success. With many resources claiming to be STEM, it can be overwhelming and difficult finding specific classroom activities to establish an interest in the subjects. The use of loose parts can address challenges teaching STEM and meeting curriculum standards in elementary schools. To better understand STEM best practices, a scoping review was implemented. The key words "STEM," "elementary," and "science" yielded 1,955 publications, which were then narrowed down to 20 articles for in-depth review. The selected publications were analyzed for STEM activities using loose parts principles. This study establishes successful science activities, discusses challenges, and shares how loose parts could be used to improve learning and student engagement in science and STEM.

Keywords: STEM, elementary, science, loose parts, experimentation.

INTRODUCTION

Teaching STEM in the beginning elementary grades can be rewarding and challenging. There are numerous resources available to classroom teachers, but educators often find that choosing activities can be overwhelming and puzzling. Exploration and experimentation using loose parts can be an opportunity to address the challenges and obstacles educators face. Gull, Bogunovich, Goldstein, & Rosengarten (2019) explain Nicholson's theory of loose parts as "an opportunity for children to express creativity through use of materials that can be manipulated, transformed, and created through self-guided play" (p. 37). A loose parts mindset, types of loose parts in STEM, the 4 C's (communication, collaboration, critical thinking, creativity), assessment methods to meet early education standards, student engagement and motivation, loose parts principles, and being a scientist concept were analyzed. There are few, if any, other research studies exploring the concept of loose parts in a STEM context in early elementary classrooms. Therefore, the goal of this scoping review was to establish successful science activities, address challenges, and share how loose parts could be used to improve learning and student engagement in science and STEM. This research contributes to the field of education with the potential to introduce a loose parts mindset and exploratory approaches

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to learning in STEM early education settings, adding to the overall body of knowledge of student experiences.

METHOD

For this research study on early STEM education, a scoping review was conducted. This type of academic review focuses on the amount of information that is available, rather than the quality of each article that was reviewed (Arksey & O'Malley, 2005). A scoping review is pertinent when exploring the current span of literature and research available on a specific topic (Arksey & O'Malley, 2005).

To conduct the scoping review the key words used in this search were: "STEM," "elementary," and "science." Initially, the term "loose parts" was included, yet yielded little to no results with the other parameters, causing the researchers to exclude loose parts as a key word. A literature review was conducted using the University of Phoenix Library which contains EBSCOhost, ProQuest, and Gale databases. To choose appropriate publications related to the research focus, inclusion criteria were further established. The search criteria included using the full text, a loose parts mindset, focusing on Kindergarten through Third grade, written in English, plus current and relevant publications, from January 2012 through December 2021. This set of criteria (see Figure 1) was created to make sure the articles were best related to the purpose of the study. While English language was a limiting factor in pairing down articles, the researchers did not exclude international articles and research as STEM is a global concept.

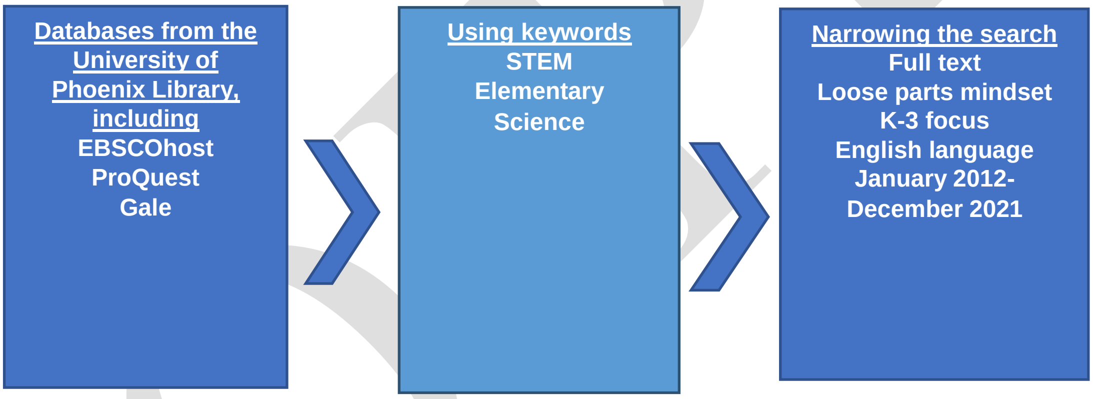

Figure 1. Process for scoping the literature. This figure represents the steps and inclusion criteria used to choose appropriate articles for the study.

Using the key words (STEM, elementary, science) to conduct an initial search discovered that the University of Phoenix Library yielded 1,955 results from academic journals, magazines, reports, books, and news articles. Then 1777 publications were removed using a title review, yielding 178 publications to review using the title and abstract. Of the 178 selected publications, seven were found to be duplicates; therefore, 171 were remaining. After a review using the title and abstract or skimming and reading the first paragraph of a news article, a total of 111 publications were removed, leaving a total of 60 publications to review in depth (see Figure 2).

The researchers reviewed and analyzed each abstract for relevancy to the key word search. The 60 remaining publications were assessed using the information provided within the abstract to ensure relevancy to the specific search criteria. Twenty-nine additional publications were removed, leaving 31 applicable publications. Upon further review, one more was deleted due to being an advertisement. An additional review of the publications focusing on a loose parts mindset within the STEM learning approaches narrowed the publications to 20 which were analyzed using a full article review process (see Figure 2).

This study used a total of 20 publications that were significantly related to the search criteria: STEM, elementary, and science. See Figure 2 for a breakdown of the search process using a PRISMA (2009) diagram.

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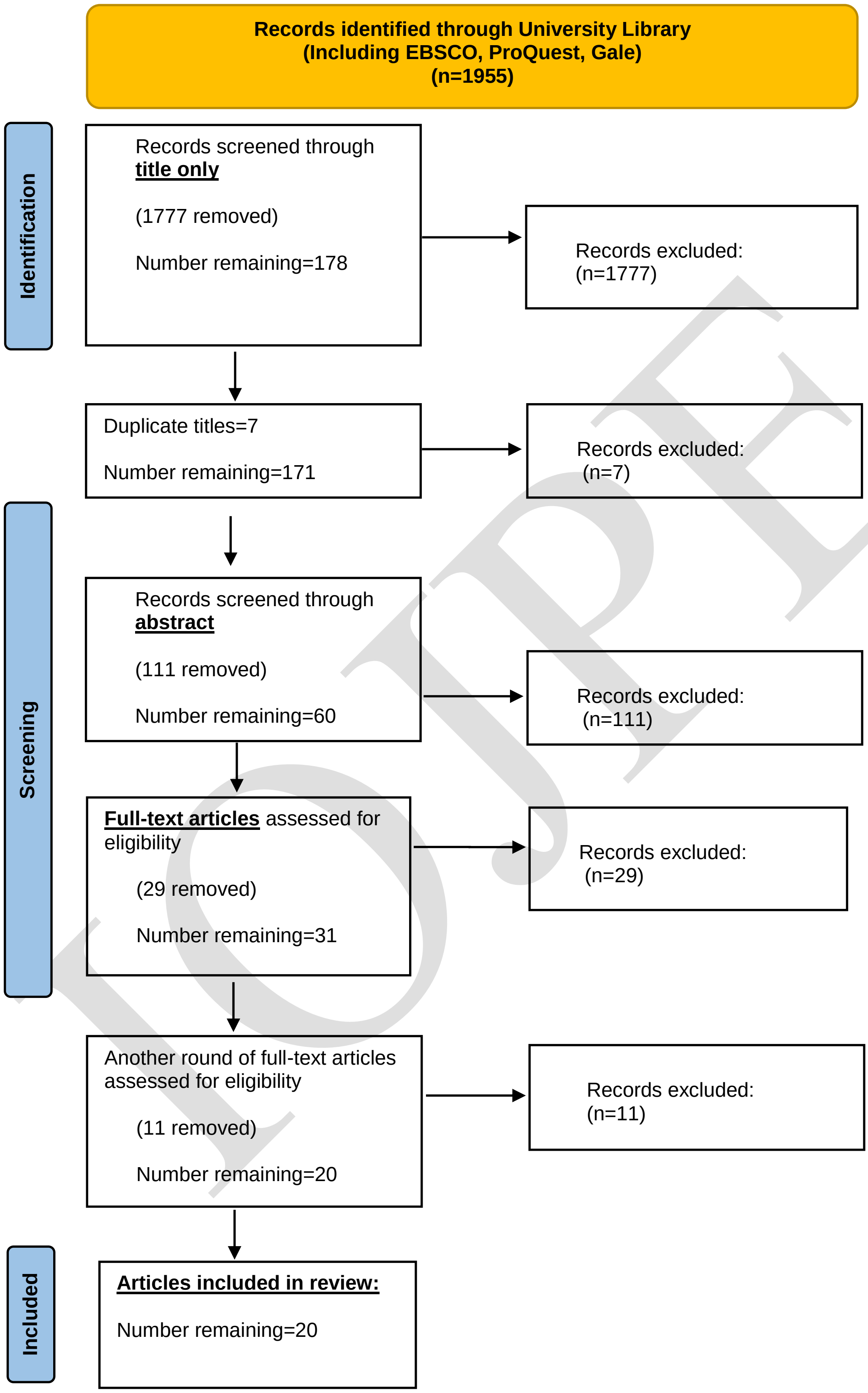

Figure 2. Article search. This figure represents the breakdown of the search process using a PRISMA (2009) diagram.

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Using an author-created template, the selected publications were reviewed based on the following concepts: a loose parts mindset, types of loose parts, the 4 C's (communication, collaboration, critical thinking, and creativity), assessment methods to meet early education standards, student engagement and motivation, loose parts principles, and being a scientist. The template further prompted the researchers to analyze each publication for verbs, connections to standards and evaluation, different educational approaches, STEM related skills, and relevant quotes that exemplified the inclusion of a loose parts mindset in the learning environment. Additionally, specific loose parts concepts: a "Yes" mentality, the involvement of children in utilizing, planning, and building of spaces, blurring the lines between inside and outside, creating a lab-like environment, solving real life problems, children being part of their learning process through experimentation, applying a variety of approaches to loose parts, using what we have naturally, and the concept of play were investigated (Gull, Levenson Goldstein, & Rosengarten, 2021).

RESULTS

The final 20 selections for more in-depth study included one news article, one book, one curriculum, four trade journals, four periodicals, and nine research articles for a diverse mix of representation within science and STEM. Table 1 provides a summary of the publication and relevant information taken from each source. The publications were placed in order based on the established search parameters and the results that were yielded.

Table 1. Summary of publications

Title/Publication	Publication	Summary	Relevancy
Crossing the Amazon by LEGO: An interdisciplinary STEM adventure. *Science and Children*	Trade Journal	Lesson summary of using LEGO WeDO 2.0 as part of a STEM interdisciplinary unit around bridge building.	"We hope this highlighted experience ignites in you a passion to attempt a challenge such as this one—transforming student learning" (Edelen, Bush, & Nickels, 2019, p. 36). "Because students have often been conditioned as passive learners and receivers of knowledge, it can be difficult for them to persevere in solving authentic problems. Nevertheless, we must persist in preparing students as problem solvers and critical thinkers" (Edelen et al., 2019, p. 31).
Supporting elementary pre-service teachers to teach STEM through place-based teaching and learning experiences. *Electronic Journal of Science Education*	Research Article	In this study, data was collected on elementary preservice teachers' perceptions of their experiences as they participated in, planned, and enacted integrated place-based STEM education lessons.	"Ballantyne and Packer (2009) identified experience-based instruction that occurs in the natural environment as a productive pedagogy, providing engaging, and enduring learning" (Adams, Miller, Saul, & Pegg, 2014, p. 2).
Invention everywhere: How STEM educators can spread the makerspace mentality throughout schools and districts. *District Administration*	Periodical	Teachers have seen student excel in STEM when they are able to experiment with tools and technology. Using makerspace can help to bridge the gap between curricular demands and student engagement.	"You have to be resourceful. Makerspaces can be done in a budget-friendly way" (Crist, 2019, p. 4).

Table 1 (Continued). Summary of publications

Title/Publication	Publication	Summary	Relevancy
A blueprint for bridging classrooms: Strategies to encourage collaboration within the school. *Children's Technology and Engineering*	Trade Journal	The article presents engaging strategies to incorporate STEM education in elementary classrooms.	"Integrated STEM activities are more engaging and increase student interest in the topics" (Hills, 2017, p. 9).
America's children: providing early exposure to STEM (science, technology, engineering and math) initiatives. *Education*	Research Article	Capturing students' interest in STEM subjects at an earlier age, a proactive approach can help students stay are on track and have preparatory measures to enter STEM degree programs at institutions of higher learning.	"While students are engaged in STEM activities, they will also gain experience with 21st Century skills such as critical thinking, collaboration, and communication that will help prepare them to compete on the global level" (DeJarnette, 2012, p. 82). "Science classes in schools need to promote more problem solving, critical thinking, and open-ended inquiry. These types of classroom activities develop process skills in students rather than simply learning content knowledge" (DeJarnette, 2012, p. 79). "Elementary students often learn about scientific theory and the nature of science rather than doing scientific investigations for themselves" (DeJarnette, 2012, p. 80).
Engineering encounters: No, David! But yes, design! Kindergarten students are introduced to a design way of thinking. *Science and Children*	Trade Journal	Design-thinking is being used to integrate STEM into the learning spaces and address 21 century skills.	"As with all design thinking steps, there are opportunities to also work on 21st-century skills, such as character, collaboration, creativity, critical thinking, and communication" (Douglass, 2016, p. 73).
Implement STEM literacy in the elementary school curriculum. *Journal of Education Research*	Research Article	Research studies have demonstrated that the early elementary years are the most effective time to build foundational knowledge in the STEM disciplines.	"Relating STEM topics to the world beyond the classroom also provides the opportunity to spark students' interest in discovering, doing, and researching. Innovation can lead students to create new products and processes that sustain the national and global economies" (Huang, 2017, p. 8).
Early-grades science: The first key STEM opportunity; Effective teaching in grade school is a make-or-break factor for future STEM success. *Education Week*	Periodical	STEM instruction is often overlooked in early elementary classrooms due to elementary teachers not being trained adequately, lack of confidence, the topics not being on standardized testing, and other reasons. However, modeling teaching, co-teaching, and having STEM courses embedded in teacher prep can make a difference. Children are ready to learn and experiment if we let them and support teachers.	"Effective teaching in grade school is a make-or-break factor for future STEM success" (Will, 2018, para. 1).

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Table 1 (Continued). Summary of publications

Title/Publication	Publication	Summary	Relevancy
Facilitating an elementary engineering design process module. *School Science & Mathematics*	Research Article	The Engineering Design Process can be an integral tool in STEM education to help students develop 21st century skills, tackle challenges, and see themselves as engineers.	"Engineering represents the application of science and mathematics concepts to make life better for people" (Hill, Mott, & Hunt, 2018, p. 53). "Engineering design challenges often ask students, even young students like the second-graders in the following example, to think about using materials and how materials work together to solve the problem" (Hill et al., 2018, p. 56).
From static to circuits: Inquiry-based STEM explorations of electricity. *Young Children*	Periodical	STEM options in the classroom can help students build knowledge and creativity. Different ideas for inquiry-based STEM are shared, with a large focus on electricity and circuits.	"Using an inquiry-based approach to introduce electricity helped children build an understanding of basic science concepts, increase their vocabulary, and reinforce skills related to communication, critical thinking, and collaboration" (Deaton, 2017, p. 93).
Tinker kit educator's guide. *Boston Children's Museum and National Grid*	Curriculum	A curriculum guide of activities to introduce early childhood educators to tinkering, aligned with PreK STE standards. After introductory material to provide the rationale for tinkering, a series of activities are included with needed materials, reflections, extensions, reading suggestions, etc.	"Encouraging children to tinker gives them the skills to be creative problem solvers out in the world" (Boston Children's Museum and National Grid, n.d., p.3).
A talent for tinkering: developing talents in children from low-income households through engineering curriculum. *Gifted Child Quarterly*	Research Article	Low-income Grade 1 students were introduced to engineering through biographies and an EiE curriculum after summer teacher training and continued support. Researchers found this intervention effective for identifying gifted and talented students.	"Young students improved both their knowledge of engineers and their reported engagement in engineering activities" (Robinson, Adelson, Kidd, & Cunningham, 2018, p. 139).
Valuing the process and product of inquiry-based instruction and learning. *Journal for the Education of the Gifted*	Research Article	Researchers looked at a year-long intervention on inquiry explorations for in 3-5th grade gifted programs. Balancing process and product for students was a challenge.	"In the end, this focus on thinking and creation of a product, even with flaws, allowed for persistence for both the teacher and for the students" (Barone & Barone, 2019, p. 59).
Engineering at the elementary level: students need the educators of today to prepare them for a world we cannot even imagine at this moment. *Technology and Engineering Teacher*	Research Article	After a review of current research, a teacher assessed what her school could do to improve STEM instruction at the elementary level.	"It seems everything in the world has been innovated, with perhaps the school classroom less so. Students need the educators of today to prepare them for a world we cannot even imagine at this moment" (McGrew, 2012, p.19).

Table 1 (Continued). Summary of publications

Title/Publication	Publication	Summary	Relevancy
Perusing the past to propel the future: A systematic review of STEM leaning activity based on activity theory. *Sustainability*	Research Article	Researchers set out to explore that STEM could be achieved through inquiry-based learning, problem-based learning, and project-based learning which engage students through scientific processes.	"Science and engineering education activities are paramount to preparing students for the 21st-century industrial revolution termed Industry 4.0. STEM" (Gyasi, Zheng, & Zhou, 2021, p. 14).
Supporting STEM success with elementary students of color in a low-income community. *Distance Learning*	Trade Journal	Students worked in collaborative groups to create a final product to present at the end of the year using the 21st century skills.	"According to the Partnership for 21st Century Learning (2011), students need to move beyond the basics and embrace the four Cs, otherwise known as "superskills": collaboration, communication, creativity, and critical thinking" (Molina, Borror, & Desir, 2016, p. 23).
Implementing joyful learning in science and math *Association for Supervision & Curriculum Development (Chapter 3).*	Book	Chapter 3 explored how to engage students in collaborative groups to complete activities that allow students to think like scientists.	"For joyful learning to occur in whole-group instruction, students need to be engaged in meaningful and interesting activities or discussion with appropriate challenge" (Brunsell & Fleming, 2014, p. 39). "To engage students in whole-group instruction, incorporate activities that require students to think like scientists or mathematicians" (Brunsell & Fleming, 2014, p. 39). "To solidify their understanding and engage students, we need to provide students with independent opportunities for hands-on experiences, choice, and creativity" (Brunsell & Fleming, 2014, p. 45).
Five principles to encourage science inquiry. *Teacher Advocate*	Periodical	The article discusses five strategies to promote scientific inquiry and encourage out-of-the-box thinking in students.	"Take time to discover what interests your students. Through meaningful, higher-level questioning you can uncover some interesting ideas" (Varano, 2015, p. 16). "When students learn science through inquiry, they gain ownership of their learning" (Varano, 2015, p. 17).
Science club makes splash at the local school's family STEM night. *Targeted News Service*	News Article	Members of the U.S. Merchant Marine Academy (USMMA) Science Club provided interactive hands-on science activities and fun math challenges to over 150 students.	"The themes provided an opportunity for the local youth to experience the fun of making slimy slime, growing instant snow, and creating colorful artwork. Through a hands-on approach, students also learned about solar energy, light emitting diodes and water solution conductivities. The activities were prepared to educate the students about the importance of using and searching for green and alternative energy and products" (Science Club, 2016, para 4).
Artful teaching and science investigations: A perfect match. *Gifted Child Today*	Research Article	This article examines how elementary teachers can create interesting science investigations for students.	"Science can be one of the most engaging content areas for students because it touches their curiosity and allows them to explore earth, physical, life, and space phenomenon" (McGee, 2018, para 4). "Teachers are encouraged to develop engaging science lessons within units of study focusing on inquiry" (McGee, 2018, para 4).

In addition to collecting information on the title, publication, and summary of relevant information, each publication was further analyzed to gather information on how students can learn STEM topics (especially science) early in their educational journey. Evaluating current research based on approaches to STEM activities using loose parts to enhance student learning was collected. The publications were further reviewed for a loose parts mindset, based on Gull, Levenson Goldstein, and Rosengarten's (2021) work around loose parts in early elementary classrooms. A loose parts mindset, types of loose parts in STEM, the 4 C's (communication, collaboration, critical thinking, creativity), assessment methods to meet early education standards, student engagement and motivation, loose parts principles, and being a scientist were aggregated in the results below.

Loose Parts Mindset

One aspect of a loose parts mindset is the actions children take when interacting with materials and concepts. Gull et. al (2021) suggest that children apply this loose parts mindset to "build, construct, play, experiment, invent, explore, discover, evaluate, modify, study, think, consider, measure, draw, model-making, calculate, destruct, slide, fold, hide, paint, and bounce" (p. 11). Student action verbs noted (see Figure 3) in the selected articles were extracted and analyzed for frequency. Verbs were standardized for similar endings and repeats were consolidated. Associated nouns in verb phrases were taken out.

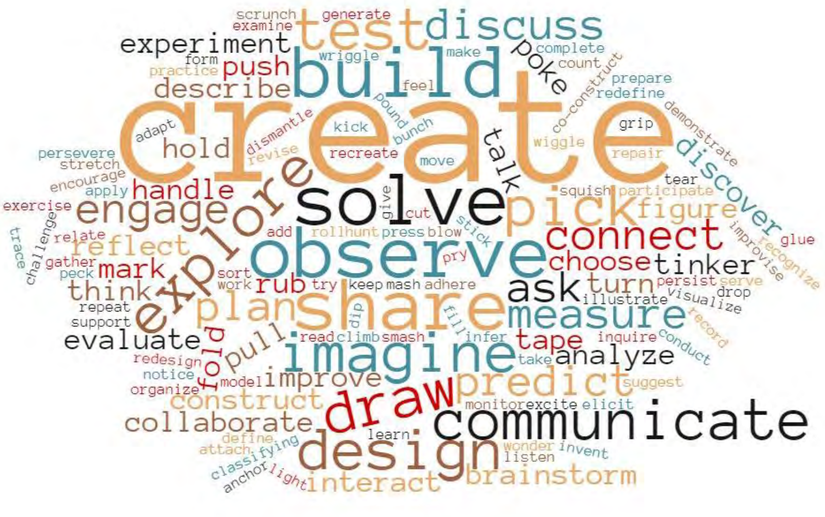

Figure 3. Student action verbs from selected publications with frequency analysis

Types of Loose Parts in STEM

Most selected publications included loose parts as the variables students interacted with in the STEM classroom. Loose parts in the publications were aggregated and categorized in Table 2, grouping like items, such as electronics, toys, office, and paper supplies, connecting materials, tools, nature, and food.

Table 2. Loose parts noted in selected publications

Category	Loose Parts Noted
Electronics and Electricity	robotic kits (LEGO Wedo 2.0 Robots), computers, 3D printers, laser cutters, robots, virtual reality headsets, drones, smartphone, magnets, solar panels, consumables, electrical materials, Snap Circuits, littleBits, Makey Makey, Sphero, Scratch, conductive/computational materials--such as LEDs, bulbs, wires conductive thread, sewable microcontroller with sensors and sound buzzer, AA batteries, FunFly stick, LightUp Edison magnetic circuit blocks, Energy Sticks, tinsel, hair, steel wool, glass container, metal box, sandpaper, furry and silky cloth, wood scraps
Toys	LEGOs, K'nex, Tinkertoys, marbles, ping pong balls, miniature car

Table 2 (Continued). Loose parts noted in selected publications

Category	Loose Parts Noted
Office and Paper Supplies	paper, tissue paper, newspaper, construction paper, paper towels, paper strips, recycled paper craft sticks, pipe cleaners, clothespins, golf tees, large beads, textiles—fabric, thread, lab coats, cotton balls, straws, rubber bands, toothpicks, paper clips, clipboards, baggies, bubble wrap, foam, Styrofoam peanuts pencils, markers, crayons, ink pad, scissors
Recycled Materials	repurposed or recycled materials, plastic from old plastic bag, toilet paper rolls old electronics, old car toys, old electronic toys, old wires, old tennis balls, cardboard, cereal boxes, egg cartons
Connectors	string, yarn, shoelaces, narrow ribbons, tape
Tools	wire cutters, stopwatches, tape measures, tools, rulers, field study tools, protective eye gear/goggles, screwdrivers, hammer, pliers, tweezers, screws, nails, aluminum foil, Styrofoam plates, painter's tape, glue stick, washi tape, colorful tape, stickers tubs, buckets, hands
Nature	artifacts, soil, ponderosa pine, materials from nature, sponges, water
Food	pizza, pies, candy bars, carrots, vinegar

Four C's and Other Skills

Certain skills are helpful for engaging in STEM activities. The selected publications were analyzed for the 21st century skills. "While students are engaged in STEM activities, they will also gain experience with 21st Century skills such as critical thinking, collaboration and communication that will help prepare them to compete on the global level" (DeJarnette, 2012, p. 82). Critical thinking, problem solving, communication, and collaboration were highly noted in the articles. While not as frequent, creativity was also noted, which is essential as noted in "The leaders of tomorrow must develop and maintain a sense of curiosity and inquisitiveness that will help them solve key challenges like the energy challenges that employees across the company are currently working to address" (Boston Children's Museum and National Grid, n.d., p. 1). Additional skills and competencies from the article included: engagement, experimenting, inquiry, perseverance, curiosity, inquisitiveness, fine motor skills, process skills, using tools, brainstorming, learning from mistakes, observation, making comparisons, visualization, using things in other ways, planning, divergent viewpoints, making revisions, sustainability mindset, information literacy, technology literacy, consuming information, leadership, productivity, flexibility, social skills, forming questions, academic conversation skills, scientific questioning, collecting evidence, and finding connections. Persistence is also an essential skill.

> Every maker, every engineer, every scientist tries and fails . . . and tries again. It is the only path to real success. If children are not allowed to learn how to fail, what will they do when they encounter the inevitable obstacles in their lives? (Boston Children's Museum and National Grid, n.d., p. 8).

Standards, Educational Approaches, and Evaluation

The reality of most STEM science classrooms is that grade-level standards should be the basis of most exploration. In looking at the selected publications, the Engineering Design Process was frequently used as both a process and a standard to meet. Additionally, several other approaches were acknowledged, which generally have a more hands-on, experiential approach to learning. Terms used to describe these approaches included: inquiry-based learning, hands-on, place-based pedagogy, project-based learning, a problems-based approach, authentic outdoor science activities, constructivist, Engineering Design Process, systems thinking, the 5E (engage, explore, explain, elaborate, and evaluate) model for inquiry-based instruction, and the concept of tinkering, engineering, making. "These practices help develop students' skills for the 21st century and create a sustainability mindset" (Gyasi et al., 2021, p. 14).

Evaluation may look different with this type of learning, so options were also examined. Rubrics, observations, and final projects were noted in three of the selected publications as evaluation formats. Open-ended questions, final product, reflections, and some type of gallery/museum walk or tour were noted in at least two of the selected publications as evaluation methods in the selected publications. Additionally, more open-ended types of evaluation were mentioned in the articles, including explanations, demonstrations, key questions, preassessment, action plans, blueprint evaluations, planning sheet, photo, video, display, discussion, worksheets, and recording sheets. Multiple choice questions and standardized assessments were also briefly mentioned.

Student Engagement and Motivation

Young children learn by exploring and discovering using manipulating materials, objects, and many different types of loose parts. Hands-on and problem-based learning activities are highly motivating for elementary students. Gyasi et al. (2021) indicated "The learning materials and methods implemented in STEM activities are significant to arouse student interests, engagement, and learning outcomes" (p. 2).

The Boston Children's Museum and National Grid (n.d.) further emphasized that motivation and engagement are high when children are encouraged to play and investigate rather than having passive instruction by completing worksheets. "This kind of learning early in life builds skills and interests that serve children throughout their school years and later in life" (p. 1). In addition, the Boston Children's Museum and National Grid (n.d.) affirmed that

> Tinkering is an active process—it is all about doing, discovering, creating. This level of creativity and activity can help shift the relationship that children have with learning, as they view learning as engaging and enjoyable. Tinkering encourages children to use their hands, senses, tools, and skills to investigate, understand, and even change their world. It builds children's capacity and enthusiasm about using their own ingenuity to create, to use tools, and to make (p. 7).

Loose parts are open-ended and afford children the ability to problem solve and practice independent thinking. Huang (2017) found that "STEM activities provided hands-on and minds-on lessons to make STEM more fun for students" (p. 2). Brunsell (2014) asserted that "To solidify their understanding and engage students, we need to provide students with independent opportunities for hands-on experiences, choice, and creativity" (p. 45). Loose parts provide the students with the opportunity to be creative problem solvers.

Loose Parts Principles

Simon Nicholson (1971) coined the term "loose parts" by stating "In any environment, both the degree of inventiveness and creativity, and the possibility of discovery are directly proportional to the number and kind of variables in it (p. 30)." As part of the publication reviews, the researchers looked specifically at aspects of loose parts principles within the science and STEM classrooms. Gull et al. (2021, p. 7) list ten loose parts principles after rethinking Nicolson's intent:

1. Limit the restrictions.
2. Involve children in using, planning, and building spaces and learning.
3. Blur the lines between inside and outside.
4. Create a lab-like environment.
5. Solve real-life problems.
6. Allow children to learn through experimentation.
7. Use a variety of approaches to loose parts play.
8. Just add water.
9. Use what you have.
10. Play.

Frequency of use of these principles was noted from within the publications (see Table 3).

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Table 3. Number of articles indicating the subsets of a loose parts principles

Number of Articles	Loose Parts Principles
15	Children part of their learning process through experimentation
7	Lab-like environment
6	Involves children in using, planning, and building of spaces
5	Solve real life problems
4	Use a variety of approaches to loose parts
3	“Yes” mentality
3	Use what we have naturally
3	Play
2	Blur lines between inside and outside
0	Just add water

Being a Scientist

Children are natural-born scientists. They enjoy experimenting and tinkering with a variety of loose parts including those found in nature and manufactured. “Children who are encouraged from an early age to tinker and solve their own problems develop a different way of thinking about the world” (Boston Children’s Museum and National Grid, n.d., p. 3). Students who tinker tend to persevere, think outside of the box, are creative problem solvers, and are self-sufficient (Boston Children’s Museum and National Grid, n.d.).

Children are curious, ask questions, and enjoy exploring materials. Will (2018) stated “If we can capitalize on that natural way they think and process information, we're just preparing them for the future development of those skills” (para 31). Adams et al. (2014) specified “In order to prepare teachers to meet the challenges of a rapidly changing human landscape, we, as teacher educators, need to provide authentic, and meaningful experiences” (p. 18). Science curriculum should be authentic with no one possible solution (Hills, 2017). Edelen et al. (2019) detailed ways students can be like a scientist by:

- Explaining and supporting thinking
- Recording the questions
- Brainstorming
- Solving real life problems

“As teachers, we have the daunting task of preparing our students for jobs that do not yet exist. We must cultivate a sense of wonder and excitement as students learn about their world” (p. 36).

DISCUSSION and CONCLUSION

Discussion

After a systematic review of thousands of articles related to STEM activities used in early elementary and analysis of the findings, there are several common themes, emerging trends, limitations, and recommendations for implementation and future research on this topic. Assessing the use of loose parts in STEM subjects enables better implementation in elementary classrooms and improved program development and teacher training. Hands-on science activities can engage and motivate elementary students; however, teachers are often reluctant to use loose parts in the STEM activities. Nicholson (1971) shared an expansive view of loose parts, which includes many scientific and STEM principles.

> There is evidence that all children love to interact with variables such as materials and shapes; smells and other physical phenomena, such as electricity, magnetism and gravity; media such as gases and fluids; sounds, music and motion; chemical interactions, cooking and fire; and other people, and animals, plants, words, concepts and ideas. With all these things all children love to play, experiment, discover and invent and have fun. All these things have one thing in common, which is variables or ‘loose parts’ (p. 30).

In Gull et al. (2019), definitions around loose parts included a focus on "manipulating, experimenting, and interacting with a variety of objects for promoting imagination and creativity" (p. 47). Leaning into experimentation in STEM and these scientific principles could enhance creativity, critical thinking, collaboration, and communication. Establishing what science activities are successful, discussing challenges, and sharing how loose parts could be used to improve learning and student engagement in science curriculum are discussed.

Several principles of merit were pulled from the articles when considering STEM and/or science learning experiences:

- Embrace cross curricular teaching with a connection between students and the surrounding world. Solving real life problems in the community around them is essential for both STEM and loose parts.
- Build upon a constructivist learning approach influenced by Dewey, Vygotsky, and Piaget.
- Tinker, manipulate, and play around with the materials early in the design process. Think of the verbs in standards and reported in the chart above.
- Encourage creativity and divergent thinking more fully in the STEM classroom, as it is an essential part of the 4 C's that was lacking in the selected publications.
- Explore lower cost, low-tech alternatives if needed and make learning accessible to all students.
- Include place-based activities, using outdoor spaces and outdoor classrooms for rich sensory experiences.
- Create dynamic and rich learning environments.
- Use inquiry experiences to engage student curiosity and increase student interest—capitalize on students' interests.
- Involve students in the design process, including the selecting of variables and establishing parameters of STEM encounters.
- Match makerspace and/or other materials with potential uses for the space or challenge. Consider students' interests when selecting materials.
- Establish constraints as needed, including planning parameters for safety. "Constraints are limits put on the design, for instance, the materials may be only those specified, or inventors have a specified amount of time" (Hill et al., 2018, p. 58).

As noted in Table 3, a variety of materials can be loose parts in the STEM classroom, not limited to the list above. Anything can be a loose part for creativity and experiments. "Tinkering is about open-ended creativity, and in that regard, almost any materials and tools can be used to engage children to create" (Boston Children's Museum and National Grid, n.d., p.11). The Tinker Kit also quoted a German scientist, Paul Erlich who mentioned, "The first rule of tinkering is to save all the parts" (Boston Children's Museum and National Grid, n.d., p. 10), as they can be used for other projects. Recycled items can be powerful as well. "Resnick (2011) noted that tinkering and the more formal domain of engineering are a good match for low-income children whose life circumstances have presented them with the need to dismantle, redesign, and repair everyday objects or to improve processes that are necessary for day-to-day living within the constraints of scarce resources" (as cited by Robinson et al., 2018, p. 131).

Encouraging students to identify themselves as scientists is very important (Brunsell & Fleming, 2014). Teachers should promote the idea of "doing science instead of just reading about it" (Boston Children's Museum and National Grid). McGee (2018) suggested that children "'take risks,' make mistakes, and ask questions during investigations. In addition, students need to learn to 'think like scientists,' realizing that their investigations and predictions sometimes fail, and that failure informs their learning, sometimes more than their successes" (p. 42). Furthermore, when students look like scientists, wearing white lab coats, protective eyewear, writing about investigations, and use real science materials, it helps them to assume the role of scientists.

As educators, we can encourage students and help supply needed materials. Notice the students' needs as stated in the Tinkering Kit, "As you are tinkering with the children, think of other tools that you might introduce. Pay attention to the tools that they ask for—and get them if you can" (Boston Children's Museum and National Grid, n.d., p. 9). Encouraging experimenting with the materials is essential as noted, "Encourage the children to fully explore different ways to work with their materials. Ask, "Can you change the shape of the Play-Doh, paper clips, pipe cleaners, or toothpicks to create new shapes and structures? What can you do if you break your toothpicks into smaller pieces? Can you try just bending them without fully breaking them? Can you roll the Play-Doh into a snake and create a line of structures sticking up from that base?" (Robinson et al., 2018, p. 131). Changing the nature of the material and experimenting with what is available gives additional possibilities for solving problems and encourages creative and flexible thinking.

Limitations

Limitations of this study include the search terms and requirements established for the scoping review. For this research, the search terms "STEM," "elementary," and "science" were used. Using a variety of search terms and looking in different educational environments, grades, subjects, and/or approaches to learning could have produced different results. Even beyond STEM, STREAM subjects and standards would benefit with additional research.

Future Recommendations

Future recommendations involve embracing more of a loose parts mindset, utilizing outdoor spaces for enhanced learning opportunities, improved teacher training and support, and creating better assessment tools to observe and evaluate student performance. Providing opportunities for students to actively play outdoors in their natural environment is important for healthy child development and increases the chance for children to take part in self-directed play in all environments (Tremblay et al., 2015). In addition, multiple assessment options provide educators the ability to promote student engagement while ensuring key standards and learning outcomes are occurring. With additional research and training, effective evaluation tools can be implemented in elementary classrooms.

Conclusion

When elementary students can learn STEM topics (especially science) early in their educational journey, they are able to develop a passion to assist in their future academic, personal, and professional success. Hands-on science activities engage and motivate the young learners; however, teachers are often reluctant to use loose parts in the STEM activities. The goal of this scoping review was to establish teaching science methodologies, address challenges of teaching STEM, and share how exploration and experimentation of loose parts could be used to improve learning and student engagement in science and STEM curriculum across the globe.

Ethics and Conflict of Interest

As the authors of this study, we declare that we collected data in accordance with ethical rules during the research process and acted in accordance with all ethical rules. We also declare that there is no conflict among the authors.

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