OULUN YLIOPISTO
UNIVERSITY of OULU

Familiarizing Children with Artificial Intelligence

Abstract

Studies regarding the digital literacy of children can be found easily. Such as teaching children about coding, involvement of children in the design and development of technology, learning of CT, and abstraction. On the other hand, the availability of literature regarding the combination of children and AI is still not enough. Especially, there is a lack of research regarding AI literacy of children which is the research problem. The gap was found while searching for material regarding AI and children through ACM Digital Library and IEEE Xplore which motivated to conduct this research. Thus, the research was conducted with the aim of familiarizing children with the AI.

Moreover, the qualitative research method was used for this study. The reason to choose this method was the lack of literature in this field. Another reason was to obtain evidence-based on observations in the real environment. Data was collected in the form of observations, texts (activity worksheets), pictures, video, and audio. The teacher was interviewed at the end of the last session to get feedback about children's learning. Also, the study was conducted at an international school in Oulu, Finland. Sessions were conducted on 19 Nov and 26 Nov 2019. Each session was of approximately 45 minutes. Children belonging to the age-group of 11-12 years were included.

To introduce AI to the children existing material with modification was used. During the sessions, children had some hands-on activities such as an online ML activity. Some activity worksheets were also distributed among them. Children were asked about AI before and after this concept was explained to them. Findings of the study suggested that some children's opinion about AI was changed after they were being engaged in learning activities. In the beginning, upon asking them about AI a few children answered as coding or robot whereas repeating the same question at the end some students mentioned "thinking by itself". In contrast, some students still mentioned robot or computer. Observations also suggest that children seemed to learn more easily through hands-on activities and by listening to stories.

Based on the results of this study, it seems that more sessions with careful planning are needed to get better results in the future. One limitation is, the results of this study cannot be applied to a large group of children. Another limitation of this study is the unknown background of participants.

Foreword

Writing the thesis was the most difficult and challenging task during the whole master studies. I started to work on this topic in 2019 almost a year ago when I was appointed as a research assistant. The main task was to write a literature review about *Artificial Intelligence and Children*. This lead to my thesis topic. I am thankful to Netta Iivari who provided me this opportunity to work. I am very grateful especially to my both supervisors Professor Netta Iivari and Associate Professor Marianne Kinnula who provided valuable guidance throughout the research process as well as helped me in finishing it. I would also like to thank my parents and sister who provided the utmost support and encouraged me during this time. Hopefully, its content will be beneficial for the readers.

Kashifa Khalid

Oulu, June 12, 2020

Abbreviations

AI	Artificial Intelligence
ML	Machine Learning
AR	Augmented Reality
CS	Computer Science
CT	Computational Thinking
DFS	Depth First Search
AAAI	Association for the Advancement of Artificial Intelligence
TA	Teachable Agent
FC	Forward Chaining
BC	Backward Chaining
CSTA	Computer Science Teachers Association
ADHD	Attention Deficit Hyperactivity Disorder
ASC	Autism Spectrum Conditions
MR	Mixed Reality

Contents

1.   Introduction

Technology is changing rapidly and with the time it is embedding in our daily lives more deeply than it was ever before. It can be seen that decades ago devices were performing the tasks based on what they were taught. Whereas nowadays devices act as living beings by gaining experiences through artificial intelligence (AI) (Williams, Park & Breazeal, 2019). It is difficult to present a specific definition of AI as there are different ways to describe the beauty of Snow white depending on one's focus i.e. white skin, red lips, or black hair (Kaplan & Haenlein, 2019). AI is defined as the intelligence showed by machines or software (Pannu, 2015). Kaplan and Haenlein (2019), defined AI as an ability of a system to interpret input (external data), to learn from it (input), and use this learning to achieve specific goals through flexible adaptation (p. 17).

Moreover, in the past technology was designed for workers and workplaces whereas at present it is shaped by and for the people of different age-groups i.e. children to senior citizens (Iivari & Kinnula, 2018). Also, children's lives are immensely influenced by the technology, as they are exposed to digital devices in a different context, not only at homes (Gottschalk, 2019). They have access to smart devices i.e. toys connected with internet and voice personal assistants (Williams, Breazeal, Machado, Maes & Druga, 2018; Williams et al., 2019). Children do not have programming skills even though they are familiar with the tablet, smartphone, and computers (Merkouris, Chorianopoulos, & Kameas, 2017).

Researchers illustrated that augmented reality (AR) helps students in learning to code more easily (Kim et a., 2019). Additionally, by actively engaging them in the design (of new technology) will help them in building better technology (Iversen, Smith, & Dindler, 2017). Nowadays, people's literacy of shaping technology is even more crucial than it was before because society is digitizing at a fast pace (Iivari & Kinnula, 2018). Especially, children should be offered a protagonist role by engaging them in design and development (Iversen et al., 2017). Children are completely different beings having their norms, and values which are different from their parents and teachers (Druin, 2002). Therefore, in the technology-rich future, they need skills, and competencies to deal with the technology (Iivari & Kinnula, 2018).

Furthermore, discussions regarding whether one should teach computer science (CS) at the K-12 level or not, and if so how early one should start can be found easily (Statter, & Armoni, 2020). For instance, the importance of introducing computational thinking (CT) in school curricula is increasing as it results in critical thinking and problem-solving skills which supports practices that lead to digital literacy i.e. programing and algorithmic thinking (Troiano et al., 2019). The emphasize on computer programming education is increasing with the increase in the diffusion of technology considering various aspects i.e. work and life (Merkouris et al., 2017).

Moreover, a tool named as ARCat helps children in learning depth first search (DFS) algorithm by AR technology (Deng, Wang, Jin, & Sun, 2019). Additionally, abstraction was taught to the 7th graders (Statter, & Armoni, 2020). In contrast to the familiarization of other CS concepts, scientific literature regarding familiarization of AI concepts to the children is not available. However, scientific literature regarding the combination of AI and children can be easily found e.g. education, and health (where AI is used for the children in various contexts). These addressed contexts are described in chapter 2 in detail.

Williams et., (2019) states, "In an increasingly AI-powered society, it is important to consider citizen's AI literacy–how much do people really understand AI?" (p. 10).

It is stated that preschool-aged children can also learn AI concepts via suitably formulated content (Williams et al., 2019). Thus, empowering children with the knowledge about smart devices will allow them to understand and develop systems according to their desires (Iivari & Kinnula, 2018). Growing up while learning about AI and technologies is vital for young children as they already had access to smart technologies at home (Williams et al., 2019, p. 10). However, one study out of five studies regarding the familiarization of AI concepts to the children was found in the ACM digital library. The reason seems to be that studies were not published in ACM. Such as, the four studies which were found through Google Scholar were published in Association for the Advancement of Artificial Intelligence (AAAI).

The main concern of this thesis is to familiarize children about AI and machine learning (ML) which makes these devices smart and intelligent. Literature review suggests that AI is addressed in various contexts concerning children. The research problem is a lack of literature regarding children's AI literacy which is also a motivational factor for conducting this study. Additionally, the thought of combining humans and technology seemed appealing and exciting. Thus, the research is conducted with the aim to familiarize children with AI. Also, to know what do children think of AI and if they are unaware of this concept then whether they understand, after it is explained to them. Thus, the research questions are:

RQ1   :   How to familiarize children with AI?

RQ1.1 :   How do children perceive AI before and after being involved in learning activities (regarding AI)?

RQ1.2 :   What were the challenges in conducting the study?

Three research questions are formulated for this study. RQ1 is further divided into two questions RQ1.1 and RQ1.2. These two sub-questions are formulated to get deeper insights into the study. Furthermore, this study is conducted at a school in Oulu, Finland. Children who participated in this study belong to the age-group of 11-12 years. The qualitative research method is selected for this study. The reason to choose this method is the less available literature in this sector as well as to obtain direct evidence form observations and experiences in the real environment.

Existing material with alterations is used during the sessions with the children i.e. Linda Liukas's storybook and online links for ML activity. Detail of the material used during sessions can be seen in chapter 4. Observations suggests that hands-on experience and storytelling helps children in understanding the concepts more easily. It is observed that after engaging the children in learning activities regarding AI a few student's perception was changed, if not all. This also suggests that children belonging to the age-group of 11-12 years can learn about AI.

As far as the structure of the thesis is concerned, chapter 2 summarizes the prior literature regarding children and AI found in ACM Digital Library, IEEE Xplore, and Google Scholar. Also, all under the age of 18 are considered as children. The third chapter illustrates the research method, how data was collected and analyzed. Additionally, it briefly illustrates consent and confidentiality. The fourth chapter explains how and where this study was conducted. Chapter 5 discusses results based on observations. It briefly compares this study's results with prior research. The sixth chapter summarizes the thesis while illustrating limitations of this study and future work.

2.   Literature Review

This section illustrates the selection criteria and categorization of the included literature. It demonstrates literature regarding AI from children's perspective. Whether AI is used for children or the concept of AI is learned by the children. Some studies regarding teaching various computer science concepts are also summarized.

2.1 Selection criteria and databases

To find relevant literature for this study, a search was conducted. The initial task was the selection of databases. It was a bit challenging because the research topic was combining technology and human i.e. Artificial intelligence and children. At first, ACM Digital Library, IEEE Xplore, EBSCO, Scopus, and ProQuest were selected. The search was conducted through all databases using the keywords artificial intelligence, and children. During the first search through all databases, there were many hits (in thousands) as compared to ACM Digital Library (hits in hundreds). Thus, the final databases used for this study were ACM Digital Library and IEEE Xplore. Also, to limit the search results filter were applied i.e. journal, conferences.

Additionally, to include more relevant studies especially regarding children's AI literacy were found through Google Scholar. The strings used for the search (through Google Scholar) were "children learning artificial intelligence", and "young children can learn AI concepts". In comparison to other databases, ACM was selected because it includes material regarding child and technology from HCI (human-computer interaction) which makes it significant for this study. IEEE Xplore was selected because it includes technology related material. The number of articles found in the ACM Digital Library fluctuated between 22-27 out of which 11 studies were included. The number of articles found in the IEEE Xplore fluctuated between 32-62 or 57-62 out of which 6 studies were included. Some studies found in IEEE Xplore were excluded because of its repetition.

The main keywords used for the search through both databases were children, artificial intelligence, and learning. Keywords of articles were not considered important because some of the articles were supporting the research topic even if their keywords were not appropriate for this search. Articles were categorized into four categories based on abstract. These categories are INCLUDED, EXCLUDED, SUPPORTIVE BUT NOT DIRECTLY, and NOT SURE. Due to the availability of a little number of articles in the INCLUDED category, some articles from SUPPORTIVE BUT NOT DIRECTLY were also included.

Studies supporting the topic directly are in the INCLUDED category i.e. usage of the device by the children in which AI is embedded or learning of AI concept by the children. Those studies in which tool was used by adults, teachers or anyone to help children are categorized in SUPPORTIVE BUT NOT DIRECTLY. Irrelevant articles are included in the EXCLUDED category. All those articles which do not give a clear idea of whether they are supportive or not, are in the category of NOT SURE.

Moreover, the main concern was to look for articles and conference papers that were mainly focused on teaching AI concepts to the children. Due to the unavailability of literature in INCLUDED category, two conditions were made. The conditions were: include literature in which the tool (in which AI is embedded) is being used by the child directly, and include those studies in which the tool was used by other users (such as teacher, parent, sibling, doctor, or any user) to help children.

Table 1. ACM digital library studies

Study Name	ID
My Doll Says It's OK": A Study of Children's Conformity to a Talking Doll by Randi Williams, Cynthia Breazeal, Christian Vázquez Machado, Pattie Maes, & Stefania Druga	S1
Multi-player Educational Video Game over Cloud to Stimulate Logical Reasoning of Children by César Villacís, Walter Fuertes, Andrés Bustamante, Daniel Almachi, Carlos Procel, Susana Fuertes, & Theofilos Toulkeridis	S2
Designing for Parasocial Relationships and Learning: Linear Video, Interactive Media, and Artificial Intelligence by James H. Gray, Emily Reardon, & Jennifer A. Kotler (2017)	S3
Enhancing Long-term Children to Robot Interaction…Engagement through Cloud Connectivity by Jordi Albo-Canals, Adso Fernández-Baena, Roger Boldu, Alex Barco, Joan Navarro, David Miralles, Cristobal Raya, & Cecilio Angulo	S4
Addressing Challenges in Promoting Healthy Lifestyles: The AI-Chatbot Approach by Ahmed Fadhil, & Silvia Gabrielli	S5
Using machine learning to support pedagogy in the arts by Dan Morris & Rebecca Fiebrink	S6
Excuse me, I need better AI! Employing Collaborative Diffusion to make Game AI Child's Play by Alexander Repenning	S7
Blending Human and Artificial Intelligence to Support Autistic Children's Social Communication Skills by Kaśka Porayska-Pomsta, Alyssa M. Alcorn, And Katerina Avramides, Sandra Beale, Birkbeck, Sara Bernardini, Mary Ellen Foster, Christopher Frauenberger, Judith Good, Karen Guldberg, Wendy Keay-Bright, Lila Kossyvaki, Oliver Lemon, Marilena Mademtzi, Rachel Menzies, Helen Pain, Gnanathusharan Rajendran, and Annalu Waller	S8
How to sustain long-term interaction between children and ROBOSEM in English class by Jeonghye Han, Bokhyun Kang, Seongju Park and Seongwook Hong	S9
A is for Artificial Intelligence The Impact of Artificial Intelligence Activities on Young Children's Perceptions of Robots by Randi Williams, Hae won Park and Cynthia Breazeal	S10
Diagnosis of ADHD using SVM algorithm by J Anuradha, Tisha, Varun Ramachandran, Dr.K.V. Arulalan and Dr. B.K.Tripathi	S11

The above-shown **Table 1** presents the ACM studies and assigned IDs. Whereas **Table 2** illustrates, the IEEE studies and assigned IDs.

Table 2. IEEE Studies

Study Name	ID
Young Children Can Learn Scientific Reasoning with Teachable Agents by Doris B. Chin, Ilsa M. Dohmen, and Daniel L. Schwartz	S12
Ultranus: a Novel Indonesian Cultural Game using Artificial Intelligence by Adelia Rokhmawati, Gradiyanto Radityo Kusumo, Irawan Dwi Wahyoho, and Rofiana Irawati	S13
Learning Platform for Visually Impaired Children through Artificial Intelligence and Computer Vision by B. K. Balasuriya, N. P. Lokuhettiarachchi, A. R. M. D. N. Ranasinghe, K. D. C. Shiwantha and C. Jayawardena	S14
Distributed Intelligent System for Personalized Therapy of Speech Disorders by Mirela Danubianu, Stefan-Gheorghe Pentiuc, Ovidiu Andrei Schipor, Marian Nestor and Ioan Ungureanu	S15
Work in Progress: Using Smart Mobile Tools to Enhance Autism Therapy for Children by Anthony Ellertson	S16
Intelligent Monitoring of Stereotypical Motion Conditions in case of Children with Autism by Giovanni Paragliola, Antonio Coronato	S17

The article, shown below in **Table 3**, does not belong to either of these two databases, rather the supervisor shared it.

Table 3. No Database

Study Name	ID
MOYA: Interactive AI toy for children to develop their language skills Ji Yoon Ahn, Dong Wan Kim, Yong Hyeon Lee, Woori Kim, Jeong Kuk Hong, Yeonbo Shim, Jin Ho Kim, Juhyun Eune, Seong-Woo Kim	S18

Table 4 presents the studies and assigned IDs found through Google Scholar.

Table 4. Google Scholar studies

Study Name	ID
Envisioning AI for K-12: What Should Every Child Know about AI?. Touretzky, D., Gardner-McCune, C., Martin, F., & Seehorn, D.	S19
30 Minutes to Introduce AI to Kids. Candello, H., Pichiliani, M., Pinhanez, C., & Wessel, M.	S20
Constructionism, Ethics, and Creativity: Developing Primary and Middle School Artificial Intelligence Education. Ali, S., Payne, B. H., Williams, R., Park, H. W., & Breazeal, C.	S21
Irobot: Teaching the basics of artificial intelligence in high schools. Burgsteiner, H., Kandlhofer, M., & Steinbauer, G.	S22

Moreover, section 2.2 illustrates literature regarding AI and children. Section 2.3 presents literature regarding teaching various CS concepts to the children. The search was conducted through the ACM digital library for the period 2019-2020. The keywords used for the search were: "computer science studies, children, teaching, and learning". The objective is to illustrate that a lot of work has been done regarding children's digital literacy though the literature is silent about the familiarization of AI concepts to the children.

2.2 Categorization: AI and children

Studies found through databases are divided into four general categories, considering the context it lies in (e.g. education or health). The four general categories are Ethics, Education, Health, and Arts and music. However, health is further divided into two categories i.e. clinical and fitness. Education is also explained from three perspectives which are: Use of AI for teaching purpose, Teaching various concepts of AI, and AI curriculum and the.

Moreover, below-mentioned **Table 5** shows, number of studies lie in one category as well as target audience's (children) age-group based on included studies. The column named as "Category" illustrates categories. The "User" column, indicates IDs in two sub-columns based on the utilization of tool (in which AI was embedded) by the child or adult. If in any study, the tool is used by both: child and adult, then the study's ID will be shown in both columns. The third column "Age group" illustrates age-group of the children. All between 0-18 years old are children. In some studies, researchers used various terminologies to illustrate children instead of presenting a specific age-group. Such as middle school, pre-school, fourth or fifth grade children, primary school children, kids, and toddlers etc.

Table 5.   Categorization Based on Context

Category	User		Age group
	Child	Adult	
Ethics	S1	-	4-10 years
Education: Teaching various concepts by using AI	S9, S12, S2, S3, S18, S13,	S7	S2: third, fourth, fifth, primary and middle school; S3: 2-3 years, child co-played - sibling 12-15years, other adults, friends and parents; elementary schools S7: developed for researcher himself, university students; children can also learn programming, middle school; S9: Elementary school; S12: Fourth graders: 9-10 years; S18: Toddlers and children S13: Typically developed children: 1-3, 4-7, 8-10; children with special needs 3-12 years
Education: Teaching AI concepts	S10, S20, S22,		S10: 4-7 years; S20: Kids and children; S22: average age 16.5 years;
Education: AI Curriculum	S19, S21,		S19: K-12 -12 graders; S21: Pre-K and kindergarten, middle school students in grade 5, 6-10years old students;
Health: Fitness	S5	S5	0-18
Health: Clinical	S15, S4, S14, S8,	S11, S16, S17,	S15: 2-2 year and 11months; S4: kids; S8: 4-14; S11: Children's training data of 7-10 years was used whereas diagnosis was made for 6-11; S14: target group 6-14 years, 4-10 years were also considered (system was not tested with children);
Arts and Music	S6		No specific age-group

2.2.1 Ethics

A smart toy "Cayla" (doll) was used to examine the behavior of children. The aim was to explore whether children's judgment can be influenced by a speech-enabled toy. Participants (children) belong to the age group of 4-10. Ethical aspects such as truth, obedience, and norms and values were observed. Children were observed in three different conditions: human condition, toy condition, and control. It was examined whether a child can be persuaded to tell a lie or disobey an instruction, and violate norms and values by listening to a toy's opinion. Cayla: a speech-enabled doll, connected with the internet was used for the experiment which means that it analyzed data and answered based on the question asked by the children. (Williams et al., 2018)

Table 6.   AI: Examine ethical aspects

Context	Study ID	Role of child	Role of AI	Place	Why use AI
Ethics	S1	User of the tool (doll)	Cayla doll	-	To analyse influence of Cayla's (doll) opinion on a child's decision

Moreover, **Table 6** illustrates key points presented in the study. "-" indicates information was not found through the study. It is crucial to know that the use of AI is unclear.

Results of the study showed, in the toy condition doll's influence on children's decision regarding moral question was similar to the socio-conventional questions. It was also illustrated that an agent directly influences children's moral judgments. In contrast, it was ineffective in changing the socio-conventional judgment of children while encouraging them to disobey an instruction. (Williams et al., 2018)

2.2.2 Education:

This section presents literature from two perspectives i.e. use of AI for teaching purpose and teaching various concepts of AI. Additionally, **Table 7**, **Table 8**, and **Table 9** summarizes some key points regarding the included literature.

Use of AI for teaching purpose

Repenning (2006), stated that many children learned programming and designing by creating their own game through agentsheets (tool). Though, he developed a diffusion framework for himself and later for university students. Collaboration diffusion is a framework that is used to create games with numerous agent that are working together. According to him, by adding AI debugging tools, the idea of Collaboration diffusion can be explained to middle school students. The goal was to assist those people in the creation of games who were not familiar with programming. It was also stated, with time, teaching material improved. More concise and compressed versions were used for the workshops at first for high school students and then for middle school students. The shortest session of a workshop lasted for approximately three hours and allowed the student with no programming knowledge to develop classic computer game e.g. Frogger. (Repenning, 2006)

Researcher presented a collaborative Soccer game simulation as well as demonstrated the issues regarding the difficulty of building collaborative agents and competition frameworks. Concerning Soccer, various variables were used to explain difficulties in the diffusion framework. For instance, while playing Soccer team member's actions were based on the situation in the game. Additionally, while discussing a 12-year-old child's perception of diffusion, it was illustrated that one-to-one tutoring sessions about 20 minutes were crucial to teach them diffusion. After the session, students setup agents and were eager to build AI-based games. (Repenning, 2006)

Table 7. Teaching various concepts by using AI

Context	Study ID	Role of child	Role of AI	Place	Why use AI
Education : Teaching various concepts by using AI	S2; S3; S7; S9; S12; S18; S13;	User	S2: Educational video game; S3: video, interactive media; S7: AI debugging tools were used; S9: robot; S12: AI is used in TA (software); S13: AI is used for FC and BC	S2: public schools; S3: one study in colorado, another in elementary school;	S2: to achieve cognitive development and mechanics of video game S3: for discussion element to administer child's interaction, S7: to convey the idea of collaborative diffusion to middle school children S12: To draw results based on what children taught

In another study, AI was used in a robot named ROBOSEM for teaching purpose because its utilization improved children's learning. This study illustrated long term interaction of children in English class from elementary school with the robot. The utilization of robot assisted learning was demanded by the parents and the government. While using ROBOSEM, some obstacles in long term interaction were also illustrated. For instance, the limitation of AI and speech recognition ability of robot (ROBOSEM). (Han, Kang, Park, & Hong, 2012)

Researchers explained that a teachable agent (TA) can teach children scientific reasoning. TA is an educational software that uses AI to draw results based on what they learned. To teach the children it uses a visual model for reasoning through hierarchies which is beneficial for novice students. To prove it, they presented a research study that was conducted with 153 fourth graders belong to the age group of 9-10 years. It was illustrated that a student teaches the TA (i.e. a computer character) instead of being taught by TA and a teaching narrative helps in organizing interaction between student and agent. Additionally, they wrote that people learn more when they are about to teach others as compared to when they are about to take tests. (Chin et al., 2013)

Moreover, Villacís et al., (2014) explained, it is crucial to design tools for the stimulation of children's thinking and development of cognitive and emotional skills. One of the tools is video games which work as an educational aid used by the teachers to motivate and stimulate children's logical reasoning in an amusing way. Therefore, this research was focused on creating an educational video game that was intended to stimulate the logical and spatial reasoning of a child. An incremental methodology based in Object-Oriented Hypermedia Design Method and Unified Modeling Language was used to produce an enjoyable environment. To achieve cognitive development, and mechanics of video game they used AI, intelligent agents, and modern 3D technology approaches. (Villacís et al., 2014)

Additionally, techniques of AI were used as intelligent agents, heuristic algorithms, and path planning agents which made the game attractive and user-friendly. Using these tools, a multiplayer educational video game running on a cloud computing infrastructure was created. This video game provided a competitive environment due to an avatar of a computer-controlled player which was described as an intelligent agent in the video game. Tests were conducted in public schools for validation purposes. Third, fourth, fifth, primary, and middle school graders were included. A total of 140 students participated in the study and were categorized into three groups A, B, and C. Results showed that this software stimulates a child's cognitive development. It was also illustrated that boys and girls perceive video games differently. Boys perceived challenges as competition, whereas girls perceived it as an opportunity of knowing their skills and abilities. (Villacís, et.al, 2014)

Later on, Gray, Reardon, and Kotler (2017) presented their experience designing for parasocial relationships between children and characters using various ways such as video, interactive media, and AI. They used empirical research as a reference, and a theoretical model and framework to understand this phenomenon. The goal was to provoke discussion regarding the future of character design in the IDC community, with a vision to guide the research, development, theory, and policy recommendations. AI was discussed in general i.e. how its (AI) techniques can be used in the educational sector because their work was still at an initial level of prototyping. Therefore, instead of presenting results, future work was discussed. It was illustrated that AI techniques can be used with Sesame's expertise. Sesame provides an opportunity for the children to see themselves with other created characters). Gray et al., (2017)

Furthermore, during the workshop children got excited when they saw themselves and their homes on a tablet screen with Grover (character: their friend) at the same place. Three types of media were explained for the identification of techniques to design parasocial learning by examples. In the first type, "one-way relationships" (p. 229) (e.g., traditional video), one study was conducted in elementary schools. In the second type, "two-way relationships" (p. 229), a study was conducted in Colorado for one week where 24 families with at least one child aged between 2-3 years old participated. It was discussed that children learn more from a familiar character instead of an unfamiliar character. It was explained, if a child believes that this character is knowledgeable then they learn more. For instance, a child solved the problem based on what the character did to solve that problem. (Gray et al., 2017)

The third type was "two-way relationships, powered by Artificial Intelligence" (p. 229), researchers explored text-to-speech, speech-to-text and a discussion element to administer a child's interaction. Such as semantic association between vocabulary words e.g. the underlying meaning of bug, spider, and arachnid. Children co-played with siblings 12-15 years old, other adults, friends, and parents. ML techniques were utilized in different modules of the system to enhance the functionality of specific modules by exposing repeatedly to relevant data. Experiments were conducted regarding the development of base-level functionality in the initial prototype by the utilization of training data sets and available data on the internet.   (Gray et al., 2017)

Moreover, Ahn et al., (2018) presented MOYA as an interactive AI toy. Its key purpose was to answer a child's curiosity. Moya was developed considering four functionalities which were: hand motion tracking, image classification, robot motion control, and graphic user interface. Toddlers and children belong to preschool point toward things which is a gesture for communication before the development of language skills. Thus, MOYA (robot) was developed to help children in developing their language skills. Researchers illustrated that the aim was to develop MOYA to conduct a few tasks. One task was to show the image and say the name of the object verbally based on the chosen language that a child points to. Another was that MOYA moves when the child moves to capture the pointing gesture. The last was when the child wants to take a test to recap the earlier learning, they (children) tells the name of the object in the picture, and MOYA responds with the result.

Furthermore, in Indonesia, the development of smartphone technology increases 17-20% every year. Study addressed a snake ladder game which was named as Ultranus (a smartphone application) created for typically developed children and children with special needs. It was an audio-video educational game. The purpose of this game was to enhance a child's understanding of the culture of the Indonesian archipelago. AI was used for both algorithms i.e. forward chaining (FC) and backward chaining (BC). FC (data-driven approach) presented results based on input information. BC was used to determine the category (i.e. various age-groups of children) of the game. Ultranus was categorized into four levels because of children's classification into four categories based on the age-groups i.e. 1-3 years, 4-7 years, 8-10 years, and special needs 3-12 years. "The results of testing in this game obtained that the accuracy of determining the level of 80% and determination category by 90%" (p. 365). (Rokhmawati, Kusumo, Wahyoho, & Irawati, 2018)

Teaching various concepts of AI

An educational project regarding teaching basic AI concepts at a high school level was presented. It covered main AI/ CS topics: problem-solving by search, classic planning,

graphs and data structures, automata, agent systems, and ML. This course was named iRobot and encompassed theoretical and hands-on components. It was divided into 7-weekly teaching units of 2h. Researchers conducted a pilot project in an Austrian high school in 2015and evaluated it. None of the students from grades 9-11 (average age: 16.5 years; 1 female, and 8 male students; they had prior knowledge in robotics but none of them had prior knowledge about AI). Activities consisted of e.g. programming exercise, robot construction, paper and pencil, discussions, group works, and homework. Results showed that participants became familiarized with these concepts and were confident regarding various topics that were addressed during teaching sessions. (Burgsteiner, Kandlhofer, & Steinbauer, 2016)

In 2019, a study illustrated challenges in designing a science museum for the children who had to learn AI in 30-minute by engaging them in hands-on playful session. This study illustrated the key decision regarding what and how it would be explored with the kids. A science museum started to plan a new exhibit that could introduce AI to children. The partnership was established with the IBM Research laboratory. The science museum received 40 school groups per day. Each group explored the museum in a 45-minute session. The challenges posed to a team were: 1) selection of key ideas and concepts to explore with children, and 2) the creation of an engaging, playful experience that would build those basic concepts with children. (Candello, Pichiliani, Pinhanez, & Wessel, 2019)

The team formulated a key question i.e. what people have to know about AI to make better decisions about its use in society. Based on the question some themes emerged. The themes led to a statement while leaving the exhibit, children should understand that AI imitates human's and society's imperfection. Thus, it (AI) needs to be controlled by its citizens. The actual task was to introduce those themes in 30 minutes. The exhibit space was similar to an AI event of 2011 where two world champions were defeated by the computer in a game Jeopardy. In the space, three talking heads competed in a trivia game. Children were invited to improve the AI system through touch displays when the heads were unable to answer some questions. The performance of the heads was improved through some examples given by the children. Thus, it was explained that the knowledge comes from people that was used by heads, heads make mistakes and humans are needed to improve their performance. (Candello et al., 2019)

An AI platform, named PopBots, was developed to teach children three AI concepts i.e. 1) Knowledge-based systems, 2) Supervised ML, and 3) generative AI. Researchers selected these concepts because children can link them with their experiences gained through entertainment apps and smart toys (in which similar AI algorithms are used) to which they are exposed daily. Popbots were introduced to the children of the age group of 4-7 years. Younger children perceived robots as toys smarter than themselves. Whereas, older children perceived robots as people who are not smarter than themselves. (Williams et al., 2019)

In AI assessment performance of children who perceived robots as toys was worse. Whereas, children who treated them as people smarter than themselves performed better on AI assessment. In this paper, researchers tried to understand, how developmental factors (i.e. perspective-taking skills) influence children's learning of AI and how their perception changes after being engaged in educational activities regarding AI. (Williams et al., 2019)

Before presenting their study, Williams et al., (2019) reported another study conducted by Mioduser and Levy (who conducted a study with kindergarten children). They

explored that children give psychological descriptions for complex tasks as well as for behavior they did not program. Whereas, they give mechanical reasoning for simple tasks performed by the robot and programmed by them. Additionally, based on the results achieved by Wellman and Liu, researchers proposed a hypothesis that the theory of mind plays an important role in a child's understanding of AI with PopBots. (Williams et al., 2019)

Researchers tested the theory of mind skills considering three things which are knowledge access, content false belief (a person's incorrect belief) and explicit false belief (knowing already a character's behavior). Children were graded based on the way Wellman and Liu graded them. Additionally, it was illustrated that a question was correct only when the child answers both target and control questions correctly. Up to 75 %, children answered knowledge access questions correctly in comparison to Wellman and Liu's study. In false belief, 55% of questions were answered correctly which is quite near to Wellman and Liu's result which was 59%. (Williams et al., 2019)

Moreover, researchers developed AI activities and assessments by conducting workshops with 26 children. Regarding hands-on activity, children built their own Lego using Lego Duplo blocks. While a child was building, the robot explained algorithm logic and motivated the child to try novel things. The picture-based interface was used by the children who cannot read yet, for training and programming the robot. Additionally, to teach the knowledge-based system (concept), rock-paper-scissor game was selected. Children entered rules for the game and played it (game) against robot. Robot interacted with the child by saying "I think you will put X, so I will put Y because Y beats X" (p. 3), if its guess is greater than chance 33%. If it is less than 33% then the robot says, "I am not sure what you'll do next, I'll just guess" (p. 3). (Williams et al., 2019)

Concerning supervised ML children marked the food items as good and bad and then they asked the robot, which category it lies in, by clicking on the food item. For the third concept generative AI, activity named as music remix was selected. Children clicked on different emotions to produce music because those emotions are associated with a different tempo. Robot produced a melody based on the emotions selected by children. In addition, this study was conducted in the Greater Boston Area during spring 2018 in four schools. Three schools were public schools and one was a private school. Activities were performed in five classrooms with 80 children who belong to the age group of 4-6 years. All children were in preschool i.e. Pre-K: age 4-5 and Kindergarten age 5-6. (Williams, et al., 2019)

Table 8.   Teaching AI concepts

Context	Study ID	Role of child	Role of AI	Place	Why use AI
Education: Teaching AI concepts	S10, S20, S22,	S10: User of tool and learner of AI concept; S20: Learner; S22: Learner of basic AI concepts;	S10: AI Concept learned by children; S20: Learned by children; S22: Course-iRobot;	S10: Greater Boston Area during spring 2018, (3 public schools, 1 private school, and five classrooms); S20: Science museums in Latin America; S22: Austrian High School;	S10: To check the impact of developmental factors on children's learning regarding AI; S20: To provide an understanding of AI; S22: AI concepts were taught;

The data collected through activities contains information of only those children whose parents completed the consent form. The assessment of each activity was done by using multiple questions through semi-structured interviews. Furthermore, AI activities were completed in 10-15 minutes which were followed by AI assessment. A pre-test and post-test about the perception of robots was conducted (in the beginning and at the end of the study). According to the results, more children accepted in the post-test (that robots can learn) as compared to pre-test. Additionally, the results of the activities show that children understood the knowledge-based system the most, then supervised ML, and generative AI. (Williams et al., 2019)

AI curriculum

AI has influenced the way we live, work, and play. Thus, researchers illustrated, created tools, and conducted studies for the development of the K-12 AI education curriculum that lays emphasis on constructionist learning, designing considering ethics, and developing a creative mindset. They also developed a K-8th grade curriculum. They explored whether a robot (that displays creative thinking) can promote creativity as a learning behavior in young children. Considering constructionist learning, the researchers used PopBots presented by William et al., 2019. PopBots provides a hand-on experience that allows children to explore with freedom. PopBots were evaluated with 80 Pre-K and kindergarten students with no previous AI or programming knowledge in four sessions. Results showed that the curriculum helped children in understanding AI. (Ali, Payne, Williams, Park, & Breazeal, 2019)

To teach ethical ramifications of AI to middle school students, researchers built hands-on AI activities. The first lesson was about familiarization of AI, datasets, supervised ML, and algorithmic bias. The second lesson familiarized algorithms as opinions and stakeholder analysis via ethical matrix. In the third lesson, students had to redesign Youtube's recommender system from the perspective of stakeholders, values of those stakeholders, and determine the goal of that system via ethical matrix. The curriculum was evaluated with 225 middle school students in grade 5. The students did not have any prior education about AI or programming. (Ali et al., 2019)

A total of 51 participants of 6-10 years were evaluated. Results showed that "robot interaction patterns for artificial creativity is a good model for robot behavior that fosters creativity in children". After teaching children about AI, researchers evaluated role of a social robot in aiding children in creative thinking. Researchers developed an interactive game through which children collaborated via Jibo (a social robot). The child and robot give title to an abstract drawing known as Droodle shown on a tablet. Results "demonstrates that our robot interaction was effective in causing children to model the social robot's creative behavior." (Ali et., 2019)

Researchers illustrated that in 2018 AAAI and Computer Science Teachers Association (CSTA) made a group for the development of guidelines regarding teaching AI to K-12. Guidelines outlined what children need to know about AI, ML, and robotics in each grade. It is stated, many products are available that uses AI and are accessible by children. Such as most cellphones have a voice assistant. In addition, the presence of computer vision can be seen in various tools such as Osmo app that can differentiate between game pieces and drawings of children. Moreover, the development of guidelines is still at the initial stage for AI for kids through collaboration among AI experts and K-12 teachers. (Touretzky, Gardner-McCune, Martin, & Seehorn, 2019)

Researchers presented five "Big Ideas" in AI which are: "Big idea 1" perception of computers through censors. The "Big Ideas 2": use of models for reasoning purposes. The "Big Idea 3": Learning of computers through data. "Big idea 4" interaction of agents with the humans -- a challenge faced by AI developers. "Big Idea 5": Positive and negative impacts of AI on society. In each "Big Idea", various levels regarding learning were defined depending on grades (K-12 – 12 graders) which the students must achieve. The detail of the draft of "Big Ideas" is mentioned in the study. (Touretzky et al., 2019)

Table 9. Curriculum

Context	Study ID	Role of child	Role of AI	Why use AI
AI Curriculum	S19; S21;	S19: Learner; S21: Learner of AI concepts;	S19: taught to students; S21: AI learned by children, used in social robot;	S21: For teaching purpose, to promote creative thinking in children;

The above-mentioned **Table 9** illustrates role of child and role of AI but does not explain the place because the presented curriculum was not implemented in any school and was in progress.

2.2.3 Health

Health is further categorized into two sub-categories named as Fitness and Clinical. Fitness addresses a solution regarding diabetes. Whereas, the clinical section illustrates various issues such as visual impairment, various speech disorders, or children under painful treatment in hospitals.

Fitness

The goal of primary care intervention is a healthy lifestyle. It was mentioned, one-third of children belonging to the pediatric age group (0-18) are exposed to a chronic disease named diabetes. There are many applications to achieve a healthy lifestyle by providing different dietary plans. Due to some reasons, those applications are being abandoned. Such as these applications require self-reporting which seemed to be a burden by the user. Thus, researchers presented AI-Chatbots, which were used as an innovative approach. Through AI-chatbots, one of the various factors such as "user personality" was considered to provide a personal dietary plan. Also, an example of 35 years old lady was also presented. (Fadhil, & Gabrielli, 2017)

Additionally, sentiment analysis and emotional conditions were mentioned as important factors to improve the effectiveness and quality of user experience. ML was used to gather and understand different factors regarding the user. In this way, the bot was trained to provide better preference (based on the understanding of the user). Additionally, the bot can notify a health care expert for the intervention whenever required. In AI-Chatbot system anatomy, conversational agents can be voice-based: which can respond based on listening, and text-based: which can respond based on reading text, or both. (Fadhil, & Gabrielli, 2017)

Table 10. Fitness

Context	Study ID	Role of child	Role of AI	Place	Why use AI
Health: Fitness	A5	User	AI-Chatbots	-	To provide better preference based on understanding of user

The above-mentioned **Table 10** illustrates the role of a child, the role of AI, and reason to use AI. "-" indicates that data was not found through the study.

Clinical

A therapy system named as TERAPERS was developed to help children with speech impairment. It consisted of two components 1) "intelligent system" (installed on therapists' system), and 2) "mobile application" (installed on mobile phones of children) which behaves as a friend of the child. Components were connected with eachother.The potential users of this system were children. Data set was dependent on the children between 2 years - 2years and 11 months. The expert system provided some suggestions to therapists regarding exercises suitable for that specific child with speech impairment. Then the therapist made the final decision about those exercises and send the homework for the child on his mobile device. The mobile application presented those exercises for the child as homework. This system was verified by interschool regional Logopaedic Center of Suceava but the detail regarding the number of children is not mentioned. (Danubianu, Pentiuc, Schipor, Nestor and Ungureanu, 2008)

Another study addressed attention deficit hyperactivity disorder (ADHD) in 2010. ADHD is a disruptive behavior disorder that is mostly found in children and it can also continue through adulthood. Its diagnosis is a bit tricky because of difficulty in differentiating between typical and atypical behaviors. In this study, an artificial intelligence technique i.e. SVM algorithm was used to develop a tool for ADHD's diagnosis. The process of diagnosis consists of three steps: collection of data, test data processing, and diagnosis. (Anuradha, Tisha, Ramachandran, Arulalan, & Tripathi, 2010)

Data of 100 children was collected from the doctors. These children belong to the age group of 7-10 years. Six questions with subparts having yes or no answers were given to the children. The diagnosis was performed for 98 and 99 rows and that's why there is no value in the diagnosis column in fig4 presented in the study. Instead, for these rows results of diagnosis by the SVM algorithm are shown in column V in fig5. This data was used by the SVM algorithm as a training data set. Later on, diagnosis of ADHD for children of 6-11 years old was evaluated by SVM algorithm. There was the success of 88.674% in diagnosing ADHD. (Anuradha et al., 2010)

In 2012, it was reported that in the United States, one out of eighty-eight children between the ages of 3-17 had autism. It was also a major problem faced by parents, school districts, and government institutions. Thus, the researcher was trying to improve therapeutic hard work through the use of smart mobile tools. These tools were specifically formed to aid therapists working with autism and relative communicative disorders. The smart mobile tools used cloud services and AI for pattern tracking and visual display of those patterns for the treatment. (Ellertson, 2012)

These tools were used for the evaluation of the effectiveness of a therapy guide the treatment depending on children's needs. Thus, the purpose of this project was to improve training for therapists and educators in this field while offering a mode for cross-communication among professionals on treatment teams. The tool was created for the adults i.e. therapists, educators, and parents to treat the children having autism or communicative disorders. Success results of using the tool are not illustrated in the study. (Ellertson, 2012)

Another study also addressed autism. In U.S. one in every 110 children has autism. It has three categories: 1. Social impairment 2. Communication difficulties and 3. Repetitive

and stereotypical behaviors. Thus, a software was presented for the detection of third category "stereotypical motion conditions" in autistic children especially considering motion conditions such as "arm flapping, hand hitting against ears, hand rotation up, and hand rotation down". (Paragliola & Coronato, 2013)

AI was used in that software and its purpose was to assist clinicians to identify children's stereotypical motion. The accuracy result of the system was 98.156%. Therefore. it was deployed at the Department of Child Neuropsychiatry at the Santobono-Pausillipon Children Hospital. In the future, researchers wanted to develop a system at home which can detect children's behavior i.e. anxiety and reacts to attract the patient to recover from that state. In this study no specific age group of children is mentioned. (Paragliola & Coronato, 2013)

Later on, the cloud-based structure was used to increase the long-term engagement of children with the robot to decrease the anxiety of hospitalized children. Cloud connectivity was used to combine AI with human intervention. "A cloud architecture for the coexistence of multiple systems that allows either the end user, a human supervisor, or an artificial agent to induce PLEO behavioral states" (p. 105). The robot was used as a substitute for a pet animal as a distractor to decrease child's anxiety during treatment. (Albo-Canals et al., 2015)

PLEO (robot) was used to direct a child's attention towards itself. This robot reacts based on experience, acquired skills, and parameters which change over time depending on the event. AI agent on the server behaves as a stimulation device which modifies PLEO's internal variables to obtain a child's attention. The goal of the AI agent is to learn relevant decision parameters. The parameter to measure useful interaction of pet/ robot with the child was "engagement". (Albo-Canals et al., 2015)

Moreover, sessions were conducted in a regular school in pairs with PLEO (with 20 kids), in various hospital faculties in one-to-one interaction, in a group with multiple kids and multiple PLEOs at the same time using the cloud, and at a summer camp with the kids who were already familiar with the PLEO. These sessions were conducted for the identification of behavioral parameters of the robot. The identified crucial behavioral parameters of PLEO were physical, feed, activity, and obedience. All the kids tried to feed PLEO and preferred PLEO to be moving. 34% of kids forced PLEO to eat. 100% of caregivers demanded to have a customized initial state of the parameters and agreed that changing its parameters would help to keep participants' attention. (Albo-Canals et al., 2015)

In 2017 researchers tried to create an application for the children having visual disabilities between the age of 6 -14. It was illustrated that children belong to the age group of 4-10 did not get enough attention. The purpose of this application is to assist them in learning to identify objects without the supervision of a third party. Thus, they combined computer vision and artificial intelligence technologies through R-CNN, RNN, and speech model for interactive learning. Additionally, the functionality of the system was divided into two separate categories indoor and outdoor objects to make it easy for the child to recognize the environment without any confusion. The system was not tested with the children but some drawbacks of the tool were mentioned for improvement. (Balasuriya et al., 2017)

Later in 2018, research regarding autism spectrum conditions (ASC) was conducted. Researchers focused on two areas: initiation of a conversation and responses. These areas were mentioned to be critical fields of difficulty in ASC. They aimed to develop an environment where an autistic child can be motivated and encouraged for natural and

continuous communication behaviors. Later on, they presented design and evaluation of a technology named as ECHOES, that combines AI and human to assist autistic children belonged to the age group 4-14 years old. ECHOES was developed by consulting experts in ASC, teachers, children without autism, and parents. (Porayska-Pomsta et al., 2018)

Moreover, a single user can interact with ECHOES. ECHOES uses an AI agent named Andy which helps children in learning and improving social communication skills. The child interacts with ECHOES through a multi-touch screen. AI agent involves children by using different gestures such as gaze to initiate action through the child. Additionally, a human partner is provided with the purpose of encouragement and praise. Initially, 29 children with ASC from five schools participated in the study but later on, 10 children were excluded. Results show a significant increase in the child's responses to the human social part for initiation. Considering responses, positive results were achieved concerning both social partners i.e. AI agent and human practitioners. (Porayska-Pomsta et al., 2018)

Table 11 illustrates the IDs of respective studies as well as summarizes key points regarding literature illustrated above in the clinical section.

Table 11. Clinical

Context	Study ID	Role of child	Role of AI	Place	Why use AI
Health: Clinical	S4; S8; S11; S14; S15; S16; S17	S4: User; S8: User and adult encourages the child S11: Patient; S15: User S16: Patient S17: Patient	S4: Robot PLEO; S8: ECHOES uses an AI agent named as Andy; S11: to diagnose ADHD; S13: AI is used in an application; S15: Provide suggestions to therapists regarding exercises suitable for that specific child S16: Used in smart mobile tool S17: AI is used in a software	S4: School and hospital faculties, summer camp; S8: Five schools; S15: Interschool regional Logopaedic Center of Suceava; S17:Department of Child Neuropsychiatry at the Santobono-Pausillipon Children Hospital;	S4: learn relevant decision parameters; S8:to assist Austistic children by combining it with human; S11: diagnosis of ADHD is a bit tricky; S13: for interactive learning; S14: interactive learning S16: for pattern tracking and visual display of those patterns for the treatment S17: to assist clinicians to identify children's stereotypical motion.

2.2.4 Arts and music

Researchers stated it is quite challenging for teachers to teach artistic skills to the children. High-level skills such as creativity and social elements are more likely to keep one's eagerness towards learning but are dependent on low-level skills such as sensorimotor capabilities. Most of the children leave the education of learning instruments after many years of training in low-level skills before the connection to high-level components is drawn. Researchers hypothesized that ML and AI techniques can be used as sensorimotor experts in computer-based learning through which bottom-up (low-level) learning in the

arts can be connected to top-down (high-level) learning. This allows students to experience high-level components even before knowing pre-requisite sensorimotor skills. (Morris & Fiebrink, 2013)

Morris and Fiebrink (2013) presented two case studies: songsmith and PLOrk (a laptop instrument). Songsmith is a software through which a novice student/ user can make music just by singing a melody. This software analyses students voice, selects suitable chords and provide those chords as a music arrangement. The user/ student can adjust chords progression through the graphical user interface. In this way, a novice user gets a taste of high-level components i.e. music creation. It was deployed in public schools and Seattle symphony's "Soundbridge" program. PLOrk students had slight or no musical training. Researchers illustrated, in Chicago in 2009, when children were offered hands-on demos of PLOrk instruments, they were fascinated to know that computers can be used to perform music. (Morris & Fiebrink, 2013)

Moreover, Wekinator (software) can be used to design an instrument. Instrument can be controlled via gestures. Each gesture was paired with the computer sound which results based on the gesture. Such as, a user can show some examples in front of the camera to create a webcam-controlled drum machine for rhythm as well as some other examples for a different rhythm. Through the ML algorithm, the model is trained regarding the relationship between gestures and sounds based on the examples. The user can test the trained model to check whether it shows the desired output or not by demonstrating some of the gestures in front of the camera. If it does not, the user can improve it by providing more examples. Twenty-two PLOrk students used Wekinator through which students can build their music instruments in minutes rather than hours. Most of the students enjoyed using that software and sometimes they even found some unexpected new sounds. (Morris & Fiebrink, 2013)

The following table, **Table 12** illustrates the role of AI, the role of child and why AI was used. "-" indicates the data was not illustrated in the study.

Table 12. Arts and music

Context	Study ID	Role of child	Role of AI	Place	Why use AI
Arts and Music	A6	User & ta and professionals	Wekinator (Software)	-	AI plays the role of sensorimotor experts

2.3 CS and children

Teaching CS to young children is one of the most discussed topics. Concerning young students, interaction through tangible objects benefits in learning. This study was focused on discovering the benefits of learning to program through robots and wearable computers in contrast to desktop computers. In this study, 36 students participated where three types of computers were used which are desktop, wearable, and robotic. Factors: emotional engagement, attitudes, and programming performance were measured through questionnaires before and after using computing platforms. Findings suggest that students were more interested in learning to program with robotic as compared to the desktop computer. Regarding the engagement of children, results show that multiple platforms (e.g. robots, smartphones, and wearables) should be used for teaching programming. (Merkouris, Chorianopoulos, & Kameas, 2017)

Another study conducted in 2019 presented a tangible programming tool named as ARCat that helps children in learning DFS algorithm by AR technology. ARCat has two parts:

the AR environment and tangible cards. Researchers stated that programming education helps in developing CT. Algorithm education helps in cultivating logical thinking and problem-solving skills. Given this, utilizing the combination of programming education with the algorithm is of worth for young children. Though considering the traditional way of learning programming seemed to be a challenge for young children, and for some children, it seemed impossible to learn. To make it easier for children to learn to program, a tangible user interface was used (i.e. tangible cards). A total of six children (age-group 8-9; 3 male and 3 female) participated in this study. Findings suggest that children get an understanding of the search algorithm as 5 children did it correctly. (Deng, Wang, Jin, & Sun, 2019)

Researchers investigated supporting mixed reality to aid students in learning to code easily. It was suggested that AR helps students in learning to code more easily. On the other hand, AR creates challenges for students and educators. Some challenges are cognitive overload, and difficulty of adaptation of the AR system by some teachers. To address these challenges, improve the learning experience of coding, and aid students to learn coding with more fun, the mixed reality (MR) coding platform using Apple's ARKit 2 on iOS was developed. It also consists of a tangible avatar object and coding game board which is user-configurable. MR was given importance for students to get hands-on experience due to their (student's) physical interaction with the program. Such as students move the physical avatar to trace coding errors. Additionally, it helps teachers to modify the platform based on their needs. (Kim et al., 2019)

Moreover, CT helps in cultivating problem-solving skills. Dr. Scratch is one of the metrics that help in measuring CT of games (especially with Scratch) designed by students. It is reported, previously scratch was used for measuring CT but did not consider development. Therefore, this study was mainly focused on utilizing Dr. Scratch to measure CT of the scratch games developed by students of 8th grade (age 13-14). Dr. Scratch automatically measures CT competency on seven dimensions (i.e. abstraction, data representation, flow control, logic, parallelism, synchronization, and user interactivity) which are based on coding practices observed in Scratch. This study took place at middle schools in the greater Boston, MA area. In this study, the curriculum was implemented over two years by nine teachers and 35 science classes participated in it. There were about 19 students in each class. The study was conducted in three different schools. A total of 435 projects were collected which were filtered to 317 projects. The proficiency of CT and CT development was measured in 317 and 217 games designed by students respectively. (Troiano et al., 2019)

Abstraction is one of the basic concepts in computer science. Still, it is difficult to teach this concept, especially to young students. Some of the difficulties faced by students in learning this concept were also listed in educational research. This study explored how did the framework (presented by Armoni reported in the study) affected the CS abstraction skills of a student. A teaching framework introduced by Armoni was utilized in this study in an introductory course with 7th graders (age 13-14). 187 students out of 213 students participated in the final exam out of which 99 boys and 88 girls Scratch was used as a programming language for the implementation of algorithmic solution. The definition of CS abstraction consisted of six dimensions illustrated in the study. Students were randomly divided into two groups control group and experimental group. The findings of the study illustrated that the framework greatly influenced in developing CS abstraction skills with some other skills. Students belong to the experimental group showed better skills regarding CS abstraction. (Statter & Armoni, 2020)

In this section, a few studies are illustrated, conducted recently regarding teaching various CS concepts to the children found through ACM Digital Library. The purpose to include fewer studies is to indicate that a lot of work has been done regarding the digital education of children and to keep the reader's attention toward the original topic "Familiarization of AI concept to the children". **Table 13** summarizes some key points (i.e. addressed age groups, no of students, CS concepts) based on the included literature. "-" indicates, required information was not available in the study.

Table 13. Computer Science Concepts

Concept	Age-group	No. of students	Study
Programming	12-13 years -middle school	36	Merkouris et al., (2017)
DFS Algorithm	8-9 years old	6	Deng et al., (2019)
Coding	Plan to conduct-middle and high school students	-	Kim et al., (2019)
Computational thinking	13-14 years old- 8th grade students	35 science classes, 19 students per class	Troiano et al., (2019)
Abstraction	13-14 years old-7th graders	187 out of 213 students participated in final exam	Statter & Armoni, (2020)

2.4 Summary

To find the literature, a search was conducted regarding *AI and children* through ACM and IEEE. This illustrated the gap i.e. the lack of literature regarding children's AI Literacy that provided the opportunity to conduct this study. As it can be seen that concerning children's AI literacy, one study was found through ACM Digital library, none were found through IEEE Xplore and some studies were found through Google Scholar.

It can be perceived that AI is addressed in various contexts from the perspective of children. The illustrated contexts are ethics, education, health, and arts and music. Literature regarding the combination of AI and children addresses various age groups between 0-18 (Fadhil, & Gabrielli, 2017). Concerning ethics, the influence of Cayla on a child's (belong to the age-group of 4-10) decision was observed (Williams et al., 2018). For teaching purpose various tools i.e. ROBOSEM, TA, educational video games, MOYA (toy robot) were utilized (Han et al., 2012; Chin et al., 2013; Villacís et al., 2014; Ahn et al., 2018). MOYA was specially designed to answer a toddler's curiosity about different things (Ahn et al., 2018).

Moreover, some studies illustrated, the tool was created for adults such as teachers, therapists, or doctors to help children and children were not interacting with the tool directly. Such as, the SVM algorithm was used to develop a tool for ADHD's diagnosis used by adults to help children (Anuradha et al., 2010). Whereas, some of the studies show that both children and adults utilized the tool where the child was a potential user of the tool, and adult was interacting to encourage the child. Such as TERAPERS was used by both therapists and children (potential users) because it had two components installed on both child's and therapist's devices (Danubianu et al.,2008). In some papers accuracy results, places: where the study was conducted, time: when the study was conducted, were not mentioned as well as use of AI was not clear, vice versa.

Furthermore, various studies regarding teaching other CS concepts to the children can be found easily. Some of those studies are reported in section 2.3. For instance, CT helps in promoting problem-solving skills and CT of games can be measured through Dr. Scratch (Troiano et al., 2019); Merkouris et al., (2017) stated, children, learn to program easily through tangible objects; Deng et al., (2019) presented a programming tool named ARCat to teach children DFS; Statter & Armoni (2020) used a framework to teach abstraction to 7th graders. This indicates that there is still a lot of research available regarding the digital education of children, even though there is a literature gap regarding familiarization of AI concept to the children.

Concerning children's AI literacy, Williams et al., (2019), used PopBots to teach AI concepts to the children belong to the age-group 4-7 years. Children were the users of these tools (Han et al., 2012; Chin et al., 2013; Villacís et al., 2014; Ahn et al., 2018Williams et al., 2018). iRobot (course) was divided into seven weekly teaching units that helped children (average-age: 16.5 years) in learning about problem-solving by search, classic planning, graphs and data structures, automata, agent systems, and ML (Burgsteineret al., 2016). Also, a team at a science museum decided to introduce children with AI in 30 minutes (Candello et al., 2019). Ali et al., (2019) illustrates studies and tools for the development of curriculum for K-12. Touretzky et al., (2019) presented a draft of "Big Ideas" to introduce AI.

The illustrated literature presents how AI was used for the children and how many studies addressed a particular context. As well as how many studies were found regarding children's AI literacy which provides a suitable background to conduct this research by illustrating the gap where the research is still needed.

Table 14 summarizes literature regarding AI and children, and illustrates the studies included in this thesis. It shows how and in what context AI was used for the children. The sub-column named "Detail" of the column named "Embedded AI" presents tools names in which AI was embedded or AI techniques were used. Another sub-column named "Unclear" illustrates studies that do not give a clear idea of how AI was used. The total number of studies that lie in one category are displayed in the column "Total Studies".

Table 14. Summarized literature regarding AI and children

Category	Sub-Category	Embedded AI				Total Studies
		Yes	**No**	**Unclear**	**Detail**	
Ethics		S1			Cayla doll	1
Education	Use of AI for teaching purpose			S7	-	7
		S9			Robosem (robot)	
		S12			Software	
		S2			Educational video game	
		S3			ML techniques-in different modules of system	
		S13			Ultranus (game)-AI for FC & BC	
				S18	No description-how AI is used	
	Teaching various concepts of AI	S10			PopBots-AI concepts learned by children	3
			S20		Understanding of AI concept by children	
			S22		iRobot(course) - encompasses theoretical and hands-on components	
	AI Curriculum		S19		Development of guidelines regarding AI education	2
			S21		Development of K-12 AI education curriculum	
Health	Clinical	S15			TERAPERS-intelligent system	7
		S8			ECHOES	
		S11			SVM Algorithm-AI technique for tool development	
		S16			Smart mobile tool	
		S17			Software	
		S4			PLEO (robot)	
		S14			Application-combined computer vision and AI (for children with visual disabilities)	
	Fitness	S5			AI-Chatbots: integrated ML	1
Arts and Music		S6			Wekinator (software)-ML algorithm	1
Total Studies						22

3.   Research Design

This chapter starts by defining the term research and leads to the general demonstration of the qualitative research method which is used for this study. The advantages of qualitative research are briefly presented. Additionally, qualitative research is compared with quantitative research in general. It concludes with the explanation of data analysis and data collection methods. It also presents consent and confidentiality briefly.

Research is an organized, disciplined, and systematic approach that answers questions about our observations and experiences in the world. Scientific research aims to observe and look for an answer critically and logically. The process of scientific research encompasses several phases which are the identification of the problem, review of literature, sampling, development of research instrument, collection and analysis of data, and presentation of results. Thus, research can be defined as a structured approach for gathering and interpreting information that allows us to understand or explain experiences. (Kılıçoglu, 2018)

The two crucial research method categories are a) qualitative research and b) quantitative research. The selection of the research method is based on the aim, objectives, nature of the topic, and research question. Concerning, qualitative research method, it is suitable for new research areas as well as fields of study with less available literature. Though the combination of AI and children has gained popularity, the area of *familiarization of AI concepts to the children* is novel. Additionally, this method provides support to explore the novel phenomenon in the natural environment (Kılıçoglu, 2018). It aids in understanding how people (children) can be familiarized with and perceive novel concepts. (Basias & Pollalis, 2018)

Qualitative research is theoretical and deals with comprehending and explaining the experiences of people and it is not as rigorous as quantitative, but it can be rigorous too (Silverman, 2016, p. 1). The qualitative research methods are used in educational sciences (Kılıçoglu, 2018) as well as in many other disciplines. It follows a systematic way to explore human experiences (Donalek & Soldwisch, 2004). It is explained that qualitative research is distinguished based on its aim, which relates to understand some facet of social life and its ways through which data is generated in the form of words instead of numbers (Bricki & Green, 2017; Basias & Pollalis, 2018).

Moreover, qualitative research is used to answer questions from participant's standpoint (Hammarberg, Kirkman, & de Lacey, 2016) as well as focus on generating meaning and understanding through the rich description. The method is suitable and good to start with when a little amount of data is available or known. As it helps in creating hypothesis which can be verified by quantitative methods. It answers the questions: what, how, or why. It is stated, "If the aim is to understand how a community or individuals within it perceive a particular issue, then qualitative methods are often appropriate" (p. 3, 4). (Bricki & Green, 2007)

Some advantages of qualitative research are: provides deeper insights, helps in understanding the complexity and nature of the phenomenon, and aids research in novel fields of study (Basias & Pollalis, 2018). Another benefit is to shed light upon un-expected issues through open-ended questions though it is time-consuming during interview procedures (Choy, 2014). On the other hand, there is a possibility that qualitative research might be influenced by the researcher's background and experiences (Basias & Pollalis, 2018).

Comparison of qualitative research with quantitative research: Basias & Pollalis, (2018) illustrates, significant dissimilarities can be observed based on goals, question's nature, data collection method, and flexibility of research between both methodologies (i.e. qualitative research and quantitative research). As "quantitative research assumes cause and effect while qualitative research assumes that human motivations are extraordinarily complex" (Donalek & Soldwisch 2004, p. 354). The quantitative research method is concerned with numeric data whereas the qualitative research method deals with verbal data (Basias & Pollalis, 2018; Kılıçoglu, 2018).

In contrast to qualitative research, quantitative research is comprised of measurements that help in avoiding the impact of the researcher on research results (Donalek & Soldwisch, 2004). Bricki & Green (2007) suggest that researchers who are familiar with the quantitative research method and intended to calculate or quantify the data, the qualitative research method is not suitable for them. As qualitative research is focused on common themes instead of a statistical explanation of data (Donalek & Soldwisch, 2004). Whereas, quantitative research is appropriate when factual data is required or when a hypothesis is made by linking variables (Hammarberg, et al., 2016).

3.1 Data collection

Data collection is one of the difficult tasks and a vital part of conducting research (Kajornboon, 2005). Concerning qualitative research, flexible collection methods are used (Hox & Boeije, 2005). Also, the selection of data collection methods depends on the goals of research as well as the pros and cons of each (data collection) method (Kajornboon, 2005). Qualitative research has various methods to collect the data (Gill, Stewart, Treasure & Chadwick, 2008). Nevertheless, for data collection, the researcher needs to be able to access the required data for the study (Kajornboon, 2005). The illustrated types of data collection methods are group discussions, semi-structured interviews, in-depth interviews, text documents, and observations (Hammarberg, et al., 2016; Gill, et al., 2008; Labuschagne, 2003). Concerning this study, observations and semi-structured interviews were used as a data collection method.

3.1.1 Interview

Kajornboon, (2005) defines interviews as a systematic way of conversation among people. Interviews are similar to daily talk though their focal point is the researcher's need regarding the specific topic (Bricki & Green, 2007). In another study, interviews are defined as verbal questionnaires (Gill, et al., 2008). Bricki and Green (2007) stated, interviews are mostly used to generate data in qualitative research. The interview was selected as a data collection method for this study because the interviewee discusses his/her understandings concerning a given situation. (Kajornboon, 2005)

Researcher illustrated four types of interviews: 1) structured 2) unstructured 3) non-directive and 4) semi-structured interviews. In structured interviews, all the interviewees are asked the same predefined and organized set of questions. Whereas, unstructured interviews are flexible and non-directed. While non-directive interviews have no pre-defined topic. Semi-structured interviews are flexible and comprise of both structured and unstructured interviews. Semi-structured interviews often used in qualitative research. As compared to other types of interviews, a semi-structured interview was specifically used for this study because it can provide deeper insights by asking more detailed questions during the interview. (Kajornboon, 2005)

In a study led in 2006 regarding dental health, semi-structured interviews were conducted at Cardiff, UK with school children that helped in explore some key factors i.e. children's choice and preference regarding food (Gill, et al., 2008).

3.1.2 Observation

Apart from interviews, there are many other sources to generate data even if they are less formal than interviews (Bricki & Green, 2007). One of these data collection techniques is observations. Concerning this study, observation was also selected for the collection of data because it benefits by providing a rich description of events, situation and behavior of participants (Kawulich, 2005). To get a clear view of a situation, observation can be the best method (Bricki & Green, 2007). It is advantageous in overcoming inconsistencies between what people say and do (Bricki & Green, 2007). It can also help in revealing the behavior of the participants that even they are not aware of (Bricki & Green, 2007). This leads to a question that why one should choose observation for data collection.

A study reported that according to Schmuck (1997) observations offer researchers to explore the expression of feelings, how and who interacts with whom, in what way participants communicate with each other as well as how much attention participants paid on the activities. In qualitative research, participant observation is specifically used in various disciplines like an instrument for the collection of data regarding people, processes, and culture. Concerning participant observation, researcher stated, "Participant observation is the process enabling researchers to learn about the activities of the people understudy in the natural setting through observing and participating in those activities". (Kawulich, 2005, p. 2)

Moreover, in various studies observation is used as a data collection method to get deeper insights regarding children's and teacher's behavior or their interaction with each other. Such as, observations were made in five European countries in a total of twenty-five technology-rich primary and secondary schools (Smeets & Mooij, 2001); McIntosh, Vaughn, Schumm, Haager, & Lee, (1993) observed teacher's behavior in classrooms towards typical and atypical students as well as the difference in the behavior of typical and atypical students; to explore children's attention pattern, observational data was collected regarding their on and off-task behaviors (Godwin et al.,2016).

3.1.3 Ethical issues

Considering qualitative studies people are often observed in everyday routines (Orb, Eisenhauer, & Wynaden, 2001). Thus, concerning data collection regarding people, ethical issues have significant importance (Kajornboon, 2005). While conducting research, the researchers have a responsibility towards its participants, colleagues, and people to whom results will be presented (Bricki & Green, 2007). Research should not be harmful to the participant in any way (Kajornboon, 2005). Thus, two crucial ethical issues that should be paid attention to any research are consent and confidentiality (Bricki & Green, 2007).

By applying ethical standards properly, damage can be prohibited or minimized (Orb et al., 2001). Williamson, Goodenough, Kent, & Ashcroft, (2005) particularly addresses ethical issues from children's perspective within the research. One (participants) should be aware of what is needed from them and reassured that leaving will not affect them in any way (Bricki & Green, 2007; Orb et al., 2001). Researchers illustrated that children should be aware, to which extent they are given anonymity and confidentiality (Williamson et al., 2005). Participants should be given confidentiality (Kajornboon,

2005). As the protection of one's identity has a great significance from whom data is collected. (Bricki & Green, 2007).

3.2 Data analysis

Good research offers logically rational results. Though, in qualitative research, it seems to be difficult to achieve. In order to produce high-quality qualitative research, rigorous analysis of data is demanded (Green et al., 2007). It is essential to understand qualitative data before explaining the process of data analysis. Qualitative data deals with the meaning associated with language and action. It is in the form of words which are obtained from observations, interviews, or documents. While looking at data in this manner is very simple but we have to understand that participant's words show their social realities. Therefore, the main task in qualitative research is to understand and represent the perception of the participant through their own words. (Ruona, 2005)

Data analysis plays an important role while evaluating the quality of research. Additionally, various analysis techniques for qualitative data are available (Kawulich, 2004). However, studies are presented in a way as data analysis was already understood (Green, et al., 2007). This leads to the question of what data analysis is (Kawulich, 2004). Data analysis is the procedure of sorting data (Ruona, 2005) and it is time-consuming (Green, et al., 2007). The aim of data analysis is to explore meanings, patterns, and themes regarding what the researchers have seen or heard (Ruona, 2005). It is an organized process of arranging and categorizing the collected data (Green, et al., 2007). Ruona (2005) states, "Qualitative data analysis is a process that entails (1) sensing themes, (2) constant comparison, (3) recursiveness, (4) inductive and deductive thinking, and (5) interpretation to generate meaning" (p. 236).

Analysis is an iterative process (Ruona, 2005), that should be conducted with data collection simultaneously (Green, et al., 2007). For instance, start to analyze the data with the first interview or observation instead of waiting until all the data is gathered which in turn helps in understanding what is evolving in data (Ruona, 2005). The most crucial part of data analysis is the exploration process and transformation of collected data (Green, et al., 2007). According to Ruona (2005), in order to understand deeply one needs to listen to the recording or watching videos, and reading again and again while making notes regarding what was heard or seen.

Green, et al., 2007 states, "Repeated reading and re-reading of interview transcripts and contextual data and listening to recordings of the interviews is therefore the first step in analysis" (p. 547). Afterward, data is simplified while breaking up and categorizing data or complicated while exploring and conceptualizing the data (Ruona, 2005). "It forces the researcher to begin to make judgements and tag blocks of transcripts. 24 Codes are descriptive labels that are applied to segments of the transcript" (Green, et al., 2007, p. 548). Finally, merging all the data is crucial which in turn aids in producing meaning that represents the desired output (Ruona, 2005).

3.3 Study procedure and analysis

The research represents an experiment which was conducted to understand how children understand AI. An international school was selected to conduct this study which is located in Oulu, Finland. Sessions were conducted on 19 Nov 2019 and 26 Nov 2019. During the first session some basic concepts were explained whereas during second session AI and ML was explained. The participants of this research were students from the fifth grade. They belong to the age-group of 11-12 years. In Class 1 there were 7 boys and 11 girls

out of which parents of 6 girls and 4 boys gave consent to collect data about their children. In Class 2 there were 6 boys and 13 girls out of which parents of 2 girls and 4 boys gave consent to collect data. **Table 15** summarizes some general information regarding the sessions.

Table 15: General information

	Session 1		Session 2	
	Class 1	Class 2	Class 1	Class 2
Total Students in each class	18	19	18	19
Allowed students to participate in research	9	6	10	6
Present Students out of allowed students	7	6	9	6
Absent Students out of allowed students	2	0	1	0
Concepts	CT: Decomposition, Pattern recognition, Abstraction, Algorithm,		AI: ML, Training data	

Furthermore, observations were made regarding children during both sessions at school while considering that whether they are interested in learning these concepts or not, do they understand it (concepts) or not, whether they are actively participating in sessions or not, are they discussing the topic with each other, whether they (children) have any questions. Children were not interviewed but observed. After the final session, a semi-structured interview was conducted with the teacher at school in order to get his feedback about the sessions and children's learning. As well as what is his opinion about the research.

Data was collected from those students whose parents gave consent. It was collected in the form of text through the activity worksheets distributed among students. Pictures were taken and video clips were made while students were busy doing activities. The teacher's interview was recorded in an audio file. Some personal notes were also taken exactly after the sessions based on observations separately for each class. Data was also collected through material produced by the children during their tasks. The data was collected only from and about those students who and whose parents gave consent. Furthermore, during the sessions children asked various questions regarding the concepts taught to them. These questions and how they were answered are explained in the later chapter named "Findings".

The textual data was collected through the activity worksheets as there were some questions about algorithm and activities regarding AI and ML. One of the worksheet named "What I Learned" included in both sessions was specifically focused on what they learned. Do they understand what they are taught and what else they learned during these sessions? There were circles right next to the definition of terms and they (children) had to cross in the circle which they think was right based on their understanding. Those circles are distinguished by colors and indicate different answers. Such as the pink circle indicates "I can do it" and the rest of options can be seen in the "Findings" section (chapter 4).

Moreover, data analysis regarding this study was conducted in a similar way as it is illustrated in section 3.2 by other researchers. Results were obtained based on

observations, and by critically analyzing the data obtained through activity worksheets, audio, and video files. Activity worksheets were read repeatedly, video and audio files were seen and listened again and again in order to present results based on evidence. Responses of the children regarding whether they understood the concepts or not were counted through the activity worksheets and presented in the tables shown-below in section 4. One of the questions in the papers was specifically open-ended i.e. "Other things I learned" (I represents' student) can be seen below in the Findings section in **Figure 3** and **Figure 12**.

Additionally, personal notes regarding observations were read frequently. After the analysis, data was combined, organized, and illustrated in the form of numbers in three tables. **Table 15** represents combined and general information of both sessions which is shown-above. Data is presented as the total number of students in one class, the number of students present and absent out of the students whose parents agreed. Whereas the rest of the two tables: **Table 16** and **Table 17** illustrates the results of both sessions separately and are presented in the Findings chapter. These tables present the number of students who understood the concepts, and the number of students who did not understand the concepts out of those parent whose parents gave consent. Chapter 4 demonstrates how the research was conducted and how children responded while doing the activities.

4.   Findings

This chapter explains how, when, and where the sessions were conducted as well as results obtained from them. Additionally, what went well and what did not.

4.1 Preparation

Prior to the research sessions, there were many hurdles to overcome. Such as approval of the school's principal to conduct this study, teacher's cooperation, and parents' consent regarding their children's participation in this research. Thus, one of my supervisors made the initial contact with the principal regarding the research. After getting the approval I contacted the specific teacher and discussed the venue for the first meeting. The purpose of this meeting was to discuss some important practicalities about sessions and consent from the parents.

The practicalities are time, equipment, consents from parents and children, detailed discussion about activities during sessions, printing (of) papers regarding activities for children, printing and explanation of consent forms for/to the children, allocation of computers for the student, seating arrangement of students as to make it easier for data collection, information about students per class i.e. total no of girls and boys in a class. Laptops were reserved for both sessions but later on, the reservation was canceled for the first session.

It was decided that the consent form will be sent to the parents by the teacher. Parents will inform about acceptance to the teacher via email or send consent form by digitally signing it. He (teacher) will let me know about those children whose data I can use for my thesis before sessions. Whereas, to get a child's consent, the consent form was distributed among students during the first session. The responsible person to deal with the queries regarding research from the parents will be me, supervisors, and the teacher. Additionally, queries regarding consent forms given to the students will be answered by me and the teacher. The pictures of both consent forms i.e. parents and students are added in appendices (see Appendix A).

During the meeting, the teacher reviewed the plan and mentioned that one session is about 45 minutes. According to him, all the activities were interesting. He said that especially the one activity using the laptop of ML is very interesting. Students will definitely enjoy it. He suggested if children had already tried this link, I should look for a similar link for them to try it. It was explained that whether they had already tried this link they still do not know how it works. So, it does not matter. In addition, we agreed to have two sessions just in case if all the activities are not completed in the first session. The final plan document and activity worksheets (that needs printing) were sent to the teacher a day before both sessions separately.

4.1.1 Material collection for sessions

To familiarize children with AI, training data, and ML, some basic computer science concepts were also introduced. These concepts are CT, Algorithm, decomposition, Abstraction, and Pattern recognition. In order to introduce these concepts to the children existing material with modifications was used. The storybooks written by Linda Liukas were used. Linda Liukas is the founder of "Hello Ruby". She is a programmer, storyteller, illustrator, and writes books for children. Her material was given preference because she

explains computational concepts through a story. Linda's way of teaching computing concepts was interesting and easy as compared to the other online material.

Concerning AI and ML, some other links were also utilized to gain knowledge personally as well as to have some extra activities for the children. These links are https://roboticsbiz.com/how-to-teach-your-kids-about-machine-learning-and-ai/ , and https://www.educationalappstore.com/blog/enlighten-kids-ai-machine-learning/. These links provide some information regarding teaching ML concepts to the children as well as provide links for some applications regarding ML. This link, https://machinelearningforkids.co.uk/ was considered to be used during the sessions but due to limited access to its feature, it was rejected.

One reason for the rejection of various materials regarding online activities was the complexity of activities as well as difficulty regarding its explanation to the children in a limited time. Therefore, simple and easily understandable material regarding concepts by the children was considered. Some activity worksheets were also distributed among children during sessions that were downloaded from https://www.helloruby.com/loveletters and altered by adding or removing some material. The detail of both sessions is mentioned below.

4.2 Session with children

Sessions were conducted on 19 Nov 2019 and 26 Nov 2019 at 10:15-11:00 with Class 1 and at 11:30-12:15 with Class 2. Also, the initial plan was modified and divided into two parts. The first part was about some basic concepts which were explained in Session 1. The second part was mainly focused on AI and ML which was explained in the second session. The plan for activities was changed almost every day by adding some new activities and removing some previously planned activities. Additionally, the sequence of activities, from which activity it should start and which should be the last activity was also altered. **Figure 1** visualizes number of participants per class concerning both sessions.
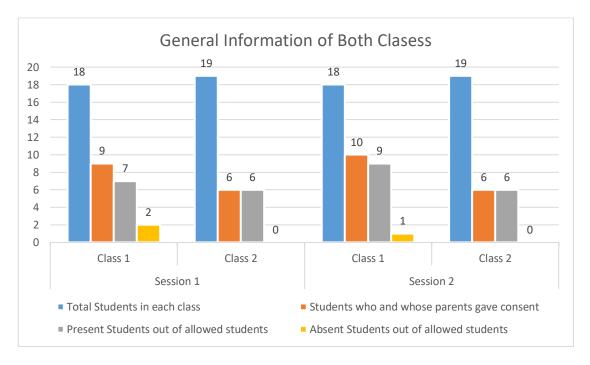

Figure 1. General information of both classes

4.2.1 Session 1: Class 1

The first session was held on 19th November 2019 at 10:15-11:00 with Class 1. In the first session, children whose parents agreed for them to participate in the research were seated on the left side and the rest of the children were seated on the right side. Though all of them participated in all activities, data was collected only from those children seated on the left side as their parents agreed.

In the beginning, the teacher briefly introduced me to the students. Then, we distributed consent forms to those children, whose parents gave consent (as it was suggested by the supervisors to get the consent of children even if their parents agreed) (see Appendix A). The teacher explained to them that this is a consent form that allows the researcher to gather their data. Students asked: *"what is a signature?"* He (teacher) explained that it is initial of your name but you can also write your full name there. Another question was *"what is Caps lock?"* It was explained that caps lock means capital letters. Students were told that their parents had also signed. They asked: *"why are we signing it if our parents had already signed it?"* It was explained that if they still do not want the researcher to use their data, they can refuse and if they (student) allow, they need to sign the consent it.

After that, I told them a bit more about me and the reason why I was there. It was explained that the main topic is AI and children but before AI is explained they need to know some basic concepts such as CT. A presentation and story were prepared beforehand. The session was started by telling them a story about ruby from the book (page 1 – 23) "Hello Ruby: Adventures in coding". The storybook can be accessed through this link: https://drive.google.com/file/d/0B03ZlEOjN-UIVEFBajF1dDB4Tmc/view. The summary of the story is written below.

Ruby is a little girl who likes to learn new things. Her superpower is to build things with her imagination and her favorite word is "why". One thing she dislikes the most is to be told what to do, especially when instructions are not clear. Such as once Ruby's dad asked her to get dressed, she puts on her dress and shoes but keeps her pajamas on. Because her dad did not explicitly tell her to change out of her pajamas. When she is asked to clean up her toys, she puts all her toys in a toy house but leaves her pens and paper on the floor. Well, pens and paper are not really toys. Ruby's dad was away due to work and she misses him a lot. Unexpectedly, she finds a postcard left by her father. (Liukas, 2015)
Postcard:

"Dear Ruby,

Today you're off on a grand adventure. I've hidden five gems for you to find. Keep going until you find them all If you have more than one idea, follow the best one. And if you need help, remember that friends can often be found in unexpected places. I can't wait to hear how you found all gems.

Kisses,
Dad" (Liukas, 2015, p. 13)

After reading it, she wants to start her adventure (finding the gems) but her dad did not leave any instructions. However, she knows that big problems are composed of little problems. While thinking about it she knows what to do. She will make a plan and looks for clues. Secondly, she makes the plan based on those clues. She thinks about getting lost

and what needs to be kept and what not. Later on, she decides she will follow the shortest route. She keeps a roll of rope with her and sets out. (Liukas, 2015)

The above-mentioned story was told to the children to get their attention and specifically for the explanation of concepts through examples (based on the story). Children paid attention to the story and grasped the concepts easily when examples were quoted from the story as compared to the concepts which were not given any example based on the story. The explanation of how examples were explained to the children is illustrated below regarding each concept separately. Figure 2 shows, students of Class 1 while listening to the story.

After telling the story, CT, and four more concepts of which CT is composed of i.e. Algorithm, Pattern recognition, Decomposition, and Abstraction were explained to the students by giving them examples based on the story and daily experiences. Additionally, activity was performed with students to explain the concept of algorithm. In that activity, I acted as the computer and a child from the class acted as a programmer and gave instructions. The explanation of terms can be seen below.

Figure 2. Class 1: Story

> ➢ *CT*: It is something that people do, not computers. Or one can say that thinking about the problem in a way that allows computers to solve them. It includes logical thinking, the ability to recognize a pattern, think with algorithms, decomposition, and abstraction of a problem.

> ➢ *Algorithm:* is a set of instructions to solve a problem. Instructions should be clear, short, and detailed. (To explain this concept some information was used from this link https://sites.google.com/sfusd.edu/k-2cs/orange/unit-1-unplugged-cs?authuser=0)

Example based on the story:

Ruby was asked to clean up the toys. So, she only picked up toys and left the pens and papers on the floor because pens and papers are not toys. Additionally, her dad asked her to dress up. She puts on her dress and shoes and keeps her pajamas on. Because she was not explicitly explained to change out of her polka-dot pajamas. Another example via activity:

Activity: Pick up the book from the box on that table.

Instructions by the student are:

- _"Standup"_,
- _"Turn 60 degrees"_ (stumbled by the chair),
- _"Take 3 steps forward"_,
- _"Take your hand up pick up the book"_,
- _"Walk backward and sit down"_.

It was explained _"you need to tell the computer again, the number of steps to walk back to the chair"_.

- ➢ **_Pattern recognition_**: Recognizing the common pattern among various things. Example based on real-life experiences:

  Researcher_: "What are the common cupcakes ingredients?"_

  Students: _"Flour, sugar, egg, flavor"_. Example based on the story: It was explained that in later part of ruby's story (which I didn't tell them), one of the gems was placed in a high place. So, she builds a ladder to get the gem. She gathers two long wooden sticks and a few small sticks. She placed the two long sticks vertically (let's say 10-15 inches apart) parallel to each other. Placed small stick onto the long sticks horizontally and tied it up. She did the same with other small sticks, placing them parallel to the first small stick and then tied them up. She repeats the steps until she ties all small sticks.

- ➢ **_Decomposition_**: Division of a big task into small tasks. Explanation based on Ruby's story i.e. Task given by her father: find five gems. Ruby divides the big task into small tasks which are:
  - Make the plan, and looks for the clues
  - Leave unnecessary details,
  - Sets off for the adventure

- ➢ **_Abstraction:_** It focuses on important factors and forgets unnecessary details. Explanation based on Ruby's story: She thinks about _how does she find all five gems? what happens if she gets lost? and how does she know what to bring with her?_ However, in the end, she stops thinking about these useless things and leaves for the journey while taking the shortest route keeping the map and rope with her. Example based on real-life experiences:

  Researcher: _"Does google map shows how many rocks are on the ground?"_

  Students: _"No"_

  Researcher: _"Exactly, when we open google maps it shows buildings, roads, and buses but does not show the number of rocks on the ground. To reach the destination one does not need to know, the number of rocks on the ground."_

After explaining these concepts, activity worksheets were distributed among students. The last page was about what they learned. The first two pages had some questions for them to solve. The questions on the worksheets were also explained on a paper for everyone to understand. **Figure 3**, **Figure 4**, **Figure 5**, and **Figure 6** shows images of activity worksheets distributed among students of both classes during session 1.

Figure 3. Session1: Learning outcome

Questions on the rest of the pages are:

➢ Help Ruby visit her friends by writing an algorithm to avoid the blue water, cross the brown bridge, and stop and say hello to each of her four friends.
➢ Can you write out the path to other three friends using the shortcut?
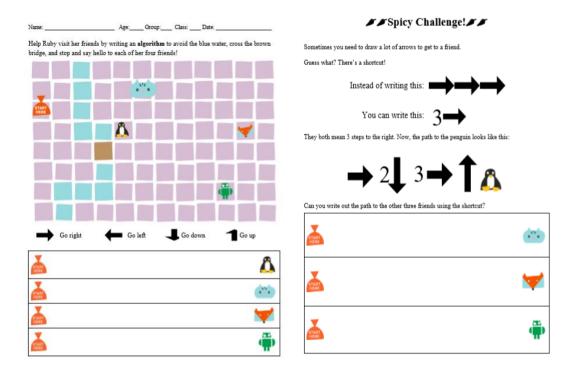➢ Can you write one giant algorithm for ruby to visit all 4 of her friends, one after another?

Figure 4. Session1: Separate algorithm

Figure 5. Session 1: Algorithm shortcut

Challenge: Can you write one giant algorithm for Ruby to visit all 4 of her friends, one after another?

Figure 6. Session1: Giant algorithm

While writing algorithms, most of the students asked _"can we meet all friends in one round?"_ or _"do we need to start from the beginning every time?"_. It was explained that on the first two pages (shown in Figure 4 and Figure 5) you need to write algorithm from the start each time to meet friends but to answer the challenge (shown in Figure 6), write an algorithm to meet all her friends in one round (shown in Figure 6).

Moreover, another activity of making a sandwich while playing a song was planned but it was canceled due to a shortage of time. Papers of "sandwich making" activity were on the table and children saw it. So they asked: _"Do you really have nuts in your bag? Are we really going to break them? what is it? Is it a sandwich?"_ They were told: _"No I do not have nuts in my bag. I planned to do this activity in today's session but I couldn't due to less time."_

When the session was finished a student came to me and asked: _"Is the book's name based on that programming language ruby?"_ I told him, _"I didn't read it on the website, whether it is based on the name of the language 'ruby'. But the writer says she was learning programming herself when she got stuck with a problem and that idea came to her mind that if ruby faces that problem then how would she solve it"_. Also, many students asked separately: _"Will you come again? we will be waiting"_. This suggests, they enjoyed activities and wanted to have more. They seemed to be interested in learning more concepts. They seemed to be fast learners.

4.2.2 Session 1: Class 2

Session 1 with Class 2 was held on 19th November 2019 at 11:30-12:15. It started in the same manner as it was with Class 1. They were seated in the same way as the students of the previous class. Consent forms were distributed among those students whose parents agreed to let us gather data. I introduced myself to the students and repeated all the activities as they were conducted with the other class. Children were excited to know that I am a student form the same University where their family members were studying or working.

Figure 7. Class 2: Story

The session was started with a story and ended the same way it was with Class 1. **Figure 7** shows the storytelling part of Class 2. After telling them the story about ruby, CT, algorithm and the rest of the concepts were explained in the same sequence. After the explanation about "Algorithm", a girl stands up and started to speak:

"Because if we do not tell the computer that there is a chair in front of you and you have to stop and then turn from here, it will stumble around so we need to make it clear."

- ➢ **Algorithm**: The same activity was performed with this class.
  Activity: Pick up the book from the box on that table.
  Instructions by the student are:
  - *"Standup"*,
  - *"Turn right"*,
  - *"Take 3 steps"*,
  - *"Take your hand up, hold the book"*, (My hand was closed. So, I could not hold the book)
  Researcher: *"Should I open my hand/fist?"*
  Student: *"Yes"*
  - *"Open your fist"*,
  - *"Hold the book"*

Later on, they were distributed activity worksheets and they had to answer the questions. Images of the pages are shown-above via **Figure 3**, **Figure 4**, **Figure 5**, and **Figure 6**. Students from this class also asked: *"Can we meet all friends in one round?"* or *"do we have to start from the beginning every time?"* They were explained, the same way the students of Class 1 were explained. At the end of this session students from this class also asked: *"Will you come again, we are looking forward to it"*. They also seemed to enjoy activities and learned the concept while playing.

4.2.3 Session 2: Class 1

Session 2 was held on 26 Nov 2019 at 10:15-11:00. In the initial plan, a story and presentation were included for this session too. The storybook name is "Hello Ruby: Robotti Koulussa". It is not available in the English language yet. So, I had to translate it. However, due to the limited time, both story and presentation were canceled. The session was directly started by introducing the topic. Additionally, laptops were already placed for the students. Before explaining the topic in detail, they were asked:

Researcher: *"When you hear the word AI what three things come to your mind?"*
Students: *"Robot, Machine"*

Later on, AI, training data, and ML were explained to them. It was told that the machine that behaves sensibly in different situations likely to use AI. Then, what is AI?

- ➢ **AI:** It can be explained by a group of computer software and hardware that works sensibly in a new situation. It can be a robot or a machine. It is also possible that machines that use voice recognition feature are using AI. But to behave sensibly they need to learn by several examples.

- ➢ **Training Data:** These several examples which are fed to the computer are known as training data. It can be pictures, text, video, or audio.

> ➢ **ML:** Based on these examples, the computer builds a model and test the new input based on that model and shows the result. For instance: If we want the computer to recognize a cat in a picture. We need to provide several pictures of the cat to the computer. Then it builds a model, such as a cat has ears, tail, four legs, and is small. Another example was about building. Buildings have windows, doors, walls, and roof.

At first, to understand these concepts better they were instructed to open a link where they had to train the machine to recognize different poses of a student. The link to the website (https://teachablemachine.withgoogle.com/) was already written on the whiteboard. Another link regarding this exercise was (https://quickdraw.withgoogle.com/) but It was skipped due to limited time. We couldn't open the link on the laptops beforehand as each student has their own username and password in order to login to the system. **Figure 8** presents the ML exercise with Class 1 shown below. The second step was to create two classes. Students were told that they can name the classes as Class 1 and Class 2 or any name they like. Then take several pictures of the same pose in one class and in another class save several photos of another pose.

Most of the students complained, the camera isn't working /taking pictures but in a few minutes this problem was solved. Many had problem in creating the classes. In the beginning, they were explained as a whole class, and then to some students who still do not understand, it was explained individually. Afterward, students started to take pictures and most of them started to say: "*mine are more than 400*", "*mine are 50*", "*mine are 38*". It was explained that there is no need to take many pictures, 30-50 pictures for one class are enough. Later on, they trained two classes by capturing different poses in both classes. 30 to 40 same pose in one class and 30-40 same pose in Class 2 but different from Class 1.

Figure 8. Session2: Class 1-ML exercise

The next step was to train the model by clicking on the "Train Model" and test whether it works or not by showing the poses with which the model is trained. What happens if you make a new pose? Students were explained that when you test it, it is not 100% sure of the output class but it considers the probability towards a class based on input and shows the output. For example, your pose shows 89% matching probability towards class 1 and 58% towards Class 2. Thus, it will show the class with higher probability in the output i.e. Class 1.

Students still had questions: *"what is training data and ML?"*. These concepts were explained again to the students based on the activity of ML. For instance, *"the set of images of your pose is called training data that you fed to the computer or this application"*. *"When you click on "Train model" the computer or this application trains itself and builds a model based on the pictures which is known as ML"*. After that they were given activity worksheets. The last page of activity worksheet was focused on what they learned. Other pages consist of some brainstorming questions which are:

1. Design your own robot, name, length, features, and weight
2. Teach your robot to recognize a greeting? Can you think of as many possible ways to greet someone?
3. When you hear the word AI what three things come to your mind?
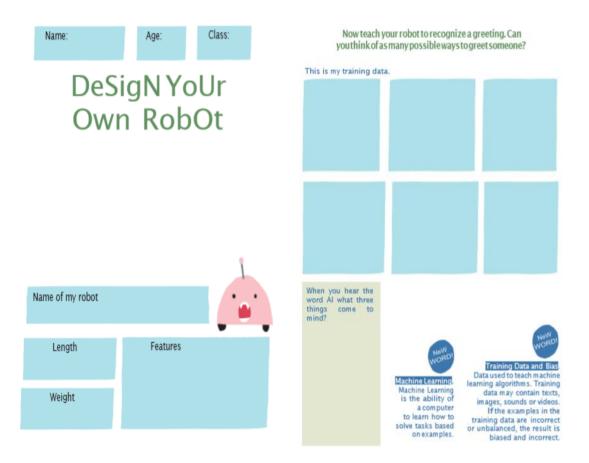4. Fill in how you and the robot are going to work together.

Figure 9. Session 2: Desired robot

Figure 10. Session 2: Training data

Figure 9, **Figure 10**, **Figure 11**, and **Figure 12** shows the activity worksheets distributed among students of both classes during the second session.
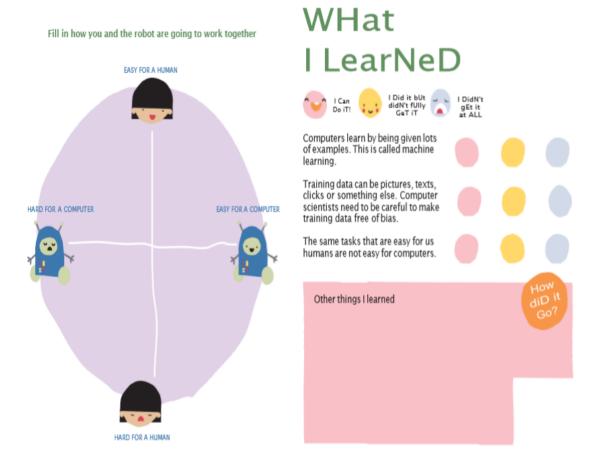
Figure 11. Session2: Quadrant

Figure 12. Session2: Learning outcome

While filling out the worksheets, the student had some questions:

> Student: "*What do you mean by features?*"
> Researcher: "*Such as voice recognition (ability to speak). Do you want your robot to speak to you?*"
> Student: "*Yeah*"
> Researcher: "*Then, this lies in feature.*"
> Student: "*I don't understand quadrant.*"
> Researcher: Quadrant (Shown in Figure 11) was explained on the whiteboard because most of the students had problems. Examples
> Easy for human and Easy for a computer: Sums such as 2+2=4, 10+4=14
> Easy for human and hard for computer: Making of cupcakes
> Hard for a computer and hard for a human: Hiring of a person in a company or your school.
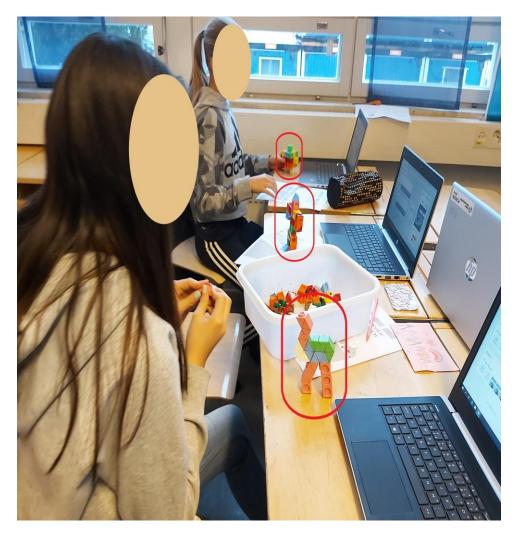> Hard for a human and easy for a computer: Weather forecasting

Figure 13. Session2: Class 1-Robot making

After filling all the papers regarding how they want their robot to look like and what features they want their robot to have. The students had to build a prototype of the robot using cubes. The above-shown Figure 13 illustrates the robot making of Class 1 students. Additionally, worksheets were not merely written tasks for them rather it was to make them think and understand concepts and then build the robot as they desire or described in the papers. While building a robot, one girl said excitedly: *"Look I made a swan"*. I asked her, *"do you want your robot to look like this?"* The girl said: *"I think yes if it is possible"*.

4.2.4 Session 2: Class 2

The second session with Class 2 was held on the same day at 11:30-12:15. **Figure 14**, and **Figure 15** show ML activity, and robot making activity respectively with Class 2. Everything was repeated with Class 2. The session was started by introducing the topic. Before explaining AI in detail, students were asked the same question:

> Researcher: *"When you hear the word AI what three things come to your mind?"*
> Students : *"Robot, Coding"*

Their answers were written on the whiteboard. Afterward, AI, training data, and ML were explained in detail. While I was explaining these concepts, a girl quickly said: *"Its like Alexa"*

Afterward, students had an online activity regarding ML. They were instructed to open the link and create an image project. Students had to create two classes and store images in those classes of different poses. Then, they train their model and test it. Later on, activity worksheets were distributed among them and they had to fill it. They asked almost the same questions as the students of Class 1 i.e. what is a feature, I do not understand quadrant (shown in **Figure 11**). A few of them questioned regarding quadrant: what is hard for humans and computers? I explained, hiring an employee. These questions were explained on the whiteboard.

Figure 14. Session2: Class 2-ML **Figure 15.** Session2: Class 2-robot making

During the online ML activity, while students were training and testing the model, some students used phrases like _"Cool" and "Awesome"_. This suggests they had fun while learning the concepts. Later on, worksheets were distributed among them. Some of the students said: _"What… are we writing again today?"_. I said: _"yes"_. Some of them said: _"No…"_, their facial expressions seemed to give the impression of being bored or sad. This suggests written tasks were boring for them even if these tasks were associated with the hands-on activities (i.e. prototype of robot).

When the students completed working sheets, cubes were distributed among them to make a prototype of the robot. While they were making a robot with the cubes, most of them asked: _"Can I say that I want my robot to be long like a pencil? Can I say I want my robot to be 500 pounds? Can I say my robot should be big like me?"_. I told them yes you can design however you want. On next page students had to teach their robot to say greetings. One student asked: _"can I teach robot to say 'hi' in my own language instead of English?"_. I answered: _"yes you can"_. These observations suggest that they paid attention to the learning activities by showing interest through various phrases and questions. **Figure 16** shows training data written by a student.
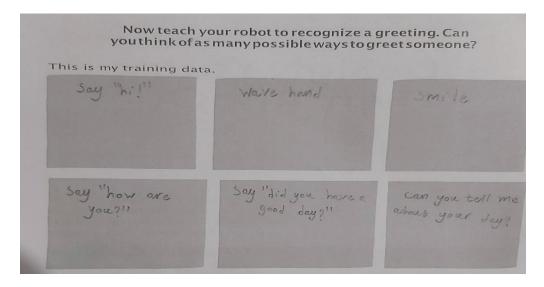
Figure 16. Training data

A student asked about quadrant: *"difficult for robot and easy for humans: robots cannot eat…?"*. I said: *"Well, that's right but let's say both of us can eat but different things e.g. we eat food and robots eat electricity"*. At the end of the session, almost all of them asked *"are we having more sessions like this… will you come again"*. I explained to them, this was my last session with them.

4.3 Results on learning and engagement

The students were distributed in two groups. One whose parents gave consent and the others whose parents did not give the consent. While familiarizing these two groups with various concepts, they were not discriminated based on whose parents gave consent for data collection and vice versa. Though they were seated separately in order to collect material (i.e. activity worksheets, pictures, and video clips). Results are presented from two perspectives i.e. observations and activity worksheets. Children's learning and understanding of concept was observed considering some factors i.e. attention of the children toward learning activities, questions asked by the children regarding concepts, discussion regarding the concept among students.

Observations suggest that most of the students were interested in learning because they paid attention to what was explained. They asked several questions (stated above) when faced with a problem. They discussed the concept with each other. During first session, students (from both classes) as a whole understood the concepts easily. At the end of the session, many students from both classes asked the name of the storybook. This illustrates that they enjoyed listening the story and wanted to read it. This was good for them because this story book explains various computer science concepts. In the next session, a student from Class 2 told me that he read the whole storybook (from which I read the story in the first session) and he liked it very much. At the end of the session teacher also told me about that student.

Considering activity worksheets, children had to write about their learning. A few children reported their learning through worksheets by providing answers of open-ended and close-ended questions. **Figure 17** and **Figure 18** presents children's views concerning Session 1. Rest of the data obtained from the worksheets is summarized in two separate tables below i.e. **Table 14** and **Table 15**.

Moreover, a student shared that his father is making robots to help to build houses. Another shared, his father writes code and he asked his father what is it… I(boy) want to learn it too? Can I(boy)? His father replied you will learn it when you get old enough. He asked me the same question: I said, *"well I wouldn't say your father is wrong but I would say you can even learn it now…"* These personal stories showed how much interested the students were in my research, as well as how keen they were to learn more about other computation concepts.
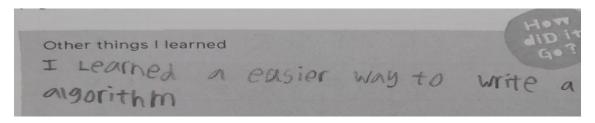

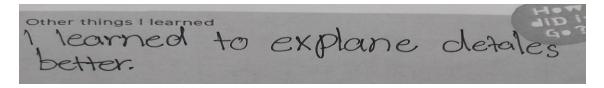**Figure 17.** Session1: Class1- feedback

Figure 18. Session1: Class2- feedback

The **Table 16** illustrates the results of Session 1 conducted with both classes i.e. Class 1 and Class 2 based on data collected through documents. The documents included questions regarding CT concepts. The detail can be seen above in section named: Session 1: Class 1 and Session 2: Class 1. In the following table column: "I can do it" means students fully understood the concept. Whereas "I did it but didn't fully get it" means students did not fully understand the concept. The column name "No response or marked all" illustrates number of students who marked all options or did not mark any option.

Table 16: Session 1: Concepts and learning of children

Session 1						
Class	**Concept**		**I can do it**	**I did it but didn't fully get it**	**No response or Marked all**	**Total students**
Class 1	CT	Decompose	6	1		7
		Pattern recognition	5	2		
		Abstraction	4	2	1	
		Algorithm	7			
Class 2		Decompose	5		1	6
		Pattern recognition	4	2		
		Abstraction	6			
		Algorithm	5		1	

Class 1: One student marked all options for **Abstraction**.
Class 2: One student did not mark any option for **Decompose** and one student marked all options for **Algorithm**.

The summarized version of **Table 16** can be seen in the following **Figure 19**. From Class 1 parents of 9 students gave consent out of which 7 students were present. From Class 2 parents of 6 students gave consent and all of them were present.
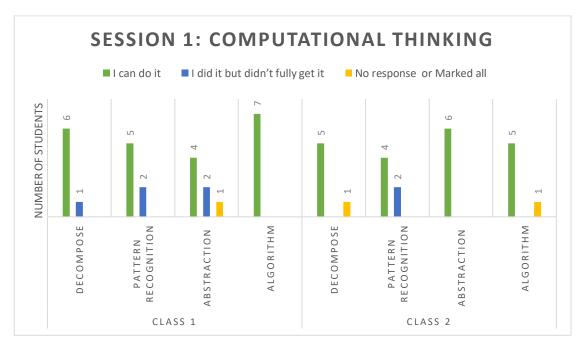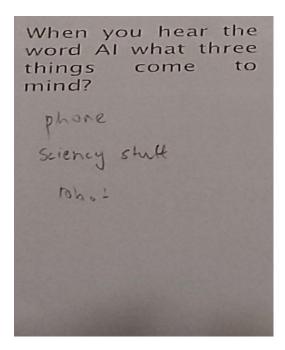

Figure 19. S1: CT

Children's understanding of AI after being engaged in learning activities can be seen in **Figure 20** and **Figure 21**. A few students from both classes wrote answers for the question: "When you hear the word AI what three things come to your mind?". Students from Class 1 answered as "*phone, sciency stuff, robot, computers*". A student from Class 2 wrote "*computers, voices and not real*" (See Appendix B for more results).
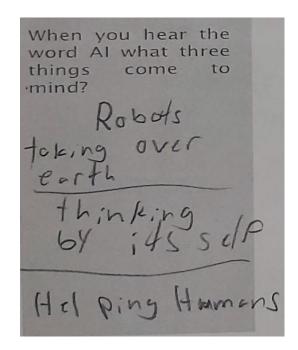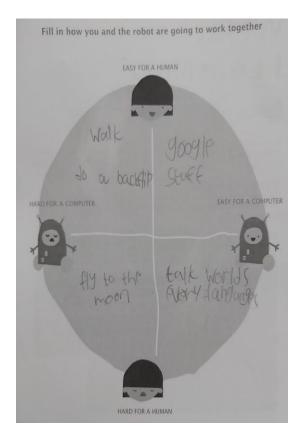

Figure 20. S2: Class1

Figure 21. S2: Class 2

Some of the students filled the quadrant. Their answers are shown-below in **Figure 22**, **Figure 23**.
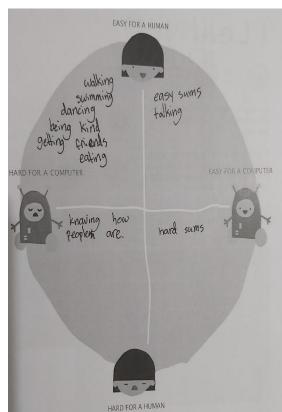
Figure 22. S2: Quad-class1

Figure 23. S2: Quad-class2

Moreover, concerning 2nd session **Table 17** shows that 5 students of Class 1 did not fully understand the concepts. Whereas 4 students understood *ML* and 2 students understood *training data* of Class 2. The result from the collected worksheets suggest that less than half number of students understood AI. In contrast, based on observations it seemed, there were more students who understood the concepts as compared to the number of students who do not. The reason can be that worksheets were only collected from the students whose parents gave consent. Considering students as a whole, in the beginning some students got confused about AI and training data but at the end most of them understood.

Table 17 presents results of session 2 of both classes. The column named: "I can do it" means child fully understood the concept. Whereas "I did it but didn't fully get it" means child did not fully understand the concept.
Class 2: Two students marked all options for **ML** and two students did not mark any circle for **Training Data**.

Table 17: Session 2: Concepts and learning of children

Session 2						
Class	**Concept**		**I can do it**	**I did it but didn't fully get it**	**No response or Marked all**	**Total Student**
Class 1	AI	ML	4	5		9
		Training data	4	5		
Class 2	AI	ML	4		2	6
		Training data	2	2	2	

The summarized version of **Table 17** can be visualized in the following Figure 24. In the second session, from Class 1 parents of 10 students gave consent out of which 9 students

were present. It shows that 4 students from Class 1 and 4 students from Class 2 understood the concept ML. Whereas 5 students from Class 1 did not fully understand the concept.
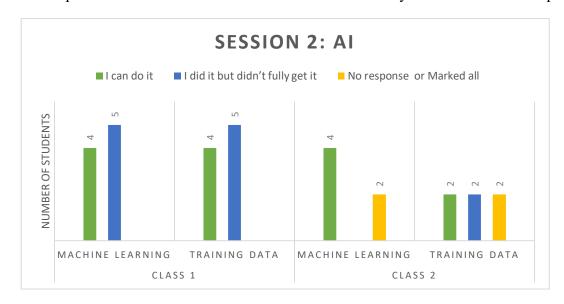

Figure 24. S2: AI

Considering both sessions, one can say that children learned a lot based on the time they were given to learn all these above mentioned concepts. One session was of 45 minutes but they had to be familiarized with all the above-mentioned concepts in session 1 in approximately 30 minutes. As, it took almost 15 minutes to guide them about their seats, distribution, explanation, and collection of consent forms. Whereas, during the Session 2, students had to learn the concepts in approximately 35 minutes because it took time for the students to login their user account, opening the link for and getting used to ML application as well as dealing with the camera problem. One of the interesting observation was that boys were excited about doing the activities whereas girls were more focused on how things work.

Regarding engagement, story-telling and hands-on experience played an important role in making them engaged in activities. During the first session, children understood the concepts faster as compared to the concepts explained in session 2. One reason is the examples based on the story which they listened attentively. Another is that activities were easy considering their age-group. Thus, they were able to answer the questions more easily as compared to the second session. Concerning Session 2, online activity regarding ML helped them in learning. The concepts explained in Session 2 were a bit difficult for them to understand as compared to Session 1. One of the reason can be, story was skipped due to limited time. Also, the activities were suitable concerning their age-group. The activities in session 2 needed brainstorming. The teacher told in the interview that:

Questions in the first session were easy for the children to answer. Whereas, the activities and questions done in session 2 engaged the children in thinking more which is good for them. Especially, in the online activity and (quadrant) questions were interesting and good considering their age-group.

From the perspective of enjoyment, students enjoyed the sessions and wanted to have more sessions. Most of them said it aloud to have more sessions and in the second session they also said that they were waiting for the week to pass quickly as they will have more sessions like this. At the end of the final session both classes wanted to have more sessions and upon knowing that it was the last session they seemed to be disappointed.

4.4 Results on process of educating children about AI

Though activities were planned long before the sessions and got approved from professors, it was still worrisome as to how sessions will progress. It was a good decision to have at least two sessions otherwise it would not be possible to explain any of the planned concepts and perform the activities. Also, this allowed me to divide the whole work in two sessions: one session completely devoted for the explanation of some basic concepts and the second session fully focused on AI and ML.

However, due to limited time some activities were skipped. It was also in the original plan to teach them a bit about programming, pair programming, debugging. But these concepts were skipped. Only the programing concept was briefly explained to them that converting the algorithm in a language that computer understands is called programing. In my opinion, this research should have had 6-8 sessions for the children to fully grasp all the taught concepts. It was a lot for them to learn in these two sessions. Even the teacher said: *"It should have been a six-week project."*

Moreover, I got help from the teacher to make them be quite and listen to me as they were discussing with each other. Miscommunication or interpretation was also a problem as I assumed that the computer for teacher's use already had a camera but it didn't. In order to explain ML exercise, I had to use camera for the exercise. Secondly, my laptop had camera but I could not use my own laptop because there wasn't any connecting wire (i.e. used to connect projector with the laptop). Another problem was limited number of cubes. The cubes were not enough that each student can build the robot separately as the whole class participated during the sessions. Thus, some students build the robot in a group of two and some students build the robot alone.

Moreover, the activity worksheets which were send to the teacher were colored while the printed activity worksheets distributed among the children were in black and white. This confused the children because I was explaining them through colors. Such as during the first session on the first page they had to write an algorithm. Students were told to be aware of water which they can see in blue color. They can cross through brown bridge. So, the students from Class 1 asked: *"There isn't any blue water…These squares are only in light and dark grey colour."*

Secondly, on the page regarding learning outcome, circles were differentiated based on colours and expressions (i.e. smileys) as it is shown in **Figure 2**. Due the black and white color (as shown in **Figure 15**) students of both classes got confused and asked: *"If I understand the concept where should I cross?... If I don't understand this concept   where can I cross?... Do we need to make smileys?"*. It was explained to the students that they can make smileys as it represents different meanings or as you can see there are three smileys which symbolize different meanings. Let's consider first smiley represents first column of circles, second smiley representing second column of circles and third smiley represents third column of circles, and made the cross sign according to that. After explaining I asked them is it clear now? Students said: *"Yes"*. Thus, some students made smileys and some made cross sign in the circle. As it is shown-below in **Figure 25.**
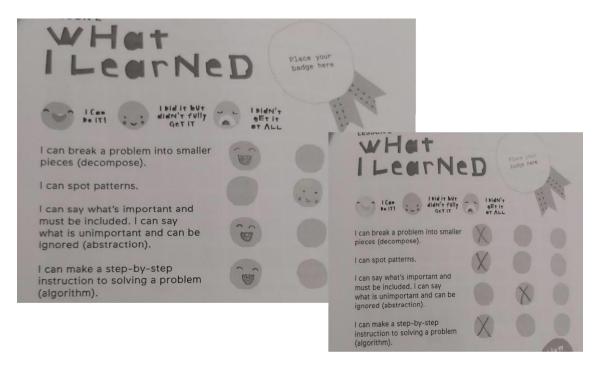
Figure 25. Session1: What I learned

5.   Discussion

This chapter summarizes findings of this study with respect to prior research. The research questions are also discussed individually in relation to the literature illustrated in section 2.

5.1 RQ1: How to familiarize children with AI?

In this study (thesis), storytelling and hands-on experience of children were given importance. Observations suggests that, children understood the concepts faster in session 1 as compared to the understanding of concepts explained in session 2. One reason seems to be that during the first session they were told Ruby's story which they listened attentively. Whereas during the second session story was skipped due to less time. Observations also suggests that children seemed to be interested in tangible objects i.e. cubes: used to build the robot as well as online activity regarding ML. According to the teacher, *"what I noticed was… how the children really like to make the robots just the physical robot"*.

Other studies (in section 2) have similar findings regarding usage of tangible objects for learning purpose. Such as, Williams et al., (2019) conducted a study regarding learning of AI concepts, in which children built Lego using Lego Duplo blocks for hands-on activity. While they were building, robot explained algorithmic logic. Participants belonged to the age-group of 4-6 years. He also illustrated that even younger children have the capability to grasp AI concepts if they are introduced with the topic through a properly formulated content. Whereas, in this research (thesis), participants belong to the age group of 11-12 years and were observed in the real environment.

Merkouris et al., (2017) suggests that for young students, interaction through tangible objects benefits in learning. ARCat (provides aid in learning DFS), used tangible user interface i.e. tangible cards to make it easy for children to learn programming (Deng et al., 2019). Similarly, Williams et al., (2019) used Lego for hands-on experience. Concerning this study, cubes for building the prototype of robot and online ML activity were used for hands-on experience.

Moreover, findings suggest that time plays an important role in learning a concept. In this study, children were familiarized with AI and ML in one session of 45 minutes. Whereas Burgsteiner et al., (2016) taught concepts in 7-weekly teachings of 2 hours each. Another study illustrates that the team of a science museum planned to familiarized children with AI in 30 minutes through hands-on experience (Candello et al., 2019).

5.2 RQ1.1: How do children perceive AI before and after being involved in learning activities (regarding AI)?

Children's perception about AI was taken into account before and after they were engaged in activities. In the beginning, students were asked (as a whole class) the question: *"When you hear the word AI what three things come to your mind?"*. A few students from both classes gave similar answers i.e. *"Robot, Coding"* and *"Robot, Machine"*. These answers were written on the whiteboard. Afterward, the concept of AI was explained to them that AI refers to a combination of software and hardware that acts sensibly during a situation and most likely it has voice recognition feature. It was explained that machines can learn

through examples like us. They gain experiences with time. Even after this, their facial expressions seemed to be confused.

To make it more understandable for them that how machines can act sensibly in various situations, two more concepts were also explained i.e. training data, and ML (detail is mentioned in chapter 4). After the explanation, students had to answer the same question through activity worksheets. A few students wrote answers for the question. Such as a girl said _"Alexa"_, another student mentioned _"thinking by itself"_ or _"not real"_. Though some students still answered the same as before i.e. _"robot"_, or _"computer"_.

Considering these answers, it can be seen that a few children's perception was changed after being engaged in learning activities. However, these finding also suggest that they had difficulty in understanding the concept and needed more time to understand it better because the answers of some students were the same as before. As compared to the first session there were less students who answered all the questions in activity worksheets in second session. During the second session (regarding AI), worksheets were collected from 16 students out which 7 students wrote answer for this above-mentioned question and 2 out of 7 students understood it as it was being expected from them.

Compare to the answers given by the students (through activity worksheets) regarding AI, my observation of them was different. As, one of the student while answering the questions, asked: _"intelligent computer…?"_ (it meant: can it be the answer of the question regarding AI stated above). They seemed to be curious (about), interested (in) and enjoying the ML activity. Such as a few of them asked _"how to create a new class?"_, _"Can I add more classes?"_. Many of them seemed to be excited as some of them expressed their feeling even through some phrases i.e. _"Cool"_ and _"Awesome"_. It seems that there could have been different results if the worksheets were collected from all of them and if all of them had answered the question. Therefore, based on the results from activity worksheets, it can be seen that the perception of a few students about AI was changed, if not all.

Burgsteiner et al., (2016) states that children became confident regarding various topics that were addressed during teaching sessions. Similarly, in another study a pre-test and post-test was conducted to evaluate the perception of children. Results of that study suggested, more children accepted in the post test that robots can learn as compared to pretest (Williams et al., in 2019). Additionally, Williams et al states that children understood knowledge-based system the most, then supervised ML, and generative AI.

5.3 RQ1.2: How was the process of conducting the study?

Regarding the process, while conducting this study some problems were faced. These problems were: less time, technology issue and miscommunication, less cubes based on number of students, activity worksheets and questions regarding AI. Firstly, Session 1 with both classes was started a few minutes late due to the explanation of consent forms and seating arrangements to the children. Students did not have enough time to learn the concepts easily. Activities were done in a rush. During the first session children had to learn five concepts in 30 minutes out of 45 minutes and had to answer the questions on activity worksheets. Also, two concepts and an activity was skipped due to the less time. During the second session presentation, story, and one ML activity was skipped. Time was also consumed while switching through different technologies.

According to the teacher: _"Overall I think… this… what you were doing… we could have had more time. Like there was always a bit of rush and maybe this… could be even more_

like a… 6-week project rather than just 2-days. So, in that way the activities that you did could have been like a good introduction… but I think that some of the children or many of them might even be ought to go further with it"

The second problem was: it was assumed that PC for the teacher's use had a camera and ML activity can be easily explained through it. If not, the connecting wire might be available to connect my laptop with the projector for the explanation of ML activity. Thirdly, cubes were not enough for the students to build the prototype of the robot individually. Fourthly, explanation of activities on the worksheet took more time than expected and was difficult due to its printing in black and white. While the concepts were being explained via colours.

In this study, for the evaluation of children's learning regarding AI concepts there was only one question to express their understandings. This question was asked before and after learning activities. Observations and results from activity worksheets suggests that more questions were needed to evaluate their understanding of AI properly because 7 students out of 15 answered it. As well as the concepts: AI, ML and training data were explained in approximately 35 out of 45 minutes. In contrast, other similar studies had more time as compared to this study and had better results. Such as Troiano et al., (2019) conducted a study lasted for over two years by nine teachers, though different concepts were taught to them. Additionally, Troiano et al., states that teachers were trained whereas I do not have pedagogical studies.

Based on the observations some activities seemed to be much easier for this age-group. Children were able to do them without explanation. For instance, children were able to write algorithm using shortcut without being explained to them. Even the teacher had the same opinion. Especially regarding a few activities in the first session he said: *"Yeah. I think… In a way I thought it was a bit too easy. I was thinking maybe even younger would be ought to do"*.

5.4 Limitations and other findings

This study was conducted in a natural environment and variables such as children's imagination cannot be controlled. Every child has their own thinking or imagination. For instance, in the second session children had their own ideas as one of the student had a small mirror and he used it for ML exercise. He placed the mirror in front of the camera and took pictures and then trained it. Some other students also followed him. This suggests children's interest in studies. It is possible that if this study is conducted again with the same group of children it gives the similar but better results because children are already aware of activities and concepts that they need to learn or explore. On the other hand, it is also possible to achieve different results if this study is conducted with a different group of children of the same age-group because children are not aware of what is it about.

In both sessions approximately 34-36 students participated in the study out of which parents of 16 students gave consent. Out of 34-36 students, some seemed to be interested in learning whereas some seemed to be playing. They gave an impression of as they do not understand of what do they have to do or what they are being taught. This lead to another result that maybe AI and ML was too difficult for them to understand and they need some basic education before learning this concept. It also suggests that there is a need of properly formulated content to introduce AI to the children which explains each concept step by step.

Moreover, some unexpected outcomes were also found under the heading: Other things I learned / How did it go? in activity worksheets. Students wrote: *"I learned that a computer is not the same thing as a human"*, *"I learned that computers can recognize picture"*, *"seeing problems with the online thing"*, *"How to use teacheable machine"*. Also, one expectation from this research illustrated by the teacher was about gender stereotyping: *"there was a chance at least for some deeper things to learn…about who should be talking about AI and who can talk about these things"*.

Concerning gender, in this study (thesis) boys seemed to be excited to do the activities and girls were more focused on how things work. For instance, during session 2 a girl said: *"Can we do these activities there… its crowded here…"*. Findings of a study by Villacís et al shows that boys and girls perceive the educational video game (running on a cloud computing infrastructure was created, that stimulates child's cognitive development) differently i.e. boys perceived it as challenges and competition, whereas girls perceived it as an opportunity of knowing their skills and abilities.

Even if there are not many students who learned the concept, a few were able to understand it. As the teacher said: *"I noticed some of them like the boy… he was understanding it quite quickly and get in on with it quite independently…"*. Observations suggests that there might have been different results if more sessions were conducted with students. So, that the children have enough time to learn. Also, deployment of AI curriculum at schools can help children to understand AI. Such as Ali et al., 2019 and Touretzky et al., 2019 presented the idea of AI curriculum that is not deployed yet.

Moreover, no data was collected regarding the background of children about computer science studies. It was found during the sessions that one child understood AI already and had a 3-year experience in programming. That student was counted in total number of participants but his/her answers were excluded from results. Other students background was unknown. They seemed to be unaware of AI and programming based on their reaction during activities because some of them asked that whether they can learn to code or not. It seems that children can go further if they have the opportunity to learn computational concepts. Such as a few students shared their personal stories which gives the impression that they are interested in learning computational concepts.

6.   Conclusions

Recently, combination of AI and children is being presented by media. Various studies regarding the use of AI for different age-groups of children can be found easily. However, in most of the studies AI is embedded in tools and software that is used by children. The search for literature review was conducted regarding AI and children that illustrated the lack of literature regarding teaching AI to the children which provided the opportunity to conduct this research. Based on the scientific articles and conference papers found through IEEE Xplore and ACM digital library, it can be seen that AI was as embedded in various tools. A study found through ACM Digital Library, was mainly focused on teaching various AI concepts to the children through PopBots. Some studies regarding awareness of children about AI were found through Google Scholar.

AI was used and addressed in various contexts for the children. These contexts are education, ethics, health, and arts and music illustrated above in chapter 2. This illustrates that a lot has been done concerning the combination of AI and children. The above-presented review also provided a strong foundation to conduct this research by exhibiting the areas where a lot of research was and still needed i.e. familiarization of AI concepts to the children. Additionally, qualitative research method was used for this study. This study was conducted at a school in Oulu, Finland. In order to familiarize children with AI, existing material was used with alterations. The story books and teaching method by Linda Liukas were used with alterations and seemed to be suitable as compared to others because she explains computational concepts through a story.

Findings suggests that some children learned about AI during the session. They were asked about AI in the beginning and a few of them answered: Robot, Code, and machine. They were not familiar as to what it is. After the explanation of AI, a few of them said intelligent machines. Moreover, it seemed that hands-on activities with tangible objects helped them in learning the concepts more easily as compared to written tasks. Such as one task was ML activity through laptop and designing the intelligent robot through cubes. Also, it seemed time was not enough for the children to learn the concepts.

Moreover, this study contributes in the field of children's AI literacy. The practitioners of this study are researchers, and educators who can be benefitted from it. Concerning practicalities, this study demonstrates one way of bringing AI to the classrooms which is easy to understand especially for novice researchers who aim to research in this area. Researchers and educators can replicate this study as each step is explained in detail while being cautious of challenges faced during the research to achieve better results than this study. Such as if color sheets are planned to use during research then one can try to be sure that color worksheets are prepared beforehand.

Additionally, if educators are also interested in AI, this study provides an idea of what is it. It provides additional links that illustrates what is AI and how it can be taught to children. It can also be observed that during the sessions students were familiar with the material that was used for hands-on activities i.e. laptops, cubes, activity worksheets. The concept of AI was explained to the students using available equipment in the classroom. No extra material was brought to the classroom.

In practice, other researchers can plan activities while keeping in mind children's background regarding AI or various other computational concepts. As, it effects the results. Unlike this study, researchers and educators can work together to plan suitable activities for the children considering age-group, and background knowledge of AI which

they plan to do with the children. Also, this study focuses on children belonging to the age-group of 11-12 years old. Unlike this study, researchers can consider younger children to teach them about AI.

Concerning the limitations, the results of this study cannot be applied to a large group of children because limited number of children participated in the study. Another limitation of this study is the unknown background of participants regarding computer studies. Due to the sole responsible person for this research it is possible that my own background affects the selection of activities and planning of sessions. Also, this study does not illustrate the literacy of teachers regarding AI.

As for the future recommendations, literature regarding familiarization of AI concepts to the children is still needed. As well as steps to bring AI in schools can be considered. Additionally, parent's and teacher's digital literacy regarding AI can be considered that plays an important role in teaching AI to the children and bringing it to schools. At what age children should start to learn AI can also be considered.

References

Ahn, J. Y., Kim, D. W., Lee, Y. H., Kim, W., Hong, J. K., Shim, Y., ... & Kim, S. W. (2018). MOYA: Interactive AI toy for children to develop their language skills. *Proceedings of the 9th Augmented Human International Conference*. 1-2. doi: 10.1145/3174910.3174957

Albo-Canals, J., Fernández-Baena, A., Boldu, R., Barco, A., Navarro, J., Miralles, D., ... & Angulo, C. (2015). Enhancing long-term children to robot interaction engagement through cloud connectivity. *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction Extended Abstracts*. 105-106. doi: 10.1145/2701973.2702045

Anuradha, J., Ramachandran, V., Arulalan, K. V., & Tripathy, B. K. (2010). Diagnosis of ADHD using SVM algorithm. *Proceedings of the Third Annual ACM Bangalore Conference*. 1-4. doi: 10.1145/1754288.1754317

Ali, S., Payne, B. H., Williams, R., Park, H. W., & Breazeal, C. (2019). Constructionism, Ethics, and Creativity: Developing Primary and Middle School Artificial Intelligence Education*, Proceedings of IJCAI*, 1-4.

Balasuriya, B. K., Lokuhettiarachchi, N. P., Ranasinghe, A. R. M. D. N., Shiwantha, K. D. C., & Jayawardena, C. (2017). Learning platform for visually impaired children through artificial intelligence and computer vision. *Proceedings of the 11th International Conference on Software, Knowledge, Information Management and Applications*. 1-7. doi: 10.1109/SKIMA.2017.8294106

Basias, N., & Pollalis, Y. (2018). Quantitative and qualitative research in business & technology: Justifying a suitable research methodology. *Review of Integrative Business and Economics Research 7*(1), 91-105.

Bricki, N., & Green, J. (2007). A guide to using qualitative research methodology. New York: Medicins Sans Frontieres. Retreived March 9, 2020, from https://fieldresearch.msf.org/bitstream/10144/84230/1/Qualitative%20research%20 methodology.pdf http://hdl.handle.net/10144/84230

Burgsteiner, H., Kandlhofer, M., & Steinbauer, G. (2016). Irobot: Teaching the basics of artificial intelligence in high schools, *Thirtieth AAAI Conference on Artificial Intelligence,* 4126-4127.

Candello, H., Pichiliani, M., Pinhanez, C., & Wessel, M. (2019). 30 Minutes to Introduce AI to Kids, *Association for the Advancement of Artificial Intelligence,* 1-3.

Chin, D. B., Dohmen, I. M., & Schwartz, D. L. (2013). Young children can learn scientific reasoning with teachable agents. *IEEE Transactions on Learning Technologies, 6*(3), 248-257

Choy, L. T. (2014). The strengths and weaknesses of research methodology: Comparison and complimentary between qualitative and quantitative approaches. *IOSR Journal of Humanities and Social Science, 19*(4), 99-104.

Danubianu, M., Pentiuc, S. G., Schipor, O. A., Nestor, M., & Ungureanu, I. (2008). Distributed intelligent system for personalized therapy of speech disorders, *Proceedings of the Third International Multi-Conference on Computing in the Global Information Technology,* 166-170.

Deng, X., Wang, D., Jin, Q., & Sun, F. (2019). ARCat: A Tangible Programming Tool for DFS Algorithm Teaching. *Proceedings of the 18th ACM International Conference on Interaction Design and Children*. 533-537. doi: 10.1145/3311927.3325308

Donalek, J. G., & Soldwisch, S. (2004). An introduction to qualitative research methods. *Urologic nursing, 24*(4), 354-356

Druin, A. (2002). The role of children in the design of new technology. *Behaviour and information technology, 21*(1), 1-25.

Ellertson, A. (2012). Work in progress: Using smart mobile tools to enhance autism therapy for children. *Frontiers in Education Conference Proceedings*. 1-2. doi: 10.1109/FIE.2012.6462271

Fadhil, A., & Gabrielli, S. (2017). Addressing challenges in promoting healthy lifestyles: the al-chatbot approach. *Proceedings of the 11th EAI International Conference on Pervasive Computing Technologies for Healthcare*. 261-265. doi: 10.1145/3154862.3154914

Gill, P., Stewart, K., Treasure, E., & Chadwick, B. (2008). Methods of data collection in qualitative research: interviews and focus groups. *British dental journal, 204*(6), 291-295.

Gottschalk, F. (2019). Impacts of technology use on children: Exploring literature on the brain, cognition and well-being. *OECD Education Working Papers,* No. 195, OECD Publishing, Paris. doi: 10.1787/8296464e-en

Godwin, K. E., Almeda, M. V., Seltman, H., Kai, S., Skerbetz, M. D., Baker, R. S., & Fisher, A. V. (2016). Off-task behavior in elementary school children. *Learning and Instruction, 44*, 128-143.

Gray, J. H., Reardon, E., & Kotler, J. A. (2017). Designing for Parasocial Relationships and Learning: Linear Video, Interactive Media, and Artificial Intelligence. *Proceedings of the 2017 Conference on Interaction Design and Children*. 227-237. doi: 10.1145/3078072.3079736

Green, J., Willis, K., Hughes, E., Small, R., Welch, N., Gibbs, L., & Daly, J. (2007). Generating best evidence from qualitative research: the role of data analysis. *Australian and New Zealand journal of public health, 31*(6), 545-550.

Hammarberg, K., Kirkman, M., & de Lacey, S. (2016). Qualitative research methods: when to use them and how to judge them. *Human reproduction, 31*(3), 498-501.

Han, J., Kang, B., Park, S., & Hong, S. (2012). How to sustain long-term interaction between children and ROBOSEM in English class, *Proceedings of the seventh annual ACM/IEEE international conference on Human-Robot Interaction*, 421-422.

Hox, J. J., & Boeije, H. R. (2005). Data Collection, Primary vs. Secondary. *Encyclopedia of Social Measurement 1,* 593-599.

Iivari, N., & Kinnula, M. (2018). Empowering children through design and making: towards protagonist role adoption. *Proceedings of the 15th Participatory Design Conference.* 1-12. doi: 10.1145/3210586.3210600

Iversen, O. S., Smith, R. C., & Dindler, C. (2017). Child as protagonist: Expanding the role of children in participatory design. *Proceedings of the 2017 Conference on Interaction Design and Children.* 27-37. doi: 10.1145/3078072.3079725

Kajornboon, A. B. (2005). Using interviews as research instruments. *E-journal for Research Teachers,* 2(1), 1-9.

Kaplan, A., & Haenlein, M. (2019). Siri, Siri, in my hand: Who's the fairest in the land? On the interpretations, illustrations, and implications of artificial intelligence. *Business Horizons, 62*(1), 15-25.

Kawulich, B. B. (2004). Data analysis techniques in qualitative research. *Journal of Research in Education*, *14*(1), 96-113.

Kawulich, B. B. (2005). Participant observation as a data collection method. *Forum qualitative sozialforschung/ forum: Qualitative social research, 6* (2).

Kılıçoglu, A. (2018). Qualitative research for educational science researchers: A review of an introduction to qualitative research. *The Qualitative Report, 23*(4), 949-951.

Kim, J., Agarwal, S., Marotta, K., Li, S., Leo, J., & Chau, D. H. (2019). Mixed Reality for Learning Programming. *Proceedings of the 18th ACM International Conference on Interaction Design and Children.* 574-579. doi: 10.1145/3311927.3325335

Labuschagne, A. (2003). Qualitative research: Airy fairy or fundamental. *The qualitative report, 8*(1), 100-103.

Liukas, L. (2015). *Hello Ruby: adventures in coding* (Vol. 1). Macmillan.

McIntosh, R., Vaughn, S., Schumm, J. S., Haager, D., & Lee, O. (1993). Observations of Students with Learning Disabilities in General Education Classrooms. *Exceptional Children, 60*(3), 249-261.

Merkouris, A., Chorianopoulos, K., & Kameas, A. (2017). Teaching programming in secondary education through embodied computing platforms: Robotics and wearables. *ACM Transactions on Computing Education, 17*(2), 1-22.

Morris, D., & Fiebrink, R. (2013). Using machine learning to support pedagogy in the arts. *Personal and ubiquitous computing, 17*(8), 1631-1635.

Orb, A., Eisenhauer, L., & Wynaden, D. (2001). Ethics in qualitative research. *Journal of nursing scholarship, 33*(1), 93-96.

Pannu, A. (2015). Artificial intelligence and its application in different areas. *Artificial Intelligence, 4*(10), 79-84.

Paragliola, G., & Coronato, A. (2013). Intelligent monitoring of stereotyped motion disorders in case of children with autism. *Proceedings of the 9th International Conference on Intelligent Environments*. 258-261. doi: 10.1109/IE.2013.12

Porayska-Pomsta, K., Alcorn, A. M., Avramides, K., Beale, S., Bernardini, S., Foster, M. E., ... & Kossyvaki, L. (2018). Blending human and artificial intelligence to support autistic children's social communication skills. *ACM Transactions on Computer-Human Interaction, 25*(6), 1-35.

Repenning, A. (2006). Excuse me, I need better AI!: employing collaborative diffusion to make game AI child's play. *Proceedings of the 2006 ACM SIGGRAPH symposium on Videogames*. 169-178. doi: 10.1145/1183316.1183341

Rokhmawati, A., Kusumo, G. R., Wahyoho, I. D., & Irawati, R. (2018). Ultranus: A novel Indonesian cultural game using artificial intelligence. *International seminar on application for technology of information and communication*. 361-366. doi: 10.1109/ISEMANTIC.2018.8549744

Ruona, W. E. (2005). Analyzing qualitative data. Research in organizations: *Foundations and methods of inquiry,* 233-263.

Silverman, D. (Ed.). (2016). *Qualitative research*. Sage.

Smeets, E., & Mooij, T. (2001). Pupil-centred learning, ICT, and teacher behaviour: Observations in educational practice. *British Journal of Educational Technology, 32*(4), 403-417

Statter, D., & Armoni, M. (2020). Teaching Abstraction in Computer Science to 7th Grade Students. *ACM Transactions on Computing Education, 20*(1), 1-37.

Troiano, G. M., Snodgrass, S., Argımak, E., Robles, G., Smith, G., Cassidy, M., ... & Harteveld, C. (2019). Is My Game OK Dr. Scratch? Exploring Programming and Computational Thinking Development via Metrics in Student-Designed Serious Games for STEM. *Proceedings of the 18th ACM International Conference on Interaction Design and Children*. 208-219. doi: 10.1145/3311927.3323152

Touretzky, D., Gardner-McCune, C., Martin, F., & Seehorn, D. (2019). Envisioning AI for K-12: What Should Every Child Know about AI?, *Proceedings of the AAAI Conference on Artificial Intelligence*, 9795-9799.

Villacís, C., Fuertes, W., Bustamante, A., Almachi, D., Procel, C., Fuertes, S., & Toulkeridis, T. (2014). Multi-player educational video game over cloud to stimulate logical reasoning of children. *Proceedings of the 2014 IEEE/ACM 18th International Symposium on Distributed Simulation and Real Time Applications.* 129-137. doi: 10.1109/DS-RT.2014.24

Williams, R., Machado, C. V., Druga, S., Breazeal, C., & Maes, P. (2018). "My doll says it's ok": a study of children's conformity to a talking doll. *Proceedings of the 17th ACM Conference on Interaction Design and Children*. 625-631. doi: 10.1145/3202185.3210788

Williams, R., Park, H. W., & Breazeal, C. (2019). A is for Artificial Intelligence: The Impact of Artificial Intelligence Activities on Young Children's Perceptions of

Robots. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1-11. doi: 10.1145/3290605.3300677

Williamson, E., Goodenough, T., Kent, J., & Ashcroft, R. (2005). Conducting research with children: The limits of confidentiality and child protection protocols. *Children & Society, 19*(5), 397-409.

Appendix A. Consent forms

Consent form for parents – page1:

Oulu International School to Participate in Research
"Artificial Intelligence and Children"

This is a masters thesis/research study conducted by Kashifa Khalid (me). I am a masters degree student at University of Oulu. The purpose of this study is to educate children about artificial intelligence.

Your child will participate in activities during Nov-Dec 2019 i.e. writing AI examples, some practical exercises with other students, teacher and me (Kashifa Khalid) and discuss what s/he has learned. Your child's participation in this study is entirely voluntary. Your child may refuse to participate in this study.

The direct benefit of this study is that your child will learn basics of Artificial Intelligence. S/he will be able to describe and give practical examples of Artificial Intelligence. Moreover, there are no risks associated with this research.

During the activities data will be collected through observations, taking pictures and audio/video recording. Data collection and data protection will be followed based on EU's General Data Protection Regulation (GDPR).

Data will be used for research purposes by researchers in INTERACT research group in University of Oulu. Researchers transcribe and analyse data. Eventually, some publications will be written utilizing the analysed data, with respect to ethical norms such as anonymization of the participants.

☐ I voluntarily consent for my child to participate in this study.

_____   _____
Signature of Parent/Legal Guardian   Date

_____
Name of Child

UNIVERSITY OF OULU   Parental Consent

Consent form for parents – page2:

Additional Information

How will my confidentiality be managed?
Your confidentiality will be handled in several steps. All data is collected and stored in an encrypted or locked digital or physical environment to ensure a level of anonymity that will not expose any personally identifiable information. Your data will be archived for future purposes of INTERACT research group.

Are there any benefits from my participation?
Your participation is really valuable for us and help us in achieving our research goals. Without participants like you, who respect research endeavours, the world would not become a better place.

What will happen if I don't want to proceed with the study?
You are free to withdraw from the study at any time, no questions asked, and without waiving legal rights. If you decide to leave the study you should inform the principal researcher.

Can I have access to data?
You have the right to ask is your personal information handled in the research and which personal information are handled. You can also request a replica about the personal information that is handled if you would so choose.

Can I request for correcting my information?
If there are inaccuracies or mistakes in the personal information related to you, you have the right to request their correction or supplementation.

Do I have the right to appeal?
You have the right to appeal to the office of the data protection representative if you feel that in the process of handling your personal information the standing data protection legislation has been breached.

Where can I get more information about the study?
If you have more questions about this study, you can contact Kashifa Khalid (me) kashifa.khalid@yahoo.com, Professor Netta Iivari (thesis supervisor & researcher at INTERACT) netta.iivari@oulu.fi , Professor Marianne Kinnula (thesis advisor & researcher at INTERACT) marianne.kinnula@oulu.fi , and Kelvey Marden (G5A Class Teacher) kelvey.marden@eduouka.fi.

UNIVERSITY OF OULU

Parental Consent

Consent form for children:

Oulu international School to participate in Research
Artificial Intelligence and Children

We invite you to participate in research conducted in Nov-Dec 2019. Participating in this project is totally voluntary. During the session you will participate in some activities with the researcher, teacher and other students. We will do some activities using computer/ laptop.

There are no risks associated with this research. The direct benefit of this study is that you will learn basics of Artificial Intelligence. You will be able to describe and give practical examples of Artificial Intelligence. Your participation is really valuable for us and help us in achieving our research goals.

You are free to withdraw from the study at any time, no questions asked, and without waiving legal rights. If you decide to leave the study you should inform the principal researcher.

If you have more questions about this study, you can contact Kashifa Khalid (me: master degree student at University of Oulu) kashifa.khalid@yahoo.com or to the teacher Kelvey Marden kelvey.marden@eduouka.fi.
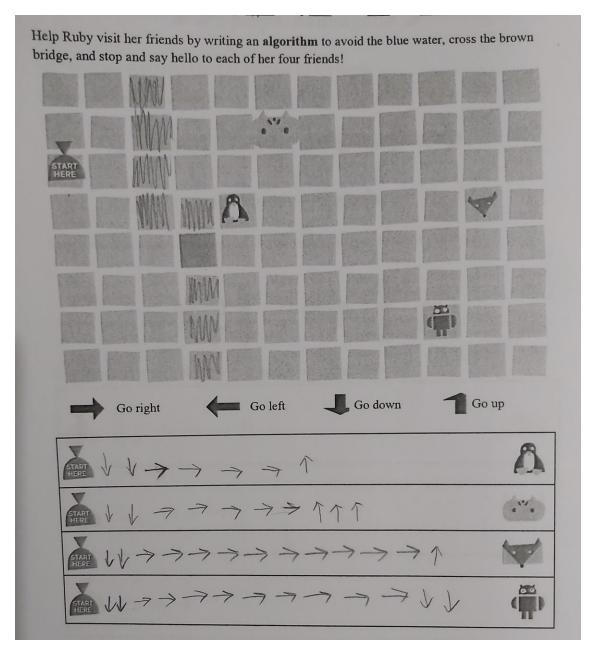
☐ I voluntarily participate in this study.

_____   _____   _____
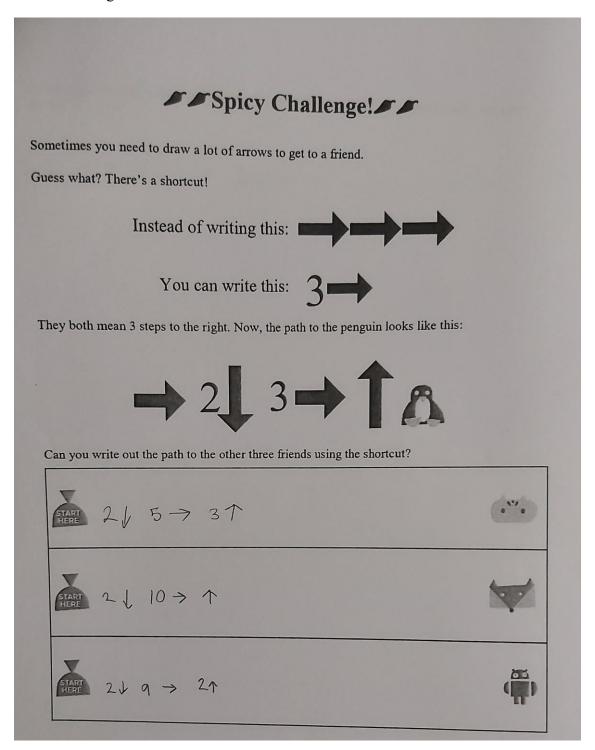Participant's Name (Caps Lock)   Signature   Date

UNIVERSITY OF OULU

Child Consent

Appendix B: Activity worksheets

Session 1–Algorithm:

Help Ruby visit her friends by writing an **algorithm** to avoid the blue water, cross the brown bridge, and stop and say hello to each of her four friends!

Session 1 – Algorithm shortcut

🌶🌶Spicy Challenge!🌶🌶

Sometimes you need to draw a lot of arrows to get to a friend.

Guess what? There's a shortcut!

Instead of writing this: ➡➡➡

You can write this: 3➡

They both mean 3 steps to the right. Now, the path to the penguin looks like this:

➡ 2⬇ 3➡ ⬆🐧

Can you write out the path to the other three friends using the shortcut?

START HERE	2↓ 5→ 3↑	🐱
START HERE	2↓ 10→ ↑	🦊
START HERE	2↓ 9→ 2↑	🤖

Session 1 – Giant Algorithm:

Challenge: Can you write one giant algorithm for Ruby to visit all 4 of her friends, one after another?

2↓ 4→3↑ 6→ 5↓ ↙

Session 1–Other learnings 1:

Other things I learned

I learned that we can make shortcuts.

Session 1–Other learnings 2:

Other things I learned

do I learned how
Can Simple algorithms
On paper with ruby

How diD i Go?

Session 1–Other learnings 3:

Other things I learned

I learned about coding and diffirent ways of doing it.

Session 2–Quadrant:

Session 2–Other learnings 1:

Other things I learned

How diD it Go?

I learned that a computer is not the same thing as a human.

Session 2–Other learnings 2:

Other things I learned

How diD it Go?

I learned that computers can recocnise pictures.

Session 2–Other learnings 3:

Name of my robot   robot123

Length
42 cm

Features
It'S big and the have a litle head

Weight
101 g