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ORIGINAL ARTICLE

An Analysis of Picture Books for Children Aged 3 to 6 Years: Portrayals of Engineers and the Engineering Design Process

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Abstract

The potential of children's picture books to provide knowledge to support STEM education is high. Engineering is a field about which children may have little awareness or understanding. Children's picture books can be an important tool in introducing engineering to children. In this study, we investigate children's picture books written in or translated into Turkish for 3–6-years-old children to address two major points: (a) how engineers are portrayed and (b) how the engineering design process is included. We examined the content of 691 picture books and identified 23 books, in accordance with specific criteria (e.g., identification through predefined keywords), relevant to engineers and engineering. Findings indicated that characters who think and work like engineers were often portrayed as male characters rather than females. While 21 of the 23 books sampled discussed the engineering design process, none of these books identified all the steps in such a process. Children's picture books are important tool to introduce engineering to children. We recommend the publication of more engineering-centered picture books to provide children with information about engineers and the engineering design process, in support of STEM education. However, it is important that such books do not allow misunderstandings to emerge about the field of engineering in the creation of characters or the messages conveyed.

Keywords Children's literature · Children's picture books · Early engineering education · Engineering design process · STEM

Résumé

Les albums pour enfants ont un potentiel élevé à fournir des connaissances et des contextes pour l'enseignement des STEM (sciences, technologie, génie et mathé-

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matiques). Le génie est un domaine que les enfants connaissent ou comprennent peu. Les livres d'images pour enfants peuvent être un outil important pour présenter l'ingénierie aux enfants. Dans cette étude, nous étudions les livres d'images pour enfants écrits ou traduits en turc pour les enfants de 3 à 6 ans pour aborder deux points principaux : a) comment les ingénieurs sont représentés et b) comment le processus de conception technique est inclus. Nous avons examiné le contenu de 691 albums et identifié 23 livres répondant à des critères spécifiques (c'est-à-dire l'identification par mots-clés prédéfinis) pour retenir un échantillon pertinents pour les ingénieurs et le génie. Les résultats indiquent que les personnages qui pensent ettravaillent comme des ingénieurs sont souvent représentés comme des hommes plutôt que comme des femmes. Alors que 21 des 23 livres échantillonnés abordent le processus de la conception d'ingénierie, aucun de ces livres n'identifie toutes les étapes d'un tel processus. Les albums pour enfants sont un outil important pour présenter la conception d'ingénierie aux enfants. Nous recommandons davantage de publications d'albums centrés pour fournir aux enfants des informations sur les ingénieurs et les processus de la conception d'ingénierie, en soutien à l'enseignement des STEM. Il est toutefois important que ces livres ne donnent pas matière à malentendus par les personnages créés ou les messages véhiculés.

Resumen

El potencial de los libros ilustrados para niños para impartir conocimiento y contenidos de educación en el área de las ciencias es alto. Los libros ilustrados para niños pueden ser una herramienta importante para presentarles la ingeniería a los niños. En este estudio, investigamos libros ilustrados para niños escritos o traducidos al turco para niños de 3 a 6 años para abordar dos puntos principales: a) cómo se representa a los ingenieros yb) cómo se incluye el proceso de diseño de ingeniería. Se examinó el contenido de 691 libros ilustrados y se identificaron 23 libros de acuerdo con criterios específicos (por ejemplo, identificación mediante palabras clave predefinidas) relevantes para ingenieros e ingeniería. Los hallazgos indicaron que los personajes que piensan y trabajan como ingenieros a menudo fueron ilustrados como personajes de sexo masculino comparados con personajes de sexo femenino. 21 de los 23 libros bajo análisis explicaron el proceso de diseño de ingeniería. Sin embargo, ninguno de estos libros nombró todos los pasos en dicho proceso. Los libros ilustrados para niños son una herramienta importante para presentar conceptos de ingeniería a los niños. Se recomienda la publicación de un mayor número de libros ilustrados enfocados en ingeniería para brindarles a los niños información sobre ingenieros y el proceso de diseño de ingeniería y apoyar así la educación en el área de las ciencias. Sin embargo, resulta importante que dichos libros no den paso a confusión sobre el área de la ingeniería cuando se crean personajes o se transmiten mensajes.

Introduction

There is increasing dependence in society on technology and engineering. This requires every person to have some level of understanding about engineering and the practical use of technologies designed by engineers (Davis et al., 2017). Early childhood is the ideal time to lay the foundations of this understanding and provide children with rich learning opportunities through knowledge about engineering (English, 2018). During these early years, it is vital to introduce children to the engineering profession so that they can appreciate the importance of engineering. Moreover, providing experiences that help children explore the engineering design process, which is the primary approach adopted by engineers to solve problems, is also essential (Katehi et al., 2009; National Research Council, 2012). Introducing engineering to children can motivate their learning for STEM (Science, Technology, Engineering & Mathematics). This research focus can raise interest in engineering as a potential career and increase technological literacy through providing engineering-related learning experiences (Ata-Aktürk & Demircan, 2021; Cunningham & Carlsen, 2014; Dorie et al., 2014). In this study, we evaluate picture books for 3–6-years-old children, written in Turkish or translated from other languages into Turkish, to explore how well picture books introduce children to the work of engineers and the engineering design process.

We live in a world surrounded by a wide variety of technologies, from the seats we sit on, to the computers, robots, and 3-*D* printers we use. These technologies, which are an inseparable part of our lives, are the solutions that engineers produce by combining their creativity with science and mathematics to solve real-life problems and improve people's lives (Bers, 2008; Davis et al., 2017). The engineering design process is the basic problem-solving strategy adopted by engineers and consists of systematically progressive and iterative steps (Katehi et al., 2009). Although the steps followed by engineers in the design process can vary, the cycle usually starts with determining a problem, or need, and continues with research into the problem, its constraints, and current solutions. In the next steps, engineers brainstorm for new ideas that could solve the problem and articulate possible solutions and, then, identify a solution that may be the best answer to the problem. In the next step, they create a model (prototype) to test whether the solution works under any known constraints and then evaluate this solution. Afterward, the solution is shared with the other colleagues and discussed in terms of its social impact and trade-offs. In the last step, engineers redesign and develop the solution based on data obtained during testing and collaborative discussions (Massachusetts Department of Education, 2016). The process generally ends up with at least one practical solution that solves the problem or meets the need (Miaoulis, 2014; National Research Council, 2012).

Despite the contributions that knowledge of engineering can provide to children, engineering is one area in which children have limited opportunities to explore this knowledge in the home environment or in early childhood education classrooms (English, 2018). During the past decade, efforts have focused on creating a frame for early engineering education and proposing some practices to

integrate engineering education into educational learning environments (Bagiati & Evangelou, 2016; Raven et al., 2018; Tank et al., 2018). In addition to providing children with various opportunities and occasions to engage in the engineering design process, one step that can be taken to give young children understanding about engineering is to make them aware of engineering practices and outcomes (Smetana et al., 2012). One way to introduce children to engineering is to use children's picture books that have the power to provide children with knowledge and also enable them to think about various topics across the early years (Jalongo, 2004). Picture books can present different problem situations to young readers in a developmentally appropriate way and integrate hands-on design activities in which children can produce their own solutions to various problems (Evangelou et al., 2010; Holbrook et al., 2009).

Engineering and Children's Picture Books

Children's picture books can be defined as publications consisting only of pictures, texts dominated by pictures, or equally balancing texts with pictures (Shulevitz, 1989). In these kinds of books, both words and pictures contribute to the meaning of the story. Picture books have an important place in children's literature to collate and combine pictures and words to order to introduce new knowledge (Lynch-Brown et al., 2014; Sever, 2019).

Picture books can be used as a tool for children to help them to become aware of the role of engineering in their daily lives. Indeed, picture books can help children gain a perspective that will enable them to understand engineering as a creative initiative that plays an essential role in developing the world and facilitating people's lives (Next Generation Science Standards Lead Pantoya et al., 2015; States, 2013). More specifically, through the use of picture books, it may be possible to develop children's knowledge of today's human-made world and the design processes of technologies. It might also be possible to provide examples through which children can gain access to positive role models representing the engineering profession (Dorie & Cardella, 2011; Holbrook et al., 2009). Thus, the use of picture books can improve children's interest in engineering as a career (Dorie & Cardella, 2011; Dubosarsky et al., 2018; Pantoya et al., 2015) and overcome possible limitations in knowledge or misunderstandings that children may have about engineering (i.e., engineers operate trains or engineers design buildings).

Previous research revealed that the use of picture books offers strong opportunities for STEM integration contexts in early childhood education (Aguirre-Muñoz & Pantoya, 2016; Dubosarsky et al., 2018; Pantoya et al., 2015; Tank et al., 2018). For example, an engineering design activity, in which children are asked to design paper baskets to collect rocks, could have associated readings of picture books that provide information about characteristics of stones or how a transformation process occurs on how wood from a tree is turned into paper. Picture books could provide basic knowledge on integration of science knowledge with engineering processes (Tank et al., 2018). Picture books may provide children with examples of the work that engineers do through the presentation of age-appropriate characters and stories (Aguirre-Muñoz & Pantoya,

2016). Illustrating engineering activities in picture books may provide children with examples of design thinking and problem-solving through fictional characters and age-appropriate stories (Aguirre-Muñoz & Pantoya, 2016; Kimmel & Carlone, 2018).

Despite their potential to offer exciting and informative content about engineers and engineering, only a handful of studies have focused on these two concepts in children's picture books (Dorie & Cardella, 2011; Holbrook et al., 2009). Dorie and Cardella (2011) focused on investigating engineering-related picture books for 3–6-years-old children. They examined the illustrations, message types, and misconceptions about engineering. They found that there was a limited number of engineering-related picture books for 3–6 years-old children, for example, picture books depicted engineers as train conductors or as people wearing pocket protectors. Similarly, Holbrook et al. (2009) examined how and to what extent engineering and science were depicted in picture books for school-age children, and found that only 71 of 4800 books identified handled the themes of engineering and science. They also found that these books contain limited numbers of engineering details, and engineers were often represented as men who work in construction or with large machines, such as automotive vehicles. These studies identified a need for more children's picture books that focus on engineering and the need for further studies of current picture books written for young children that provide engineering-related content (Dorie & Cardella, 2011).

The Current Study

Examining how engineers are depicted in picture books can provide understanding on what engineering-related messages are currently being provided to young readers through children's literature. Introduction of the engineering design process in children's picture books would enable young children to learn about problem-solving processes; increase understanding about how technologies are produced; and apply design and problem-solving processes in STEM-related activities.

In the current study, we provide a content analysis of picture books suitable for children aged from 3 to 6 years and assess how, and to what extent, they portray the work of engineers and the engineering design process. In the research presented, we investigate the following research questions:

(1) How are engineers and engineering portrayed in picture books that are designed for children aged 3 to 6 years?
(2) How do picture books designed for children aged 3–6 years include and address the engineering design process?

Method

Book Selection

Books translated into Turkish or written in Turkish are the focus of this research and constituted the sample of books selected for analysis. This ensured easier

access to the books for review, as well as lower costs to purchase by the authors who live in Turkey. Additionally, the research provides an evaluation of picture books with engineering-related content in the Turkish language. This research can inform early childhood educators in Turkey about these resources to support children's STEM learning.

In selecting the books, we used a criterion-sampling approach (Patton, 2015), which identifies cases that meet certain predetermined criteria. We focused on three primary criteria and processes to identify books: (1) Written in Turkish or translated into Turkish from other languages, (2) Fictional storybooks that targeted children, aged 3–6 years; and (3) Identification of books through online searches using the keywords: engineer, engineering, design, invention, inventor, and problem-solving.

The book selection process is illustrated in Fig. 1. In the first phase, we searched for children's picture books online from two popular Turkish bookselling sites (Sites: https://www.kitapyurdu.com.tr and https://www.dr.com.tr), which sold approximately 15 million books in 2020 (Ulukan, 2021). Using the identified keywords, 308 children's books were identified from the online sites. In the second step, we filtered these books to identify books catering for children aged 3–6 years and 57 books were identified for this age category. In Step 3, non-fiction books (e.g., activity books, coloring books) were eliminated and remaining books were further screened for specific relevance to this research (e.g., how keyword "design" was applied). One book at this stage was also found to be no longer available. After eliminating these books, 6 books were identified to include in the final sample.

In the second phase (Steps 4 and 5), we physically visited a number of bookstores in our province (Ankara). Bookstores were identified that were known to have a rich children's book archive. We identified 383 possible picture books for 3–6-years-old children during the visits, and reviewed their contents on inclusion of the pre-determined keywords and/or 'design' examples. In Step 4, 42 books were identified. We then read the 42 books and eliminated non-fiction books

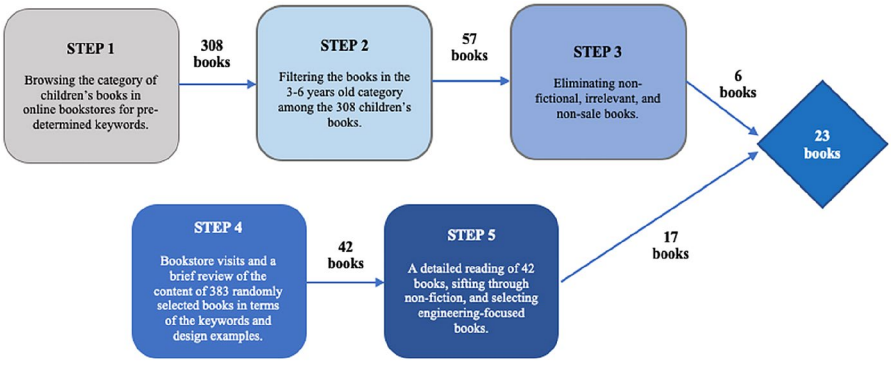


Fig. 1 Steps followed in selection of books for the analytic sample

or books that did not include engineering-related content. Further 17 children's books were identified to include in the final sample.

The final sample comprised 23 picture books. Seven of these books had been originally written in Turkish, and 16 had been translated into Turkish from other languages. Book titles author names, and other detail about these 23 books are listed in Table 1 in Appendix.

Coding Procedure and Data Analysis

We used content analysis for each book to address the research questions. Neuendorf (2017, p. 19) defines content analysis as "… the systematic, objective, quantitative analysis of message characteristics". In this qualitative research, the messages that each book conveys are contained in the text and pictorial content. In picture books, the messages to readers are mediated through the combined messages from the text and illustrations in each book (Axell & Boström, 2021).

Data Analysis

We prepared a codebook with two parts that related to the two research questions. The first part of the codebook focused on the analysis related to how engineers and engineering are portrayed in children's books, including a gender analyses. This included identifying characters' names, clothes, gender characteristics (beard, mustache, etc.), and statements identifying gender (e.g., mother, father, a little girl, etc.). Three specific categories were coded in these analyses: (1) gender of the character who works or thinks like an engineer (female/male/non-gendered); (2) whether this character is human (animal/human/robot/other); and (3) examples of engineering designs used by the characters.

The second part of the codebook focused on how the engineering design process was portrayed in the children's picture books. For analysis of the existence and portrayal of the engineering design process, we used the model proposed by Stone-MacDonald et al. (2015), which was designed for use in ECE programs. This model identifies four steps to understand the process by which early childhood educators can support the development of young children's problem-solving skills with specific applications to the engineering design process.

A template for coding the content in the picture books was devised to include the four main steps and the sub-steps, proposed by Stone-MacDonald et al. (2015). Data were coded using steps identified below and these steps are also outlined in Fig. 2:

- M1 (*Think about it*) with sub-steps (S1, S2, S3): Identify the problem and negotiate the problem-solving objective; examine the needs of those who have the problem; and discuss and consider possible solutions to this problem.
- M2 (*Try it*) with two sub-steps (S4, S5): Constructing something to solve the problem; including working independently or cooperatively with others.

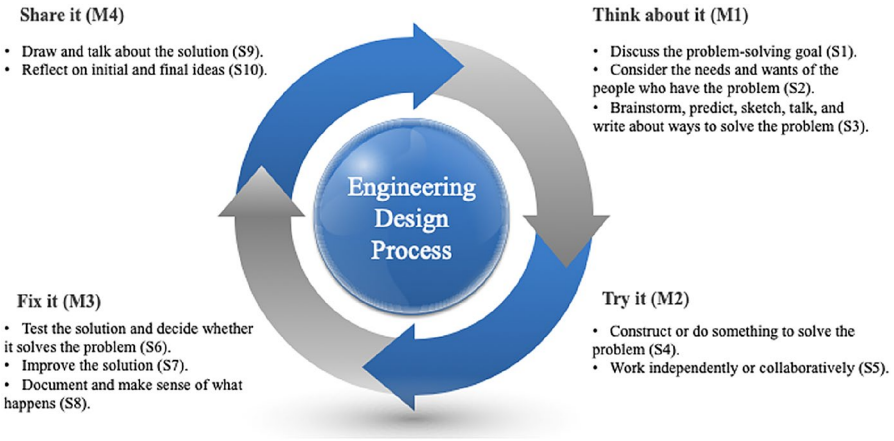


Fig. 2 Main steps for coding in the engineering design process and sub-steps (modified from Stone-MacDonald et al., 2015)

- M3 (*Fix it*) with three sub-steps (S6, S7, S8): Test the solution and make a decision whether the solution solves the problem; improve the solution in the light of the testing process; and interpret what happens.
- M4 (*Share it*) with two sub-steps (S9, S10): Draw and discuss the solution(s); reflect on ideas generated from the early steps through to the end of the process.

After an initial reading of the selected picture books to become familiar with the data, we reviewed the data repeatedly and the two authors coded the books independently using the codebook categories. We coded evidence from the text and visual elements of the picture books of actions and behaviors that reflected the descriptions of the steps and sub-steps in the model. This information was coded as present or absent (1, 0) so that counts of important features in the design process in each book could be reported. Each picture book in the sample was reviewed at least three times, across a period of approximately 2 months. The two coders determined points of agreement and disagreement and discussed any differences in coding to arrive at strong consensus. Final percentage agreement between the coders on final coding decisions was 0.92.

Findings

How are Engineers and Engineering Portrayed in Children's Picture Books?

Our first aim was to explore the portrayal of engineers and engineering in the 23 selected picture books designed for children aged from 3 to 6 years. We examined how characters who think and work like engineers were depicted, whether they were human characters and the gender of these characters. We found that in most books the engineers were humans (52%; $n=12$) or animals (39%; $n=9$). In the other two

books (*Norton and Alpha*, *Little Miss Inventor*), the characters that made the designs were a robot and a 'round shape' (9%). With respect to gender, characters of both sexes were portrayed as engineers in two books (9%) and in five books (22%) the gender was unclear. There were five books (22%) in which female characters thought like an engineer and produced (e.g., *Izzy Gizmo*, *The Most Magnificent Thing, Iggy Peck Architect, Little Miss Inventor*). However, engineers were portrayed most often as male (39%, $n=9$).

Our findings also showed that children's picture books provided many examples of engineering designs (see Appendix, Table 2). Some examples were designs that children might encounter in their daily lives, while others were 'imaginary' ideas. Some examples for designs that could be used in daily life included design of a walnut cracker made with two wooden spoons and a wire, in the book, *At Picnic.* A design for a walker made of tree branches was a design included in *Different But Same.* Shoes that make it easier to walk on snow were proposed in *Oaken's Invention*. And, a tricycle cargo bike design was included in *Tom's Magnificent Machines.* Some of the 'creative' design ideas included *On the Contrary*, the museum design that can fly, swim and run in *Tom's Magnificent Machines* and the flying pants in *Rosie Revere Engineer.*

We also encountered content (17%; $n=4$) that could result in misunderstandings by children about engineering, gender roles, and consumption. For example, in *Norton and Alpha*, the characters find something new, but they throw it out of the window because they think that this thing does not work and that there was no room for something that is not useful. In another book, *Oaken's Invention*, everyone in the family promotes their own inventions, We found that women's inventions contain subliminal messages for gendered tasks (e.g. knitting and playing a musical instrument). In another book, *I Will Be An Engineer When I Grow Up*, children are given the message that being an engineer requires hard work and high academic skills. In the same book, the characters want to grow as soon as possible to become engineers. Considering that to become an engineer one needs to be an adult and have high academic skills, then this might cause children to see engineering as a challenging profession to access, if it is only accessible after getting a university degree in engineering; even if engineering skills are often common practices that have considerable value in daily life.

How do Children's Picture Books Include and Address the Engineering Design Process?

The findings indicated that most of the picture books (91%; $n=21$) included some steps applicable to the engineering design process. However, when examined in detail, we found that no books dealt with all the sub-steps of the engineering design process, as identified in the coding model applied. Three books (13%) included nine of the sub-steps (*Izzy Gizmo*, *Yellow Bird,* and *Izzy Gizmo the Invention Convention).* Examples of the content related to each of the 10 sub-steps in the engineering design process are presented in Table 3 in the Appendix.

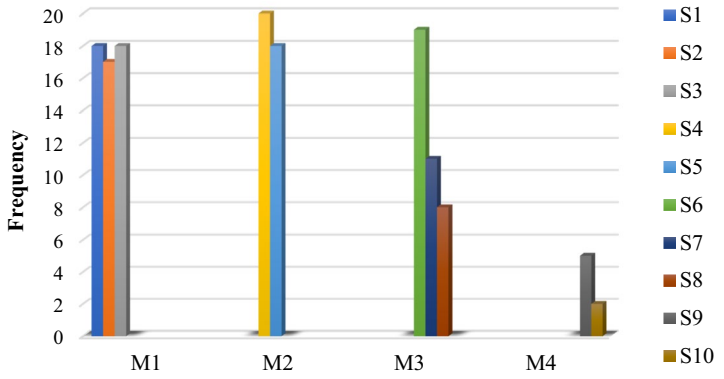
The number of books using the main steps of the engineering design model are identified in Fig. 3. The findings indicate that 'Think about it' (M1) was represented in 39% of the books. Two other main steps, 'Try it' (M2) and 'Fix it' (M3), were each represented in 28% of the books. The least mentioned step in the books was 'Share it' (M4), which was identified less often, in only 5% of the books.

In relation to the sub-steps discussed in the engineering design process, we found that the majority of the picture books (87%) included content related to construction of objects and devices to solve a problem and then testing the designed solution to identify if it solved the problem with identified in 83% of the books. Other sub-steps frequently included in the books discussed the purpose of problem-solving, brainstorming and/or sketching a plan, and working individually or cooperatively during the design process. These sub-steps were featured in 78% of the books. The sub-steps addressed less frequently were the steps about reflection on possible ideas at the beginning and/or end of the design process (9%), as well as drawing and talking about solutions to share it with others (22%).

Among the 23 books examined, two did not contain any content about the engineering design process. One of these books (*I Will Be An Engineer When I Grow Up*) introduces children to the profession of engineering and various fields of engineering but did not mention any design features of engineers' work. In the other book (*Norton and Alpha*), various design examples are presented, but it was not mentioned what steps the characters followed to progress these designs.

Discussion

The design processes in engineering provide a problem-solving framework that can be introduced to children so that they can understand processes used in science, technology, engineering, and math (STEM). Across the last decade, this focus has



Note: M1 includes S1, S2, S3; M2 includes S4, S5; M3 includes S6, S7, S8; M4 includes S9, S10

Fig. 3 Frequency of coded categories for main steps and sub-steps identified in the engineering design process in children's picture books ($n = 23$).

become increasing important in education and should begin in early childhood education. Engineers use problem-solving methods to find solutions to everyday problems. There are many literacy and learning experiences that can be planned in early childhood classrooms to facilitate children's knowledge and understanding of problem-solving and design processes that relate to the work of engineers.

In the current study, we investigated how engineers and engineering are portrayed in picture books for 3–6-years-old children. Our findings indicated that engineers and engineering topics were addressed in only a limited number of picture books. In other research, similar findings are evident, revealing a lack of focus on engineering in children's literature (Holbrook et al., 2009; Pantoya et al., 2015). Research findings also indicate a lack of knowledge and awareness by young children about engineering, although young children have the potential to produce creative solutions to various engineering problems (Bagiati & Evangelou, 2018; Raven et al., 2018). Not many young children know what engineering is and what engineers do (Ata-Aktürk & Demircan, 2021; Malone et al., 2018; Pantoya et al., 2015).

The findings in this research revealed that engineers were portrayed as male characters in the majority of the picture books examined. Similar findings are reported by Holbrook et al. (2009) and children also tend to portray engineers as male (Aguirre-Muñoz & Pantoya, 2016). Across the research literature, women are often depicted as passive characters who are neither producers, nor users of technology, in picture books for young children (Axell & Boström, 2021). According to a report from National Science Board's (2018), women constitute 29 percent of the total workforce in science and engineering in the United States. In Europe, this rate is 41 percent and in Turkey it was 45 percent in 2017 (European Union, 2020). In results from PISA (*Programme for International Student Assessment)* in 2018, engineering ranked third among the career expectations of 15-year-old male students. It was not even in the top 10 preferences for females. Similarly, data for career expectations of top performing students in math and/or science in Turkey show a statistically significant gender gap in the number of engineering and science-related professionals (Mann et al., 2020). Encouraging interest in STEM areas, including engineering from an early age, helps children to gain knowledge and skills in these disciplines and this is very important for both genders (McClure et al., 2017).

If picture books in which engineering is most often depicted through male characters, children may perceive engineering only as male business. These findings point to a need for more Turkish picture books for young children; books that provide accurate information about engineering as a career field; and which include female characters who can be role models for young girls (Holbrook et al., 2009). In these findings, engineers were most often shown as human and animal characters in children's picture books. As Sever (2019) noted, characters should be created to appeal to young children so that can identify with characters, as humans or animals, whom they can see and love. Presenting engineering to children through human and animal characters may help children to develop more positive attitudes towards engineering as a professional role.

When the steps of the engineering design process are included in children's picture books, this enables children to understand systematic problem-solving processes and inform them how problem-solving is used in engineering and in the

development of technologies. Our findings revealed that most of the picture books included some steps of the engineering design process, but none of the books reviewed in this study touched all the steps. In the majority of the analyzed picture books, most content related to the first steps of the engineering design process that involve presenting a problem situation and encouraging the characters to understand the dimensions of the problem. Many of the picture books also included content in which characters constructed a design to deal with the problem and tested the design to determine if it could solve the problem.

Children's books are a key socializing agents and messages in the content must be considered carefully (Holbrook et al., 2009). These findings indicated that some picture books contain content that may cause misunderstandings by children about engineers and engineering. These issues included how picture books reinforce gender stereotypes that engineers are more likely to be male; that engineering problems can consume extensive resources rather than promoting engineering solutions as simple problems of everyday life; and that engineering requires adult skills and high academic competence which could discourage engagement and enthusiasm for engineering. In order to create accurate and positive perceptions and perspectives on engineering, book content for children can be structured to avoid such messages being conveyed and misunderstandings.

There are several limitations to this research. This study focused only on children's books written in Turkish or translated from other languages into Turkish. Future studies of children's books in different languages focused on engineers and engineering are recommended. In addition, during the visits to the bookstores, it was seen that some of the books did not contain the keywords predetermined for this study, although having engineering-related content. The searches in online bookstores also did not locate an extensive number of books with the predetermined keywords. It is possible that some of the books online may have contained engineering-related content but were not identified for this research. It is recommended in future studies that physically visiting bookstores is important to ensure adequate coverage of books relevant to this topic focus of engineering and other STEM topics.

Conclusions

In this study, we examined Turkish picture books for children aged 3–6 on how engineers and engineering were portrayed. This research located a limited number of books with engineering-related content. Most of the reviewed books included many of the steps about the engineering design process in the model identified for use in this research. However, no books covered all the steps in the problem-solving model. Additional findings were that content in some picture books might mislead children about the nature of the work of engineers. It is important for children to understand how engineering can involve practical problem-solving processes.

Children's picture books that address engineering and the engineering design process can be used as an effective means to promote and support STEM education.

Children's picture books can also be the basis for positive attitudes towards engineering as a career field. The findings of this study reveal a need for more children's picture books that comprehensively address engineering and the engineering design process and which include more female characters with engineering roles. To create positive and accurate perceptions on engineering, content of picture books should not promote misinformation. An implication of this study, is the desirability of consultation with engineers in the preparation of children's books about engineering.

Appendix

See Appendix Tables 1, 2, and 3.

Table 1 Children's picture books selected for the analytic sample in the research

Name of the book	Author(s) and illustrator[1]	Language	Year
Rosie Revere, Engineer	Andrea **Beaty**, David **Roberts**	Translation	2016
Iggy Peck, Architect	Andrea **Beaty**, David **Roberts**	Translation	2016
Big Adventure of the Little Kırıntı	Aysun **Berktay-Özmen**	Turkish	2016
Benjamin and the Super Spectacles	Rachel **Bright**	Translation	2015
Walter and No Need to Worry Suit	Rachel **Bright**	Translation	2015
The Three Little Pigs	**Collective**	Translation	2017
Yellow Bird	Olga **de Dios Ruiz**	Translation	2016
At Picnic	Üstün **Dökmen**, Esin **Şahin**	Turkish	2015
The Ostrich Who Wanted to Fly	Aurélien **Ducoudray**, Bérengére **Delaporte**	Translation	2017
Little Miss Inventor	Roger **Hargreaves**	Translation	2019
Osman, der Angler	Anna **Hoffman**	Translation	2017
Izzy Gizmo	Pip **Jones**, Sara **Ogilvie**	Translation	2017
Izzy Gizmo The Invention Convention	Pip **Jones**, Sara **Ogilvie**	Translation	2019
Oaken's Invention	Jessica **Julius**	Translation	2017
Norton and Alpha	Kristyna **Litten**	Translation	2017
Short-Eared Bunny	Julia **Liu**, Leo **Tang**	Translation	2017
Different but the Same	Feridun **Oral**	Turkish	2017
Who Ate the Fruits?	Feridun **Oral**	Turkish	2017
My Mother's Bag	Sara **Şahinkanat**, Ayşe **İnan-Alican**	Turkish	2017
Tom's Magnificent Machines	Linda **Sarah**, Ben **Mantle**	Translation	2018
The Most Magnificent Thing	Ashley **Spires**	Translation	2017
I Will Be An Engineer When I Grow Up	Duygu **Ün**, Recep **Aydın**	Turkish	2015
The Bears Winter House	John **Yeoman**, Quentin **Blake**	Translation	2017

[1]Full references for these books in the analytic sample are listed in the References

Table 2 Engineering-related character(s) and examples of engineering design in children's picture books

Name of the book	Character(s) shown as engineers	Engineering design examples
Tom's Magnificent Machines	Tom (male) and his father	Tricycle cargo bike, Banana-powered rocket, moving museum, etc
The Bears Winter House	Bear (non-gendered)	Winter house built with logs, moss, and branches
The Ostrich Who Wanted to Fly	Ostrich (non-gendered)	Small planes, helicopter
At Picnic	Duru (female) and Doruk (male)	Cracking a walnut, a design constructed by using two wooden spoons
Rosie Revere, Engineer	Rosie (female)	A hat that keeps snakes away, cheesecopter
Who Ate the Fruits?	Frog (non-gendered)	Gondola made of watermelon peel
Walter and No Need to Worry Suit	Animals	An outfit with emergency phone and interplanetary impact protection
The Most Magnificent Thing	Young girl (female)	Object made of waste materials that can carry the dog on the scooter
Iggy Peck, Architect	Iggy (male)	Tower built with diapers, skyscraper, a castle built of chalks, a bridge made of rulers and shoelaces
Izzy Gizmo and The Invention Convention	Izzy Gizmo (female)	Sewing machine that can fix Grandpa's jacket, a sailboat made of open-ended materials, a robot making clothing designs, a cake copter that will deliver the cakes to their addresses, night-time-erizer that will turn off the lights before going to bed at night, broken tool repairer and recycler
Different but the Same	Shepherd (male)	Bike from tree branches for the goat with a walking disability
Benjamin and the Super Spectacles	Animals	Glasses with X-ray vision adjustment, preventing evaporation, providing night vision and adhesive handles
Little Miss Inventor	Nonhuman (female)	House on wheels, a super-speedy page-turner that makes it easy to read fast, a chatter-natter hat that allows talking to many people at the same time, a backpack that allows carrying junk food, a machine that made rude noises

Table 3 Examples identified of main steps and sub-steps in the engineering design process

Book name	Sample texts from the book	Coding[1]
Different but the Same	"She/he was born a little differently than other offspring in the herd. She/he wasn't holding her front legs, it was impossible to walk like this." (Oral, 2017a, 2017b, unpaged)	M1, S1
Little Miss Inventor	"So, Little Miss Inventor decided to visit Mr. Rude in the hope that this might give her inspiration." (Hargreaves, 2019, unpaged)	M1, S2
Izzy Gizmo and the Invention Convention	"Are all these tools broken?" Izzy gawped in dismay. You could mend them! You don't have to throw them." (Jones, 2019, unpaged)	M1, S3
At Picnic	"They wanted to make a tool to crack walnuts. They took two wooden spoons, tied them together by wire. They put walnuts between spoons and squeezed them." (Dökmen, 2015, unpaged)	M2, S4
Benjamin and the Super Spectacles	"Together they made an ingenious plan." (Bright, 2015a, 2015b, unpaged)	M2, S5
Rosie Revere, Engineer	"…then hauled her cheese-copter out onto the lawn to give her invention a test… then froze for a heartbeat and crashed to the ground." (Beaty and Roberts, 2016a, b, unpaged)	M3, S6
Yellow Bird	"Working together they adapted the invention so the ostrich could fly." (de Dios Ruiz, 2016, unpaged)	M3, S7
Izzy Gizmo	"Izzy fastened the wings… but the wings, the wrong shape, turned the crow topsy-turvy!" (Jones, 2017, unpaged)	M3, S8
Tom's Magnificent Machines	"…then quick, as that leaf falling he had an idea. He rushed home to share it with Dad." (Tom shows his sketch to his Dad) (Sarah, 2018, unpaged)	M4, S9
The Most Magnificent Thing	"… she comes across the first wrong thing she made. Then she noticed something surprising. The are some parts of the wrong things that are really quite right." (Spires, 2017, unpaged)	M4, S10

[1]Descriptions for coding categories for main steps (M1, M2, M3, M4) and sub-steps (S1 to S10) are included in Fig. 2

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