Multimodal Technologies and Interaction

MDPI

Review

Interaction Order and Historical Body Shaping Children's Making Projects—A Literature Review

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Abstract: The importance of familiarizing children with the Maker Movement, Makerspaces and Maker mindset has been acknowledged. In this literature review, we examine the complex social action of children, aged from 7 to 17 (K-12), engaging in technology Making activities as it is seen in the extant literature. The included papers contain empirical data from actual digital Making workshops and diverse research projects with children, conducted in both formal and non-formal/informal settings, such as schools or museums, libraries, Fab Labs and other makerspaces. We utilized the theoretical lens of nexus analysis and its concepts of interaction order and historical body, and as a result of our analysis, we report best practices and helping and hindering factors. Two gaps in the current knowledge were identified: (1) the current research focuses on success stories instead of challenges in the working, and, (2) histories of the participants and interaction between them are very rarely in the focus of the existing studies or reported in detail, even though they significantly affect what happens and what is possible to happen in Making sessions.

Keywords: digital fabrication; technology making; intergenerational; child; teacher; facilitator; mentor; parent; interaction order; historical body; nexus analysis.

1. Introduction

The importance of familiarizing children with the Maker Movement, Makerspaces and Maker mindset has been recognized recently [1–8]. Being a competent technology user is no longer seen as sufficient in the current technology-rich world and the literature emphasizes educating and empowering children to start innovating, designing, and building technology [9–17]. There are even studies arguing for the importance of 'maker literacies', for example, highlighting how Making related skills have become so central in the current world that they are comparable to other literacy skills, such as reading and writing, and for example, 'media literacy' [18,19]. Regarding education, the collaborative, self-directed, playful, and informal aspects of Making and Maker Movement are seen to benefit teachers and schoolchildren alike [7,12,14,17,20–28]. Making is not only tied to educational context, however, but it is seen as empowering, engaging, and inspiring children during their leisure time as well, in many different kinds of settings [2–4,6,7,14,15,20,25,29,30]. Making is actually an integral element of being a human: for human beings, it is natural to make tools for our own use as well as for the use of others. Making also truly enables democratizing innovation: ordinary people are given the access and opportunity to innovate, design, engineer, and program (digitally enhanced, physical) tools by themselves and for themselves. This has become possible with the emergence of affordable cutting-edge digital fabrication and physical computing technology [1,11,31,32].

The picture painted of Making in the literature emphasizes passionate individuals driven by their own issues and interests engaging in Making activities and collaborating with the like-minded people. This is partly correct; there are, however, certain issues that need to be highlighted concerning children and adults alike, but especially children: Engaging in Making activities in Makerspaces tends to necessitate a considerable amount of help and facilitation from other people, and there are many restrictions related to Making caused by the background, expertise and knowledge of the participants. The existing literature has already acknowledged that multiple stakeholders are involved in children's Making activities and the intergenerational aspects of making (see for example, [33–35]). The importance of teachers [3,7,9,14,16,17,20,24,36,37], facilitators [7,24,26,27,38–40], mentors [5,9,10,26,41], and peers as influencing (helping or hindering) children's Making activities has already been pointed out in the literature. Likewise, studies have already indicated that children's skills, knowledge, and experiences may be highly significant in shaping how children engage in or are discouraged from Making activities [2,3,5,7,8,10,13–15,17,20,21,24,26,27,30,35,36,40,42–49]. Previous literature reviews have already focused on the potential of Making on children's empowerment [50] and in the educational contexts [28,51], specifically pointing out that there is a need to study more systematically how backgrounds and histories of participants as well as interactions between them shape children's Making experiences [52]. This is where this study aims to contribute. We argue that the existing vast body of research on children and Making has, on the average, reported on individual projects with specific participants, aims, and outcomes, not always acknowledging that with children, conducting Making projects is a highly complex endeavor with a multitude of actors and influencing factors. Then again, we also argue that a large amount of useful insights have already been generated in these individual studies and they need to be systematically analyzed and combined. This way, we can offer a valuable, in-depth picture of the topic and its complexities. As the purpose of a literature review is to identify the limitations of the existing body of knowledge, we also hope to arouse further research interest on this topic.

Hence, this paper presents results from a thorough literature review of the state of the art in research on children and Making, utilizing nexus analytic concepts of interaction order and historical body (see [53]) for getting new insights to the topic. We use these concepts to frame and focus the literature review on certain phenomena and how they are reported in the extant literature. Nexus analysis has been considered suitable for addressing complex topics in depth, such as racism [54], transnational adoption [55] as well as literacy abilities and identities [56]. As regards education, studies using nexus analysis have focused for example on language learning [57,58]. Nexus analysis has also been utilized to understand complex issues intertwined with technology design and use (some examples: [50,59–62]). These studies, altogether, reveal that nexus analysis enables drawing attention to deeper, underlying aspects shaping the work and projects with children. As this study is a literature review, it needs to be noted that we do not utilize nexus analysis in the manner originally intended, i.e., to guide in-depth empirical research (see [53]), while we claim that the nexus analytic concepts are valuable sensitizing devices also when reviewing literature, helping in shedding light on the complexity involved in any social action. The nexus analytic concepts of historical body and interaction order have also already been utilized to structure and sensitize literature reviews [52,63]. Inspired by these studies as well as by the limitations of the existing research, we ask as our research question: *Which factors seem to be helping and hindering the endeavors around the social action of children engaging in Making activities*, focusing particularly on the histories of participants and the interactions between them as reported in the extant literature. With this, we aim to help both researchers and practitioners to gain deeper understanding of the complexities involved, of the challenges and good practices already identified, and of the limitations of the extant literature.

The structure of the paper is as follows. The next section presents the methodology of the literature review and discusses our theoretical lens. The third section presents our findings, while the fourth section addresses their implications and limitations in addition to identifying some interesting directions for future work.

2. Materials and Methods

2.1. Nexus Analytic Concepts as a Theoretical Lens in the Literature Review

We use concepts from the qualitative research approach of 'nexus analysis' [53] as a theoretical lens for this study. The basic unit of analysis in nexus analysis is social action (for example, children engaging in Making activities is the social action, as in our study), which is always studied in its context and linked with other actions, situations, and events [53]. Nexus analysis [53] draws on Goffman's theory of social interaction [64], Bourdieu's practice theory [65], cultural-historical activity theory [66], and the thinking of, for example, Bateson [67] and Nishida [68]. In nexus analysis, the links between micro-actions and broader social issues are acknowledged and studied [53]. Regarding digital technology design and use, nexus analysis has been used for studying complex topics, such as 'imitation in the design process' [59], discourses on children's online safety [60], different genres children use and subject positions they take when making video diaries [61], and factors shaping children's participation in the design process [62]. It has also been used for structuring literature reviews [52].

In nexus analysis, social action is always seen to be in the intersection of the three concepts of interaction order, historical body, and discourses in place [53]. These concepts can be analytically distinguished from each other but in real life they are intertwined in the social action [53]. In this study, the concepts of interaction order and historical body are used as a lens to study the literature on technology Making and children (see [62] for further discussion of the use of these concepts as analytical tools). When studying social action, interaction order [64] between the actors places the focus on why and how people interact in certain ways when situated in different groupings and how that affects the examined social action. For example, related to our context, in Making sessions children may discuss different issues: (1) with their close friends as compared to with peers they know only distantly, (2) with facilitators of sessions, and/or (3) with their teachers. Participants' historical bodies [53], a concept originally from Nishida [68], refers to their accumulated life histories in the form of, for example, cultural background, upbringing, studies, and personal experiences. These affect participants' possibilities to act as productive members in a team and how they act and react in different familiar or unfamiliar situations. In the context of our study, for example, children's Making activities may be hindered by children being unaccustomed to: (1) work in a self-directed manner, or (2) be helped by other children having prior experiences with different Making tools. In nexus analysis, studying discourses in place [53], that is to say studying how participants engage in different discourses that are situated in a certain time and place, offers a possibility to see how actors position themselves and the issues they discuss. In the context of our study, the participants may for example, discuss the relevancy of Making skills and, while doing so, draw on related societal-level discussions of children's technology education.

In this literature review, the concepts of interaction order and historical body are used as our sensitizing device to get a deeper understanding on the social action under study: for looking how interaction between actors is described in the extant literature on Making and children, how historical bodies of actors show in the literature, and for structuring this literature review. As there is not enough original data visible in the studied publications on discourses, including the concept of 'discourses in place' in the analytical lens was not meaningful. Thus, the resulting paper set was examined from the perspectives of (1) how interaction order and historical body reflected in children's Making endeavors, and (2) whether they seemed to be helping or hindering the endeavors.

2.2. Data Collection

This literature review is a narrative one that has been conducted in a very systematic manner. Through the creative process of conducting a narrative literature review, by in-depth reading, interpreting and categorizing the publications, we tried to address the complex social action of children engaging in technology Making activities, aiming to develop comprehensive understanding and critical assessment of the knowledge relevant for this topic (see [69]).

To collect high quality data, we used the Scopus and the ACM databases for searching for papers from such conferences and journals that: (1) have long been at the forefront of the field in publishing research on children, and (2) have a focus on technology development; (the authors thus having a combined understanding on both working with children as well as what it means to work with technology). Those conferences and journals are: the Interaction Design and Children conference (IDC), the Human Factors in Computing Systems conference (CHI), the Participatory Design

Conference (PDC), and the International Journal of Child-Computer Interaction (IJCCI). We filtered our search results by looking for (child* OR student* OR pupil* OR kid*) and (fabricat* OR maker* OR making OR 3d OR hacker*) search terms in the titles, abstracts and keywords. We also limited the publication year starting from 2009 until May 2019. The primary database that we utilized was the Scopus and the complementary one was the ACM digital library. This phase resulted in 254 papers.

2.2.1. Inclusion Criteria

In this phase, we excluded non-peer reviewed papers, workshops, and posters, as well as papers with topic that was not relevant for this review. Furthermore, we excluded papers that presented projects with very specific target groups, for example, children with disabilities (discussed as one of the limitations of this study), projects involving only design, mere description of an artifact designed for children, or only testing a design toolkit with children, not involving children in any actual technology Making activity.

To be included in this review, the papers needed to contain empirical data from actual digital Making workshops (diverse research projects in both formal and non-formal/informal settings, for example schools or museums, libraries and other makerspaces.) with children of different ages between 7 to 17 (K-12). Only qualitative studies are included. Taking these criteria into account, we narrowed the number of selected papers down to 49.

2.2.2. Data Analysis

In this phase, the concepts of 'interaction order' and 'historical body' were used as a lens to analyze the papers. As there was not enough original data visible in the studied publications on discourses circulating around, including the concept of 'discourses in place' in the analytical lens was not meaningful. Thus, the resulting paper set was examined from the perspectives of (1) how interaction order and historical body picture in children's Making endeavors, and (2) whether they seemed to be helping or hindering the endeavors. In practice, this means that we read the papers, identified the actors, roles, and responsibilities as well as other basic information of each study and extracted that to a large table. We identified also all the mentions of interactions and relationships between the actors as well as all the mentions of the experiences, backgrounds, knowledge, and skills of the actors. After that, we identified the ways those were reported as shaping Making with children (positively and negatively). We generated a set of initial codes, searched for broader themes among them, and finally defined the themes. This procedure led to the sub-categorization of our findings under the concepts of interaction order and historical body. The analysis was mostly conducted by the first author, but the interpretations of the findings were discussed collaboratively among all of the authors in every phase.

2.2.3. List of the Analyzed Papers

Table 1 presents the list of the analyzed papers (49 papers in total) in this literature review.

Table 1. Number of the papers in the literature review, published from 2009 to 2019.

Publication Year	Reference Number
2009	0
2010	0
2011	[70]
2012	0
2013	[17,71]
2014	0
2015	[7,15,22,24,36,45]
2016	[9,10,13,16,23,29,42,44,72]
2017	[5,8,12,14,20,21,25–27,30,46–49]
2018	[2–4,6,37–40,43,73–75]

2019	[41,76,77]

2.2.4. Background Information of the Included Papers

In this section, we present some background information of the included papers such as children's age group, country, length of the activities and type of the Making activities. We follow Eshach's framework [78] to categorize the context of the activities as formal, informal, or non-formal based on the provided information in the papers, unless there are specific mentions of the context in the papers. Eshach [78] differentiates formal, non-formal, and informal learning as follows:

- Formal: usually at school, may be repressive, structured, usually prearranged, motivation is typically more extrinsic, compulsory, teacher-led, learning is evaluated, sequential.
- Non-formal: at institution out of school, usually supportive, structured, usually prearranged, motivation may be extrinsic but it is typically more intrinsic, usually voluntary, may be guide or teacher-led, learning is usually not evaluated, typically non-sequential.
- Informal: everywhere, supportive, unstructured, spontaneous, motivation is mainly intrinsic, voluntary, usually learner-led, learning is not evaluated, non-sequential.

Sometimes some activities had the characteristics from two or three of these categories, hence we brought our own interpretation based on the presented information of the whole activities. For example, we considered an activity non-formal if it was: held at school, not graded/evaluated, not part of the curriculum, voluntary, and structured.

Table 2 indicates the countries in which the activities occurred. We present activities conducted in formal, non-formal and informal contexts in separate columns.

Table 2. Countries in the studies.

Country	Formal	Non-formal	Informal
Belgium	-	[76]	[6,38,76]
Brazil	[20]	-	-
Canada	-	[25]	-
Denmark	[4,7]	[29]	-
Finland	-	[2,3]	-
Germany	-	[15]	-
India	-	[8]	[27]
Israel	-	-	[5,10]
Japan	-	[48]	[48]
Norway	-	-	[49,74]
Portugal	-	-	[72]
Spain	[16]	[30,39]	-
UK	[42]	[24,39]	-
USA	[9,12,14,21,36,37,43,45,75]	[13,17,22,23,26,40,41,44,70,71,73,77]	[46,47]

In the following, Tables 3–5 summarize the background information of the studies conducted in formal, non-formal, and informal contexts. In these tables, we have unified different items in order to present a bigger picture to the reader at a glance. For example, children's age group and length of the activities were reported in various ways in the papers. As we summarize the data here using three different age ranges (7–11, 12–15, and 16–18 years) the age range of 11–13 years is reported in two categories, 7–11 and 12–15 years. However, in order to provide more precise and specific background information for each individual paper, we report them explicitly in the text before each summarized table.

Formal Context

- Children's age group: 6–11 [42] | 8–10 [43] | 8–11 [12] | 9–10 [20,21] | 9–11 [9,37] | 10–12 [74] | 11–12 [16] | 11–13 [36] | 11–15 [4,7] | 13–15 [45] | 16–18 [14],

- Length of Activity: 45 min–1.5 h [37] | 4 days (each 45 min) [43] | 4 classes (each 90 min) [14] | 18 weeks [9] | 6-week course (15 h) [7] | 8 weeks [45] | 36-week school year [12] | 4 months, twice a week (each 50 min) [36] | 2 trimesters of the school year (7 h on average per week) [16] | Half a year (7 workshops) [20] | 1.5 years (45 min-1.5 hours sessions) [21] | 2 school years (18 activities, full time school course) [74],
- Type of the Making Activity: 3D printing, electronics [43] | Science topics (Arduino microcontroller programming) [21] | Biomakerlab activity [14] | Science and language arts topics (3D printing, electronics, and crafting) [9] | Making an electronic cube (Electronics programming, sensors, The MakeMe cube (an interactive cube), LED) [42] | Building a roman template (Laser cutting, SAP Programming) [16] | Wearable game controllers (Scratch, electronic fabric, MaKey MaKey, textiles and other conductive materials) [36] | Making board games (Gaming, coding, crafting (MaKey MaKey and Scratch)) [45] | Science topics (electronic circuit, Lego, motor) [12] | Science topics (Electronics, electronics programming, art and craft) [37] | Digital fabrication and design thinking (3D modeling and 3D printers, LittleBits, Arduino's, MakeyMakey and Sphero) [7] | Innovation, entrepreneurship and digital technology (from 3D printers to electronic devices, microcontroller boards, text-based programming, and block-based/visual programming) [4] | Making activities utilizing problem-based science model (fabrication technology, like 3D printers and laser cutters, as well as more traditional making skills, like electronics, robotics, sewing and carpentry) [74].

Table 3. Summary of studies conducted in Formal context (14 papers).

Children's Age Group
7–11 [4,7,9,12,16,20,21,36,37,42,43,75] | 12–15 [4,7,16,36,45,75] | 16–18 [14]
Length of the Activity
45 min–1.5 h [37] | Max 4 sessions, 45–90 min [14,43] | 1–6 months [7,9,20,36,45] | 6–12 months [12,16] | 12–24 months [21,75]
Type of the Making Activity
3D printing [4,7,9,43,75] | Electronics [4,7,9,12,36,42,43,75] | Programming [4,7,12,16,21,36,42,45] | Laser cutting [16,75] | Robotics [75] | Crafting combined with digital Making [9,37,45]

Non-Formal Context

- Children's age group: 2–13 [76] | 3–13 [29] | 4–11 [48] | 7–10 [70] | 7–11 [23] | 8–9 [22,24] | 9–10 [13,44] | 9–15 [15] | 10–12 [2,3,69] | 10–13 [40] | 10–14 [41,75] | 12–14 [72] | 12–21 [17] | 13–15 [8,26] | 14–18 [39] | 15–17 [25] | 15–18 [30],
- Length of the Activity: 1 h [24] | half day (3 h) [76] | 80–130 min [39] | 90 min [48] | 2 workshops (4 h) [22] | 1 day [25] | 3 days (each 3 h) [8] | 3 days (each5-6 h) [40] | 3 sessions (each 1.5 h) [23] | 4 day (20 min-3 h) [29] | 5 days (14 h) [13,44] | 5 weekly sessions (each 1.5–2 h) [69] | 10 sessions (3 h) [41] | 11–18 days (each 1 h) [72] | a yearlong ethnographic study [26] | a 2-week summer program [30] | 11 weeks (260 h) [2,3] | 2 months [70] | half-day workshops [75],
- Type of the Making activity: Game Making (E-Crafting, paper circuits, electronic textiles, Scratch, coding) [40] | Making interactive board games (robot programming, laser Cutting and MakeyMakey, Touch Board, 3D printing and 3D design) [2,3] | Physical game (Arduino, LED, wires and breadboard) [24] | Creating board games (art, craft material (e.g., cardboard, paints, straws, etc.) and digital fabrication tools (e.g., 3D printing pens, laser cutter, vinyl cutter, and paper circuits)) [76] | Using programmable battery (Programmable battery, motors, Lego bricks, craft materials, musical instruments, and toys and program with Scratch) [48] | Creating e-textiles that represent their anatomy (e-textile and bags of stuff) [70] | Making electronic Bean bag stand (electronics, digital fabrication tools such as conductive paint and Craft) [26] | Physical computing workshop (Arduino, electronics (sensors, actuators and components) and programmable electronics) [8] | Manipulating different connectors (electronics (connectors), circuit building) [23] | Personal wearable computing projects (basic circuit concepts (lighting an LED) to programming the LilyPad Arduino) [69] | Building zoetrope, aeroplane or musical

instruments (LittleBits (electronic building blocks)) [75] | Making their own musical instruments (sensors and Lego and a tangible music-making platform called Hitmachine) [29] | Tinkering with music (Arduino Programming, electronics Building) [41] | Building a toy for younger children (laser engravers, 3D printers, conductive thread, sewable computer chips, and conductive ink) [13,44] | Programming in Logo and robotics, video game design [17] | Building robotic hand (robotics with Arduino, 3D modelling, 3D printing and assembly) [25] | Creating and programming interactive projects (physical computing toolkits (Talkoo), crafting material and tools (scissors, cutter knives, cardboards, colored papers and etc.) [39] | Storytelling (Maker Theater kit) [22] | Physical computing workshops (programmable construction kits (including Lego RCX,1 Crickets,2 Arduino and Arduino LilyPad3), visual programming environments (usually Amici4) and crafting materials) [15] | Making, art and network programming (programming system named BlockyTalky) [72] | Exploring Madrid's architectural landmark (3D modeling, laser cutting, using CNC machine) [30].

Table 4. Summary of studies conducted in Non-Formal context (24 Papers)

Children's Age Group
7–11 [2,3,13,15,22–24,29,40,41,44,48,70,71,76,77] | 12–15 [2,3,8,15,17,25,26,29,30,39–41,70,73,76,77] | 16–18 [25,30,39]
Length of the Activity
One session, 45–180 min [24,39,48,77] | Under one month, various session number and length [8,13,22,23,25,29,30,40,44] | 1–6 months [2,3,70,71,73] | 6–12 months [26] | 12–14 months [-]
Type of the Making Activity
3D printing [2,3,13,25,44,77] | Laser cutting [2,3,13,30,44,77] | Electronics [8,15,23,24,26,29,40,41,70,71,75,77] | Programming [2,3,8,15,17,41,48,70,73] | Crafting combined with digital Making [15,26,39,48,77] | Robotics [25] | Vinyl cutting [77] | CNC machining [30] | Using different kits or platforms such as Hitmachine [29], Talkoo [39] and maker Theater [22]

Informal Context

- Children's age group: 4–11 [48] | 5–12 [46] | 6–10 [6,38,75] | 8–11 [47] | 8–12 [5,49] | 8–14 [27] | 10–16 [71] | 12 [73] | 15–16 [10],
- Length of the activity: 3 sessions 8each 90 min) [47] | 90 min [5,48] | 4 h [49] | 5&10 days (each 3–5 h) [27] | 40 h [10] | 27 months [71] | 3 four-day [46] | half-day workshops [75],
- Type of the Making activity: Exploring opportunities of 3D printing in everyday life (Lego and 3D modeling) [47] | co-making activity focusing on entry-level making (mechanics and electronics (paper circuit)) [5] | Story Making (design practices and sweable circuit and paper electronics and programmable projections) [27] | Making own toys and devices (programmable battery, motors, Lego, bricks, craft materials, musical instruments, and toys, program with Scratch) [48] | Interacting with digital robots and creating games (Scratch and the Arduino hardware platform) [49] | Mentoring activities (digital fabrication such as 3D printing, digital prototyping, paper circuit, and coding (Scratch)) [10] | Designing a new construction kit (crafting, electronics (circuits & programming), 3D printing) [71] | Creating wearable (a wearable construction toolkit (MakerWear) [46] | Diverse activities such as games or crafting (electronics, robotics, hardware and software via LittleBits, Ozobot, Makey Makey and soldering) [6,38,75] | Interactive game development (sensors, motors and actuators, Arduino boards, visual programming tool (Scratch)) [73].

Table 5. Summary of studies conducted in Informal context (12 Papers).

Children's Age Group
7–11 [5,6,27,38,46–49,72,76] | 12–15 [5,10,27,46,48,72,74] | 16–18 [10,72]
Length of the Activity
One session, 45–180 min [5,48,76] | Under one month, various session number and length [27,46,47,49] | 1–6 months [10] | 6–12 months [-] | 12–24 months [-] | More than 24 months [72]

Type of the Making Activity
3D printing [10,72] ǀ Electronics [5,6,10,27,38,72,74,76] ǀ Programming [6,10,27,38,48,49,74,76] ǀ Mechanics [5] ǀ Crafting combined with digital Making [6,38,48,72,76]

3. Results

We have structured our findings in two main sections: the ones related to interaction order between the actors and the ones related to historical bodies of different actors. It is important to note that in real life interaction order and historical body are deeply intertwined and the separation in this paper is analytical only. The sub-sections are categorized based on the different actors of the studies and the discovered variety of themes attached to each actor.

Summaries of our findings and our interpretations are presented in Tables 6 and 7, while more in-depth details from the literature are presented in the text. Therefore, tables are not necessarily following the same global structure as the content of the text.

3.1. Interaction Order

In this section, our goal is to clarify the beneficial and challenging aspects regarding the interaction order between different actors in Making projects as reported in the literature. Interaction order between participants represents a tremendous impact on children's learning but it seems seldom to be recognized as such. We believe that the intergenerational aspect in Making projects is counted as one of the prominent aspects that has far more to offer than just pointing out the presence of various stakeholders involved in the projects (see Table 6).

We extracted from the analyzed papers everything that can be considered to be related to interaction order, not only between children but also between all the other actors who have roles in Making projects. In addition to those actors who are directly involved (teachers, parents, researchers, facilitators, tutors, instructors, helpers and mediators), we specified some other actors, who mainly play roles in the background. In the following, we report the interaction order in the form of themes that have emerged from our interpretation of the related studies. We introduce identified engagements as well as challenges. Therefore, for each actor, we organize our findings in two major categories of (1) engagements and (2) challenges, and for each category, we dig deeper and introduce different themes in more detail.

Table 6. Interaction order related issues in the reviewed literature.

ACTOR ǀ THEME for BENEFICIAL ENGAGEMENT)	REFERENCES
CHILD ǀ Autonomous work of children and taking initiatives improves their decision-making skills.	[7,12,14,17,20–27,74]
CHILD ǀ Children develop their understanding and experience rich learning opportunities through engaging in collaboration, discussion, idea sharing and supporting each other.	[2–4,6,8,13–17,21–27,30,37,40,42,45,49,70–73]
CHILD ǀ Children establish satisfactory in-group and inter-group relationships and build community.	[3,6–8,13,17,20,24,42,44,45,72–74]
CHILD ǀ Building confidence in children does not lie beyond overcoming challenges, autonomous work, and the empowerment of technological core competences.	[6,15,29,30,75]
CHILD ǀ Children are more creative when engaging in a collaborative creativity challenge.	[7,14,20,21,25,27]
CHILD ǀ When children are responsible for others and also share their results with others while they maintain a sense of achievement, their motivation increases.	[7,9,17,22,26,42,44,75]
TEACHER ǀ Teachers' engagement opens the ways for further enhancement of children's learning.	[3,4,7,9,14,16,17,20,24,29,36,37,42,75,76]
PARENT ǀ Parents' participation offers emotional security and assistance in Making, hence children are more encouraged and engaged, and also a tight-knit family might improve.	[5,6,20,22,26,46,48,77]

RESEARCHER ǀ The presence of the researchers contributes to the facilitation of the sessions.	[8,9,22,42,43,70,73,77]
HELPERǀ By providing encouragement and facilitation children are guided toward a path in which they are able to explore things in a more open manner.	[7,9,10,12,15,21–23,26,27,30,37–41,43,49,71,74,75]
ACTOR ǀ THEME for CHALLENGES	**REFERENCES**
CHILD ǀ Children's tendencies in working independently, having difficulties in negotiating, lack of interest in the topic, physical arrangements, and taking leader/passive position discourage children from interacting with their peers.	[3,4,7,8,21,39–44,49,72]
CHILD ǀ Fear of trial and error hinders children to interact in a self-directed manner.	[7,8]
TEACHER ǀ Teachers may face confusion in assessing children's learnings/works.	[7,16]
TEACHER ǀ The instructing style of the teacher could have a discouraging impact on the children.	[4]
HELPER ǀ Dependency on helpers: Children could give up easily if they do not have immediate assistance from helpers.	[43]

3.1.1. Children's Group Work Engagements

Working autonomously. Many studies such as [7,12,14,17,20–27] emphasized children's autonomous work and open exploration. The self-directed learning approach led to the enhancement of children's decision-making skills and creativity [25,75]. Children were involved in a self-organizing manner of their work and their time [7]. Open exploration [27], "free-flow-interactions" [12] and fluid and "through the air" interactions [73] are considered in some studies, as those provided children with agency over how to work with each other. Some researchers situated the children in maintaining the ownership of their process [7,17,26]. Children were also allowed to freely define the elements of their product [20]. Although the activity was constrained, children were still able to interact openly [14] and to create their own projects in various ways [74]. There is also the discussion of giving the highest possible independency to the children [23]. Sometimes children were free to shape groups by themselves [17,24,45]. Children evaluated each other's work and modified their works based on the received feedback [22].

Collaboration. Another study also reveals the potentials of designing networked technology in supporting children's collaboration and social interaction [73].

Supporting each other. Our findings reveal a broad repertoire for successful interaction of children while working in groups [2–4,6,8,13–17,21–27,30,37,40,42,45,49,70–75]. Analyzing the projects considering collaborative engagement enabled us to identify some themes such as supportive peers, older/younger peers, successful collaboration and enhancing learning, idea sharing and discussion, friendly competition, collaborative decision making, equal group work contribution, breaking the traditional ice, grouping and role taking. Children supported each other and learned together; while were engaged in Making activities. In most of the mentioned studies, verbal communication is reported as the way peers seek help from each other.

However, in [8,42], there is a remark about supportive peers copying each other's ideas. This imitation strategy is highlighted as a means of facing with resource constraints [8]. Sometimes the project was set in a way that older children supported younger children during the activities [13,42,72] or, conversely, younger children shared expertise with their older peers [17]. Interestingly, older and younger children were able to maintain a friendly competition as well [72]. The tendency of children in collaboratively making decisions [49], discussing and negotiating [21,37,45,49,70,72], sharing ideas [4,14,15,21,25–27,30,39,42,45–47,70–72,74], creating a shared understanding of the problem [2,49] and shaping groups [22–24,45] reveals important beneficial aspects of their collaborative engagements. Successfully overcoming the challenge of equal sharing of all the responsibilities is also reported among children having high Making literacy in hands [21]. Children having fun in their interactions as an influential factor in overcoming challenges is also pointed out [6]. Some roles such as 'inventor' [3], 'builder' [3], 'designer' [3,15], 'leader' [3,16,72], 'smart', 'maker'

[26], 'creator'/ 'producer' [15], 'mentor' [40], 'tech-nerd' [4] and 'protagonist' [2], emerged among groups, and despite some reports on the challenges arising with these emerged roles, they mostly carried positive stances and led to group work contributions. Furthermore, the thriving of children, who performed weakly in a traditional classrooms as they become leaders or experts in non-traditional environments is identified [16,75].

Satisfactory in-group and intergroup relations. Being open to new members and trusting them [8], delighting in supporting peers in copying them [42], being comfortable with each other [45], showing interest in each other's ideas [45], community building [17], building personal connections with other children (pre-k clients) as well as engaging them in some activities [13], ensuring being recognized as part of the team by other group members [44] and satisfaction with the leader position of the others [3] are debated pertain to in-group relations. Some studies not only considered in-group relations, but also left some room beyond the boundaries of private groups and dedicated to the promotion of interactions in higher levels such as the classroom level. For example, we interpret the enormous potential of inter-group relations in socializing due to the children's interaction with other groups [6,7,20,24,42,72], pranking other groups [73] and a public way of thinking [17], along with the pleasure that they experience consequently [6]. In addition, there is a report of utilizing multimodal interactions that consequently led to gaining richer experiences and also to the ability of reflecting on those experiences [74].

Confidence gaining. The analyzed papers were almost devoid of explicit debate regarding confidence gaining. Some authors however believe that children gained confidence due to their involvement in autonomous collaborative work [30]. Engagements of even shy children in the group works is recognized [29]. Confidence raising in girls in relation to technological competences is also remarked [15]. Besides, children seemed to gain more confidence due to overcoming the challenges [6]. Engaging with science literacy, inventing and solving problems are also identified as influencing factors in boosting children's confidence [75].

Creativity. Although creativity is embedded in the heart of digital fabrication and Making process, not much affirmative discussions about creativity in relation to the peer interactions could be found in this review. In [7,14,20,25,74] the subject of the engagements of the children in a collaborative creative challenge is brought up.

Motivating children. Children were motivated in different ways to take part in the activities and to express themselves: presenting their product to their peers [9,22,42], being responsible for others to understand their design [26], Making things for younger children [44], holding the ownership of their project [7,17,26], and being allowed to help others and fixing stuff [75].

3.1.2. Children's Group Work Challenges

Individual work. Authors [8,21] report about the children's tendency to work independently instead of team work. Johnson et al. conducted their research including two different groups, ready-made and Making groups, and these researchers believe that children maintain a partial interaction within the ready-made groups [42]. Moreover, some children had the tendency to work with only 'like-minded-peers' [4].

Discussing and negotiating challenges. Children met lots of disagreements in negotiating [3,7,72]. Children with low Making literacy were able to discuss their ideas only in brainstorming phase [21], and children faced difficulties in reaching a shared understanding [3,49].

Role taking challenges. Children are reported as asserting the opposite of 'leader' role taking by others [3, 45]. There were some evidences of "Peer-to-peer domination" and the less involvement of the passive partners due to holding a dominating role by others [9], as well as some children being dominant and some acting as an 'observer' [8]. A misassumption of a girl as being distracted from the activity was also reported, although she was deeply engaged in the activity. The reason of this misunderstanding was because she had a more vocal and extrovert teammate, who took the role of the mentor [40].

Fears. fear of trial and error was discussed in the literature [7,8]. In case of errors, children stopped their group work and joined other groups [8]. Initially, children had the tendency of seeking help from the teacher, instead of working through trial and error, though eventually they learned to work through trial and error [7].

Discouragement. Children were unhappy to give, what they had made, away to others [44]. Within a classroom setting, children were discouraged from consulting or interacting with their peers due to belonging to an educational culture with teacher-centric teaching models [8]. In a music Making workshop, children disliked working on the selected song and therefore were disengaged from the activity [41]. Children were provided with a toolkit. Although it was motivating for them, they were not successful in having a good collaboration compared to the university students. Authors suggest that in addition to toolkits, there are some other influencing factors such as physical arrangements, group size and assistance from adults as that need to be taken into consideration [39].

Lack of creativity. Our findings related to this theme is limited only to two studies. Berman et al. argue that in their study (about 3D printing), children were not able to explore new perceptions and got stuck in the repetition and recreation of the same product through the same process ("Keychain Syndrome") [43]. And in [8], children had difficulties in coming up with ideas due to not having exposure to outside learning resources.

Unequal group work contribution. There was an evidence of not contributing equally to group work [3,44]. Iivari et al. explain that children were unhappy with those, who were seeking to have more fun instead of dedicating to the group work [3].

3.1.3. Teachers' Engagement

We report on the: (1) status of the teacher's involvement to clarify their roles and responsibilities in the projects, (2) facilitation approach, and also (3) advantages that teacher's contribution brings that majorly pertain to children such as group division, motivating, and informal interaction.

Teachers engaged in the projects, maintaining a variety of positions such as: co-designers of the Making activity [16], informants by collaborating with researchers and designers and providing feedback and suggestion [3,9,29], a project concept appropriator [17], an instructor of a Making task [9], a facilitator of learning for children [75], a leader of the digital fabrication process [8], a data collection conductor [36], a learner (student role) [17], a co-learner who meanwhile tried to ensure that students had gained a good understanding of their tasks [75] a lecturer [37], framing, presenting and instructing the activities [4], children's plans reviewer [7], a classroom organizer [3], audience to children's presentation [20,42], reviewing children's work [37], a caretaker [76] and guiding the children's work [2].

Group division. Some studies state that dividing children into groups was the responsibility of teachers, mainly due to knowing children better [3,14]. In another study, it is declared that although grouping was first and foremost done by children themselves, teacher provided an additional facilitation in forming groups [24].

Motivating. Teachers were involved in some creations to be used as examples and sources of encouragement for children [20]. Moreover, teachers introduced the Making activities in a way that triggered children's enthusiasm [9] and also inspired students in idea generating [7].

Informal interaction. In some studies, the informal interaction between teacher and children is highligted [16,17,37,42]. These results particularly revealed the fact that children could reach to a certain comfort zone that is rarely flourished in a traditional learning environment. As a result, it led to a higher student-teacher interaction or even higher confidence gaining, which was clearly noticeable when children were teaching some certain tasks to their teacher [42], children having better grades [16] and even a better understanding of the children of the context [9]. Teachers becoming learners and taking the 'student' role [17] is also another different interaction that can contribute to children's confidence and encourage their engagements and enhance their learning.

Facilitation style. Teachers: did not limit children in doing their tasks and meanwhile ensured that they are doing something [17] and avoided from bringing up critical topics, in order to preserve the children's creativity in a self-directed manner [7].

3.1.4. Teachers' Challenges

Assessing challenges. The first teacher-related challenge that we identified in these studies, is regarding teachers being pushed in the direction of confusion in assessing children's learnings in the scope of digital fabrication and Making process [7,16].

Discouragement. The second reported challenge is about the discouraging impact of the teacher's instructing style on the children that eventually led to the children's request for more explorative activities [4].

3.1.5. Parents' Engagement

Parents' participations were dedicated to: offering emotional security and encouragement [6,46,77], helping children in Making activities (a peer parent) [6,46,48,77], providing constructive prompts [46], being audiences to children while children were enthusiastically socializing and representing their results [6,20,22,26], acting as facilitators [77], acting as mentors [5] and asking for help on behalf of their children [77]. When mentoring children, some topics such as high/low attention, high/low initiative and positive/negative interaction has been brought out as regards of the occurred successes and challenges [5]. One study reports about parents leading brainstorming sessions in various ways such as: (1) parents and children discussing common things that they have in mind, (2) rapidly moving to the Making phase, and (3) parents encouraging their children to start working with the material instead of brainstorming [77].

3.1.6. Researchers' Engagement

For the purpose of this paper, we confine our focus on the exploration of those interactions of the researchers, wherein they are connected more directly to children's activities.

Beneficial engagement is mentioned, when the projects were set in a way that researchers played the role of the: facilitators of the activities [8,42,70,77], assistants to the children by providing answers to children's questions as well as to the teachers' questions [9], lecturers, who provided presentation on the topic and introduced the activities to the children [22], 3D printing operators, triggering the "situational awareness" of 3D printing and reducing children's disappointments regarding 3D printing challenges [43], teachers of the Making lessons and leaders of the classroom [42], sources of learning for children [8], and mediators of digital fabrication machines such as 3D printers, laser cutters and vinyl cutters [77].

Facilitation styles of the researchers was related to challenging children by posing questions, instead of representing a direct solution [8,42], providing prompts as guidance and also showing some examples of the games that they made by themselves [77], encouraging children to seek help from their peers prior to approaching the researchers [8], teaching some concepts to children by providing some clear examples from children's everyday lives [73], and minimizing the power of the student-instructor structure by taking the role of peers and assisting the children instead of directing them [70].

Informal interactions of the researchers were mentioned in relation to gaining the trust of the children, which was effective, because as a result, children felt comfortable with the researchers and started to make jokes and also to ask about researchers' lives [70].

3.1.7. Facilitators', Tutors', Instructors', Helpers' and Mediators' Engagement

In the literature, different terms were used for different actors, such as facilitator, mentor, instructor, tutor, mediator, youth worker, and helper, whose task was mainly assisting children during the activities in different ways. In table 6 we refer to all those actors as 'helper' for simplicity but here we present the original terms from the papers.

Verbal instruction and technical assistance. (1) **facilitators** described the tasks to the children and ensured that they understood the tasks [24], provided children with technical assistance [24], (2) **tutors** assisted children with technical issues [15], (3) **mediators** contributed in providing technical supports by recording some certain moments and ideas on the whiteboard for children [71], (4)

helpers provided some technical assistance by performing the task for children [23], and (5) offering assistance if requested by children was pointed out in some studies [10,12,21,43,49].

Motivating and encouraging. (1) **facilitators** validated children's competences by positioning the children as experts and encouraged children by providing constructive prompts [26], encouraged children in completing tasks, described the tasks to the children and ensured that they understood the tasks [24], (2) **mentors** allowed children to express their confidence and pride in the created artifacts [9], children acted as mentors for other children as well, by triggering them to create and to be creative [10], and (3) **instructors** working with children led to the confidence gaining of the children [30].

Facilitation style. (1) **facilitator** balanced scaffolding with openness (leaving room for open exploration in a way that children do not feel lost) [27], avoided from adopting the manner of a typical teacher [39], listened to children actively, helped children in developing their voice by understanding their background, engaged children in conversations and reflecting, triggered ideas by sharing their creative process [27], divided children into groups [38], avoided providing children with specific didactic guidance during ideation sessions [39], reviewed children's plans and guiding them [7], probed into the process by asking questions [7,40], and one study highlights the importance of expanding the network of facilitators, in order to connect with local mentors, and eventually to connect those mentors to the children [75], (2) youth **mentors** should act as agents who play active roles in both designing and leading activities [41] and children mentors avoided teaching directly [10], (3) **instructors** let children experiencing using the machines in the Fab Lab by themselves and helped them if needed [30], treated "activities as objectives for the students to achieve learning targets", assisted children when they asked for help and led the workshops' introductions [74], (4) **mediators** also contributed in providing emotional supports by managing in gaining trust of the children [38], youth workers acted in somewhat similar roles as proxies, mediating between children and researchers [38], and (5) **helpers** let children having full independency as far as possible [23], helped with logistics and also with the management of the classroom [37], looked at children's works [37], and were audience while children were presenting their products to them [20].

Problematic engagement. As a problematic engagement, dependency on the helper was reported, in a way that if the immediate intervention of the helper was not met, children easily gave up on the task in hand [43].

3.1.8. Other Roles

The central actors and related findings presented in Sections 3.1.1–3.1.7 are summarized in Table 6 together with the beneficial and challenging aspects regarding interaction order among the actors in Making projects. In addition to those actors, we identified some other actors with different roles and responsibilities who were engaged in Making activities with children. These actors have not been emphasized in the literature but they still are somehow engaged in and related to the activities. As we wanted to include a thorough report on all of the involved stakeholders, we present them here: The literature included mentions also of prison leadership, in charge of choosing the participants [17], undergraduate students, supervising the project with teen mentors [10], a lead designer in charge of developing initial technical sketches of the Maker activity [9], designers in charge of assisting children in the field testing sessions [39] and building the prototype of the activity [9], adult peers, engineering students, in charge of motivating children by presenting their ideas through an entrepreneurship pitch [25], youth workers in charge of assisting children and evaluating children's gains (since children used to talk to them regularly, youth workers were qualified enough to evaluate user's gain) [6], acting as motivators, motivating children as well as other colleagues in Making activities and caregivers, mitigating arguments among children, acting as playmates while engaging with children and taking the role of a friend when interacting with researchers [38,76], master students in charge of designing and creating the game [2], a multidisciplinary team in charge of designing the workshop [25], STEM educators in charge of ideating about workshop activities [46], university professors in charge of theoretical classes [30], a program supervisor in charge of tracking the teenager's progress [30] and "Staff as socio-cultural actors" [26], staff in charge of digital inclusion [72] and also in charge of planning and evaluating [15], and some other roles such as an artist game developer, PhD and master students with expertise in game development, and a project manager acting as instructors of the activities [74].

3.2. Historical Body

This section outlines our findings relevant to the historical bodies of various actors. Although children's learnings could undergo drastic changes influenced by some notable factors, for example the historical body of the participants, our findings are not very rich with the historical body-related information pertained to the participants; hence it reveals that aspects related to the 'historical body' of the participants are not richly and deeply interwoven in the literature.

The main actors and related findings on their historical bodies, presented in Sections 3.2.1–3.2.6 under themes that emerged from the data, are summarized in Table 7. In Table 7, the term, 'helper', refers to different roles such as facilitators, tutors, instructors, mentors, and mediators. Important to note here is that we did not categorize the findings in this section as beneficial or problematic as it mostly remained unclear what was their effect in the reported Making projects.

Table 7. Historical body related issues in the reviewed literature

ACTOR ǀ THEME	CONNECTION TO EVERYDAY LIFE	REFERENCES
CHILD ǀ Connected to Everyday Life	Children influenced by their personal interests and relying on their past experiences, therefore they broaden their repertoire for ideating.	[5,10,14,15,17,20,27,36,41,43–45,76,77]
CHILD ǀ Disconnected from Everyday Life	No/limited experience in working in a real-life context hinders children's ideating capabilities.	[7,8,20]
ACTOR ǀ THEME	**CULTURAL & SOCIOECONOMIC STATUS**	**REFERENCES**
CHILD ǀ Cultural Hurdles	Children belonging to a culture with resistance to do-it-yourself activities or underestimating their capabilities.	[8,72]
CHILD ǀ Socioeconomic Status	Children belonging to low or high-income families / low or high-fee charging schools.	[8,9,23,26,42,43,70]
ACTOR ǀ THEME	**GROUP WORK STATUS**	**REFERENCES**
CHILD ǀ Good Team Spirit	Children benefit from knowing each other or sharing the same strategy in design and Making.	[39,45]
CHILD ǀ Weak Team Spirit	Children's lack of experiences in collaborative creation is a contentious issue that become entangled in collaborative negotiation.	[7]
ACTOR ǀ THEME	**ACADEMIC & OCCUPATION STATUS**	**REFERENCES**
CHILD ǀ Academic Status	Children are either good or in need of some training regarding to STEM skills.	[8,30,42–44]
TEACHER ǀ Field of Teaching	Biology, mathematic, technology, history, English, art, music and science teachers involved.	[3,9,14,16,36,37]
HELPER ǀ Occupation and Expertise	Educational background, occupation and expertise of those acting as mentors, facilitators, instructors and helpers might impact children's learning.	[5,7,10,15,30,36–38,43,45]
ACTOR ǀ THEME	**LEARNING & TEACHING CULTURE**	**REFERENCES**
CHILD ǀ Traditional Culture of Learning	Unfamiliarity with the self-directing approach might situate children in a path surrounded by a lack of courage to explore freely.	[7,8,14,16,30]
TEACHER ǀ Teaching Style	Interest toward both the traditional and non-traditional teaching style is specified.	[3]
ACTOR ǀ THEME	**TECHNOLOGY & MAKING LITERACY**	**REFERENCES**
CHILD ǀ Technology Literacy	Children both with and without prior experience in technology are participating in Making activities.	[8,13,15,26,27,36,40,42–45,47,49]
CHILD ǀ Making Literacy	Children with both high and low Making literacy but mostly the low one are identified.	[2,3,7,13,21,24,26,48,76]
TEACHER ǀ Technology/Making Literacy	Most of the teachers were in need of training connected to the design and digital fabrication.	[3,4,7]
MENTOR ǀ Technology/Making Literacy	Mentors were not confident enough and thus were not able to provide participants with enough support.	[41]

3.2.1. Connection to Everyday Life

Child, **connected to everyday life**. Children's ideating accomplishments lie not only in weaving themselves into the fabric of everyday life (hence, a real-life context is usually provided for them) [20,30,39,46,75], but also in personal interests and personal meanings [5,7,14,15,27,36,44,45,74]. Moreover, relying on their past experiences, children achieved significant accomplishments in the planning phase [43]. In the music Making activities, it is highly recommended to consider flexibility and space for personal interests of the participants in the terms of selecting songs and/or artists [41]. In organizing workshops, children also had a voice in representing their ideas for designing the activities [76]. Initializing the activity with traditional fabrication that participating families including children were familiar with, and then moving to digital fabrication lowered the barriers to Making and increased families' collaborations [77].

Child, **disconnected from everyday life.** However, children's abilities to ideate were at odds possibilities due to not being exposed to the outside learning resources [8]. Besides, it is highlighted that children had no prior/ limited experience in working with real-life issues [7]. The argument of children's desires of making such products that they had never experienced with (in this case, snow), is also raised in [20].

3.2.2. Cultural and Socioeconomic Status

Child, cultural hurdles. Children belonged to the society with cultural resistance to do-it yourself activities [8] or to the culture with limiting perceptions of girl's task as merely home cleaning or babysitting younger siblings [72].

Child, socioeconomic status. Children belong to a low-fee charging school [8], low-income families [8,9,26,70], rural state school [42], or children face low expectations because of the nature of their surrounding [17]. Only in one study the high socioeconomic status of the children is highlighted [23].

3.2.3. Group Work Status

Child, good team spirit. Children are reported as knowing each other due to sharing an academic schedule; hence, this familiarity facilitated shaping groups [45]. Children received training prior to the workshop in order to adopt the same strategies in the activities [39].

Child, weak team spirit. From the perspective of the collaborative challenges, children's lack of experiences in group work skills count as an impediment to the adoption of collaborative creation and negotiation activities [7].

3.2.4. Academic and Occupation Status

Child, academic status. We found three different types of information that we could relate to the poor STEM skills of the children: firstly, children were in need of some introductions to the geometry related concepts in physics and mathematics [30], secondly, a child felt that he was not good enough with his math skills, although it was not necessary for the task, [44], and thirdly, children belonged to a population that was underrepresented in STEM-related career fields [43]. On the other hand, the children's well academic performs [8] and having prior experiences with computing tools are identified [42].

Teacher, field of teaching. Although the presence of the teachers are reported in lots of studies, there is limited information about their academic backgrounds, which we believe profoundly affect children's learning outcomes. Only in a few studies, the teaching fields of the teachers are pointed out; for example, a trained biologist [14], a STEM coordinator of a school [14], a technology teacher [16,36], a mathematics teacher [3,16], a science teacher [37], and eventually teachers in some topics such as history, English, art and music [16].

Helper, occupation and expertise. Helpers, facilitators', mentors' and tutors' occupations, educational backgrounds and expertise significantly shape children's Making projects. In the literature, if mentioned, these stakeholders are reported as being: (1) graduate students as main instructors [36,45], undergraduate students as assistants to the main instructor [45], college students as instructors [30], (2) undergraduate students as helpers [37], (3) design researcher as the main facilitator [7], (4) youth workers as facilitators, whose prior knowledge were beneficial in forming well-balanced groups [38], and (5) Fab Lab staff as tutors with "educational, technological and scientific background for planning, tutoring, evaluating", who had some experiences due to attending the previous workshops [15]. Another study reports the beneficial presence of different facilitators with different backgrounds and expertise; because if the facilitators did not know some certain things, they could ask other facilitators' helps [77].

In a case that children were the only mentors of the Making space, it is specified that they were trained mentors, who had prior experiences with STEM subjects or working with children. Moreover, those who had prior experiences for example in programming or working with children were confident and comfortable with technology and also with kids. However, some mentors had some doubts in their technology-related knowledge, as well as in their ability in playing the mentorship role (they needed not to act as teachers) [10]. Only in one study, where parents act as mentors of the Making activity, there is a touch on the parents' occupations as being a product manager, a teacher, an architect or working in marketing [5]. Moreover, the experiences of a researchers in 3D printing were influential in acting as 3D operators [43].

3.2.5. Learning and Teaching Culture

Child, traditional culture of learning. Children's lack of courage/experiences in freely exploring and having the traditional perception of learning were witnessed as a self-directing approach ran its course [7, 8, 14, 16, 24, 29]. It is also revealed that some children were doing well in the non-traditional environment compared to the traditional classroom and vice versa [16].

Teacher, teaching style. Some Finnish authors have mentioned the experimentation and enthusiasm of the Finnish teachers in the integration of programming in the Finnish education system [3].

3.2.6. Technology and Making Literacy

Child, technology literacy. Identified technology-related backgrounds are: (1) having prior experience with computers [8,13], interacting with the mobile phones [8], with circuits [40], with some tools intended for practicing programming [42] and (2) having no prior experience or limited knowledge of: electronics/ programmable electronics/ circuits [8,26,27,40,73], 3D printers [43], 3D modeling software [47], tools/technologies used in the activities [36,77], and coding [49]. Furthermore, we diagnosed some themes regarding children's assumptions of themselves with the technology as: not being confident/empowered enough [15,44], being good enough or OK but having the fear of messing up [44], and being poor and consequently not engaging in the activity [44,45].

Child, Making literacy. The single mention is related to the children with high Making literacies [21]. In addition, in another study the familiarity of the children with the similar tools and materials as the workshop's ones, is highlighted as a beneficial condition for children [2]. Conversely, in some other studies, there are mentions of children with basic/low Making skills/knowledge [3,7,13,21,24,26,48].

Teacher, technology/Making literacy. Most of the teachers were in need of training connected to the design and digital fabrication [3,4,7].

Mentor, Making literacy. One paper discusses mentors of a youth club who were not used to act as agents. Therefore, they were not confident for leading the activities. Moreover, they were not familiar enough with the used technologies. Hence, this unfamiliarity with the used technologies led to a situation, in which the mentors did not have enough voice to support the participants. [41]

3.2.7. Others

The literature includes also less emphasized participants as well as some mentions of their background that we believe might be very relevant for their contributions and influences. For completeness sake, we present those here. The other participants and their backgrounds encompass of: a design researcher working in a fab lab [6], staff of a makerspace with educational, technological and scientific backgrounds [15], staff of a makerspace being experienced in running a makerspace [72], professional STEM educators collaborating in designing ideas about workshop activities, who are "staff from an interactive children's museum and a STEM education consultancy" [46], master students collaborating in designing and creating the game, who are "majoring in a combination of software engineering, information systems, and human-computer interaction" [2], a multidisciplinary team collaborating in designing the workshop, having expertise in "3D Computer-Generated Imagery (CGI) modeling, 3D printing, human-computer interaction (HCI), mechanical engineering, electrical engineering, computer engineering, robotics, and project management." [25] and activity designers, who had expertise in electrical engineering, computer science, child-computer interaction and design, and education and classroom pedagogy [21].

One study highlights the importance of forming relationships with children and also with adults in the backstage activities as an essential factor in gaining trust from both children and adults and establishing their long-term participations. Children, who were involved only in frontstage activities, were interacting with adults in a more formal way, compared to the children, who were involved in both frontstage and backstage activities [76]. Successful interactions among participants despite communicating in another language is outlined [77].

4. Discussion

The aim of this paper was to examine the social action of children engaging in Making activities as it is seen in the extant literature, identifying which factors seem to be helping and hindering the endeavors around this social action.

On a general level one can state that our review of the literature shows that the interest in the topic of Making with children has aroused quite recently: most of the studies were published 2015 or afterwards. The studies we examined were mostly conducted in USA or Europe, studies originating from USA clearly dominating in the dataset. The studies have examined both formal and non-formal/informal learning contexts, while the emphasis in the studies has been on less formal learning contexts. Primary school aged children have been the most often studied age group in Making projects. The length of the activities has varied a lot: the dataset includes both very short activities and those lasting for several months or even years, even if long term studies were in clear minority. The types of Making activity also included a lot of variety, while electronics and programming were the most often included. All this indicates a number of research gaps and interesting paths for future work: For example, studies conducted outside of USA or Europe are warmly welcomed, particularly those addressing developing country contexts. Long term studies are also needed in the future to understand longer term consequences and trajectories of Making activities among children.

When examining the literature in more detail, we utilized the nexus analytic concepts of historical body and interaction order [53] for both structuring our study as well as for gaining deeper understanding of this complex social action where a multitude of actors engage, with varying historical bodies. Two clear themes were found in our study from this examination: first, historical bodies of the participants and interaction order between them were mostly ignored in the studies, and second, the focus was mostly on successful Making activities, leaving the challenges for lesser notice. Next, we discuss our central findings further.

4.1. Ignoring Interaction Order and Historical Body

Even if we report numerous historical body and interaction order related issues in this paper, a general observation is that these issues have been quite neglected by researchers interested in digital technology design so far. Even if Making projects involving children are highly multidisciplinary and intergenerational endeavors, interactions between the different actors and how all these different actors – in subtle or not so subtle ways – shape the projects and working within (for example, by affecting the interaction order) are mostly ignored in the studies. Some mentions can be found from the literature, as the analysis reported in this paper shows, but intricate, in-depth analyses are still missing. In the literature, the huge influence of our previous life experiences (for example, participants' historical bodies) is also mostly ignored. Very rarely are researchers really considering that; usually one can find only few lines mentioning it.

In addition to separately discussing aspects relating to interaction order and historical body, we also wish to highlight that they are intertwined in practice [53,62]. When actually engaging with children in Making activities, historical bodies of the participants and interaction orders established and emerging among them form complex constellations that shape and direct the work in various ways. Additionally, there are always discourses circulating around and shaping what is being said and done [53]: there are discourses produced in situ among the participants as well as broader societal discourses addressing for instance children, Making, and education that may in significant ways influence the in situ action. When conducting nexus analytic research on children engaging in Making activities, this complexity needs to be apprehended and appreciated. In-depth ethnographic studies are recommended for grasping this complexity [53].

4.2. Neglect of Challenges

Another noteworthy observation is that quite few papers talk about challenges, the studies mostly reporting on success stories. From the perspective of interaction order [53] in particular, one could expect to find much more discussions on the complexities of working in groups. It is quite self-evident that children have to face difficulties when they engage in group work, as we know that even adults face challenges when trying to work in groups. The same goes for historical body related findings. Even if some hindering factors were reported in the studies, much more emphasis was again on positive aspects. It seems that in our discipline, researchers are quite rarely reporting challenges. This raises the question of how can we make changes and improve our practice if we do not know the difficulties and troubles in the current practice. If we are only describing the success stories, we do gain a lot of useful information about what seems to work, but unsuccessful issues would be very valuable to know by the research community as well. Currently, we lack knowledge on what does not work. Even more importantly, we lack knowledge on why something works or does not work. Especially for this type of consideration, nexus analysis provides useful means.

4.3. Towards Best Practice Recommendations

As the literature mostly seems to concentrate on success stories it is relatively easy to identify best practices or at least seeds of such. Based on our analysis of interaction order related factors, we can recommend researchers engaging in Making projects with children to encourage and facilitate: (1) autonomy and initiative of children (for more information on how to support their genuine participation and their adoption of the protagonist role, see e.g., [2,3,79,80], (2) collaboration among children, (3) positive relationships among children, community building, (4) confidence building among children, and (5) creative work among children. Such best practice suggestions are not too surprising as they align very well with the spirit of the Maker Movement: passionate and enthusiastic makers create by themselves tools for themselves and while doing so collaborate with the likeminded, share their work with others, and receive help and feedback [1,11,31,32].

However, we also warn that encouraging and facilitating such aspects with children, potentially even in the context of school and formal education, likely is a very complex endeavor. Some of these aspects may even contradict the formal schooling culture [21,35,37]. Our literature review reports also that autonomous work and collaboration among children might not be easy to accomplish for them. In addition to that, even if the literature so far has not addressed these challenges, we wish to point out the challenges related to motivating children as well as to nurturing their creativity [81,82]. Indeed, as motivation is essential for learning, it has been argued that in a "constructivist-informed classroom" student motivation needs to be explicitly planned and integrated in the learning process by, for example, challenging the students on such level that they can experience success, using teaching techniques that both deliver new knowledge but also motivate the students, and planning for supportive classroom climate [83].

As for the best practices, we can also recommend that various kinds of adults need to be involved in the Making endeavors in addition to children. Particularly significant are: (1) teachers, who are valuable and competent in engaging children in different kinds of activities, including Making, (2) different kinds of adult facilitators, who are needed in encouraging and assisting children in the Making activities, and (3) parents, who may especially contribute through offering emotional security. However, our literature review also warns that the adults' participation may be also counterproductive in the sense of the adults unintentionally ending up discouraging children, even if their goal was the opposite [4]. Hence, it is not a trivial task to encourage and engage children in Making activities. This is backed up by the understanding from the education field that contextual factors shape student's motivation and learning in the classroom [84]. More research on the complex multidisciplinary, and intergenerational nature of Making when it involves children is obviously needed.

Further, based on our analysis of historical body related factors, we recommend researchers engaging in Making projects with children also to acknowledge and inquire (1) children's everyday life experiences and issues in order to connect the project with them, and (2) children's experiences, knowledge, and cultural assumptions around learning, teamwork, technology, STEM, and Making, in order to be able to modify the work to match those and to provide adequate support, if needed. Again, this is not an easy task to do. Inquiring children's experiences, knowledge, and assumptions should be done early on in the project, but such experiences, knowledge, and assumptions are dynamic and evolving (see for example [62]). In longer-span projects follow-up inquiries are needed, too. Additionally, depending on the age of the children, inquiring these issues might be quite a challenging task. Particularly young children's ability to express and reflect upon this type issues might be very limited, while it might be challenging even for adults to articulate their underlying assumptions that still powerfully shape their current action (see for example, [63,85]).

Then again, the literature advises us that also adult participants' historical bodies are significant to consider. Particularly the literature points out the need to acknowledge and inquire teachers' knowledge, skills, and experiences (relating to teaching, technology, Making), while some mentions about other type of adult participants' background could be also found. Those definitely play a crucial role in determining what is made available and visible for children to begin with. Adult participants' decisions as regards the space, tools, materials, tasks, task assignment and other arrangements fundamentally limit what the children end up in doing and Making. Hence, inquiries on these issues are recommended, despite the challenges involved.

4.4. Limitations to This study

A large amount of traces of interaction order and historical body were identified from the studied papers. Very rarely, however, these issues that significantly affect what happens and what is possible to happen in Making sessions are reported in any detail. In the current study we have done what is doable with the data (i.e., literature) we have—we carefully report all that is reportable in a systematic and comprehensive manner. It needs to be noted, however, that we needed to do a lot of interpretation when analyzing the literature, which definitely is a limitation to this study. Moreover, a problem in this kind of review is that richness of the data has to be abstracted very much when synthesizing the results, otherwise the paper grows too long. Furthermore, we excluded papers that presented projects with very specific target groups, for example children with disabilities. Including those papers might have yielded additional insights in light of nexus analytical concepts. Additionally, our dataset leans towards European or US settings, non-formal or informal learning contexts, and primary school aged children. All this surely influences the results. A general limitation is also that this is a literature review on the topic – empirical inquiries are surely needed in the future.

5. Conclusions

With this systematic literature review of children and Making we have made visible the intricacy and complexity of the intergenerational working within the topic. We utilized the nexus analytic concepts of interaction order and historical body as sensitizing devices, and report best practices and helping and hindering factors in Making project with children. Two gaps in the current knowledge were identified: (1) the current research focuses on success stories instead of challenges in the working, and, (2) histories of the participants and interaction between them are very rarely in the focus of the existing studies or reported in detail, thus their possible effect on the results of the studies is difficult to know. In addition to that, studies covering longer time-span, conducted outside of United States or Europe and with older children are called for.

When looking at the findings of our literature review, it is important to acknowledge that the analytic lens chosen always frames and focuses the analysis. By utilizing the nexus analytic concepts, we have specifically focused on how actors, their backgrounds, and interaction between them has been described in the previous studies and what is the significance of them in the studies. It might be that with another analytic lens, similar kinds of issues relating to histories and interaction among people would have emerged, but the nexus analytic concepts enable underscoring them in particular.

We acknowledge that some of our best practice recommendations are not only Making related. We do not see this as a weakness as such—instead we think it is a strength that our recommendations are valuable for broader audience than Making oriented. However, we do think that some aspects are more specific to Making (for example, the emphasis on autonomy and initiative of children that are characteristics of Maker mindset; the need of various kinds of adult participants with divergent skillsets, e.g., for operating the associated Making machinery).

In this study the discourses in place concept was left out as the existing research did not enable analyzing discourses in any depth. In the future, critical examinations on the discourses circulating around Making projects with children are called for. Furthermore, as mentioned, we excluded papers that presented projects with a very specific target groups, for example children with disabilities. We think this excluded knowledge base could however offer valuable insights, as indicated by studies such as [86,87]. Hence, we call for more comprehensive reviews of the literature. Moreover, nexus analysis overall guides to consider social interaction among people in-depth and we think that Goffman-inspired [64] rich and detailed analyses of interaction orders among the participants provide an interesting path for future study. Naturally, many other theoretical and methodological frameworks than nexus analytic or Goffman inspired could be of value in these inquiries. Finally, as researchers interested in digital technology design and Making with children have neglected to report on challenges in Making endeavors so far, we call for in-depth studies on the intergenerational engagement in Making projects, reporting both successes and challenges and empathic understanding regarding the actors.

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