Fun in Making: Understanding the Experience of Fun and Learning through Curriculum-based
Making in the Elementary School Classroom

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Abstract

In this article, we investigate the child's experience of fun and learning within curriculum-integrated Maker activities in the elementary school classroom. Little is currently understood as to how Making makes learning fun, particularly in formal educational contexts. We conducted an in-the-wild week-long study that implements Maker activities designed with 3rd, 4th, and 5th grade teachers during science classes. Qualitative video-based analysis of the sessions for six students and analysis of all the students' self-reports were performed to derive an understanding of the determinants of fun and learning in the children's experiences. We highlight issues that may inform future directions in the investigation of Making as entertainment technologies in education.

Keywords: Making; Children; Fun; Learning; Elementary school; Science

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1. Introduction

We address the key question of how learning is made fun through Making. According to the 2014 Gallup student poll results (Gallup Inc., 2014), 47% of students from 5th to 12th grades are either not engaged or actively disengaged in U.S. public schools. Historically, involvement in and enthusiasm for learning activities within the bounded spaces of the classroom have long been a problem in education worldwide. A common way to address the challenge of making students interested and wanting to learn is to make learning fun. Beyond attempts to innovate on curricular designs and improve teacher training to infuse fun in learning, technology-based learning, ranging from virtual environments and digital games to social media and tablet apps, has been seen as a transformative approach for education. As aptly put by Buckingham (2013), “learning via technology, it is repeatedly asserted, is ‘fun’, exciting and motivating for young people in a way that more traditional methods are not”. Yet, the use of technology in education is often clinical, unimaginative, and far from empowering for students. Making is well-positioned to make learning less of a burden for the child, and more of a fun experience.

Despite significant interest in using Making to support learning, our understanding of the child’s experiences in a Making-based educational context is deeply lacking. The growing number of efforts in Making-based learning programs tend to occur in informal settings, such as summer camps, after-school programs and special workshops, and are much more practice- rather than research-oriented. Research into understanding the role of the fun factor in the learning process is found mainly in the area of serious games and gamification in education. This article presents research on the child’s experiences in terms of fun and learning in a project that implements Making-based instructional materials in elementary school science classrooms.

In the next section, we define Making and contextualize it in children’s education. Section 3 surveys work that describe the Maker experience with a focus on fun and learning in prior studies. Section 4 reviews various understandings and perspectives of ‘fun’ in the literature, and Section 5 presents our research questions. In Section 6, we describe the Making studies we conducted in an elementary school with children aged 8 to 11 years old (3rd, 4th and 5th graders). Section 7 presents details about the methods of data analysis used, and Section 8 presents our findings, before a discussion on the significance and implications of the findings for progress in the role and design of Making technologies in education.

2. Making in Children’s Education

Making is broadly understood as a term that refers to the use of a set of technologies, that includes for instance, electronics, 3D printing, programming, microprocessors, etc., as despecialized means of prototyping and creation of technology-based artifacts. The Maker movement has been defined as a “growing community of hobbyists and professionals dedicated to making their own functional devices, whether it be technological gadgets, open source hardware and software, fashion apparel, home decorating, or nearly any other aspect of physical life” (McCall, 2009). Little empirical research on Making in education can be found as of now. Much literature about the promise of Making for teaching science and technology to children is in the form of reports of practical initiatives, e.g., the Makerspace Playbook (Dougherty, 2012; Hlubinka et al., 2013),

or theoretical essays about the role that Making may play in education, e.g., (Blikstein, 2013; Blikstein & Krannich, 2013; Halverson & Sheridan, 2014; Martin, 2015).

We review prior empirically-based work on Making in education below, highlighting two main points: the prevalence of technology-focused evaluation as opposed to evaluation of the learning experience of the users, and the paucity of research in actual classroom settings. Much work in Making places emphasis on the presentation of a novel and highly significant Maker technology, but with either informal evaluations or ad-hoc analysis of data collected that results in generalized statements. *AutoGami* (Zhu & Zhao, 2013), for example, describes custom hardware and software to produce automated movable papercraft. An evaluation was conducted in the form of a workshop with 10 participants, and self-reported scores of toolkit usefulness and capacity to be engaging (enjoyment) were collected. The potential of the kit to support the child's creativity was done through a cursive analysis of the various types of papercraft created, and a mention is made of the potential to use the toolkit to learn basic circuitry. Similarly, *Blockuits* (Prachanronarong, 2013) consists of wooden free construction blocks of various shapes that are augmented or made interactive through electronics. Three playtests were conducted with Blockuits, and broad observations related to enjoyment and learning are reported, e.g., "Without communicating the purpose of *Blockuits*, one boy was able to recognize that the toy was about simple circuitry and exposing children to circuitry at a young age." and "The children enjoyed playing with both toys, but preferred the foam *Blockuits*." Another example is *Invent-abling* (Guler & Rule, 2013), which is a "girl-centric design construction kit for 'wearable electronics' targeted at children ages 5-15". The kit brings together an assortment of smart materials and electronic components to be used to complete interactive craft projects detailed in a guidebook. The kit was tested in workshop settings. Reactions of children were collected, e.g., "*Putting science and art together...to make it real fun...art and science go together totally*".

Empirical research with greater focus on learning through Making include, for instance, Posch and Fitzpatrick (2012) who report on case study experiences of children aged 10 to 14 years old attending a workshop at a FabLab that provided instruction on 2D and 3D design and fabrication, printed circuit board (PCB) fabrication and assembly, and software programming. Flores and Springer (2013) describe the assessment of self-directed learning that occurs in the Makerspace created at the Hillbrook Middle School to support science curriculum. They draw out several guidelines from their experiences, e.g., the need to allow for iteration in assessment, the need to allow for experimentation time as opposed to strictly structured classes, allowing students to set their own goals for the day.

In the Robot Diaries project (Hamner, Lauwers, & Bernstein, 2010; Hamner, Lauwers, Bernstein, Nourbakhsh, & DiSalvo, 2008), middle school students are made to design "affective, programmable tangible communication devices using familiar crafting materials and then use motors, lights and computation in novel ways to animate their creations". The project was tested in a six-session workshop with 7 participants. Video-based analysis was done, and brief reports are presented on whether the children learned, and what they learned. They found increases in learning specifically for robotic components. Qiu, Buechley, Baafi, and Dubow (2013) organized 3 individual workshops on computational textiles whereby middle and high school students used the LilyPad Arduino toolkit with a designed STEM curriculum to create different artifacts. Survey questions were administered to measure the children's attitudes toward programming and electronics before and after the workshop. The Fab@School study by Alexander, Tillman, Cohen, Ducamp, and Kjellstrom (2013) studied the implementation of activities that integrated digi-

tal fabrication into math and science 4th- and 5th-grade classes with the help of pre-service teachers across two schools. The intervention activities in the classroom included, for example, creating virtual 3D models, constructing those models into physical objects with cardstock and other materials, and re-designing the models based on initial testing. Through the use of a validated Math and Science instrument, the study reported positive gains in students' perceptions towards STEM.

More recently, others have advocated different perspectives for integrating learning in Making. For instance, Smith, Iversen, and Hjorth (2015) argued for a focus on design thinking to enable children's fuller involvement in Making processes, such as reflection and iterative design cycles. Building on their work, Gourlet and Decortis (2016) proposed the idea that orchestration of the environment (through the implementation of designed artifacts) in which Making takes place is needed for 'designerly learning' to take place. Sharon Lynn Chu, Quek, Bhangaonkar, Ging, and Sridharamurthy (2015) presented the approach of a 'means-to-an-end' to integrate Making with learning, with emphasis on the development of a Maker's mindset, a concept akin to that of 'bildung' put forth by Katterfeldt, Dittert, and Schelhowe (2015).

Generally, our review showed that research in Making for children has addressed issues of fun and learning but only at a surface level. There is little work attempting to understand the actual qualitative experience that the child goes through in learning through Making. A focus on the 'lived' experience of the child learning through Making may serve at least 3 purposes: to allow us to understand the richness and texture of Making in the classroom, beyond statistics and generalized statements; to obtain a more accurate depiction of Making engagement that does not rely only on students' self-reports; and to provide us with insights on how to enhance not only Making technologies for children, but also the experience of the child engaging in the process. Our work contributes to that perspective of children's Making for learning.

3. The 'Fun' Experience in Making

Making in an educational setting is not inherently prone to fun experiences. Smith et al. (2015) report on how elementary school-aged children found it "tedious to engage more deeply with their (Making) challenge", saying "But we've already solved that problem. You are giving us a problem (. . .) But honestly, we are done". We found one particularly relevant work that analyzed children's Maker experiences with respect to positive and negative experiences. Weibert, Marshall, Aal, Schubert, and Rode (2014) presented a feminist grounded theory analysis of 3 groups of 8 to 12-year old children doing e-textile activities in computer clubs. They report 4 key themes that arose from their coding of the children's experiences. According to their findings, negative affect could arise from i) challenges in Making that included the children's concern of breakage, lack of tool knowledge, and ability to use tools, ii) trouble in visualizing Making with regard to several processes, e.g., circuit layout, making objects from fabric, iii) difficulty in finding creative inspiration, iv) wanting a sense of ownership and a need for individualization, and v) self-imposed quality standards. Possible positive affect could arise when the children had i) moments of discovery: "technology was acting according to their will in a fashion they felt was aesthetically pleasant", ii) feelings of achievement in successful materials and tool manipulation; and during iii) the sharing of creations, and iv) being able to produce aesthetically and skillfully-executed artifacts.

To gather further understanding of fun and learning in the child's Maker experience, we looked beyond literature on Making for children to prior work that present more in-depth studies

of the adult Maker experience. In an ethnographic study of a community of adult steampunk Makers, Tanenbaum, Williams, Desjardins, and Tanenbaum (2013) describe DIY Maker technologies as ‘hedonized technologies’, characterized by pleasure, utility, and expressiveness. Steampunk practitioners find playfulness by “often us[ing] obsolete and appropriated materials to create improbable fictional technology designs” and accompanying personas. They experience embodied pleasures through the process of selecting, repurposing and working with old materials. Contrary to the study above with children, enjoyment of Making for the adult Maker comes mainly from the process, with secondary focus on end product. Sharing of fabrication techniques with others remain a source of pleasure. Buechley and Perner-Wilson (2012) examined the “physical and mental experience of building electronics by hand” through a Mechanical Turk survey of 40 craftspeople spread across 4 different areas of craft (sewing, painting, carving and electronics building). They also found that enjoyment comes from the process of Making, e.g., “A feeling of contentment comes when I complete a carving”, and sharing products. Negative aspects of the experience come in the amount of time required and feeling of frustration or stress. However, while there is a focus on aesthetics as providing pleasure and relaxation for other crafts, sources of “motivation, enjoyment, or pleasure” for electronics construction included toying with and materializing ideas and theories (emphasis on abstraction and discreteness), personal usefulness of created artifact, and engaging physical expertise.

4. Characterizing ‘Fun’

The nature of fun is very rarely directly confronted, or defined, in most studies on Making. Fun is often stated simply as a justification for the transformative effect of Making on learning. A variety of constructs, for instance flow, immersion, presence, absorption, enjoyment, engagement, and pleasure, have been associated with fun. We looked at literature in education, psychology and communication to help provide some background on understanding the concept of fun.

In a large-scale study of people’s perceptions of fun, McManus and Furnham (2010) distinguished 5 different types of fun: *Sociability* characterized by joking, laughing, talking, entertainment; *Contentment* characterized by peaceful, warm, relaxed, loving, caring; *Achievement* characterized by focussed, challenged, accomplished, absorbed and engrossed, some sense of a flow state; *Sensual* characterized by lustful, intimate and romantic; and *Ecstatic* characterized by crazy, excited and energetic. In learning, Jago (2009) advocates the necessity of ‘deep fun’ – fun not from external motivations, e.g., entertaining teacher persona, novelty, but from “intrinsic fulfillment of meaningful work”. Zinn (2008) analyzed surveys on when learning is fun, and derived 6 common themes: choice, relevance, engagement, active learning, teacher attitude, and camaraderie. Work on media enjoyment (Rogers, Carpentier, & Barnard, 2015) define determinants of enjoyment as including feeling a sense of control over aspects of the content, caring for the content, and being able to suspend disbelief.

Research on fun in technological learning contexts can mostly be found in the area of serious or educational games and software. In evaluating 3 different educational software for elementary science, Sim, MacFarlane, and Read (2006) collected self-reported fun ratings from children using the Smileyometer (Read & MacFarlane, 2006), and produced a fun score for each child based on counts of behavioral indicators of fun (e.g., “comments, smiles, laughter, or positive body language”) recorded in observation notes. Analysis showed a weak correlation between reported and observed fun scores. In Malone (1980) seminal paper on ‘What makes things fun to learn? Heuristics for designing instructional computer games’, he outlined 3 main features based

on a series of experiments: i) challenge of a player's ability, ii) fantasies that evoke images of physical objects or social situations not actually present, and iii) curiosity through an optimal level of informational complexity.

Fredricks, Blumenfeld, and Paris (2004) summarized the literature on student engagement, which is a construct often closely associated with fun, as having 3 dimensions: *behavioral* engagement drawing on the idea of participation and involvement, *emotional* engagement focusing on the extent of positive and negative reactions, and *cognitive* engagement defined as the level of investment in learning. This illustrates the challenge of understanding fun, and the significance of efforts attempting to elucidate it. As eloquently said by Jago (2009), "Fun is not elitist. She has many styles." Therefore, what is fun in learning through Making?

5. Research Questions

Our review of the literature revealed that prior work on understanding learning in children's Making have been fairly separate and distinct from prior work on understanding fun. We aim to integrate understandings of the two constructs in our work. Moreover, in studies of Making-based learning, evaluations tend to be based solely on self-reports. We aim to analyze the Making experience on a moment-by-moment interactions basis, on top of self-reports. Thus, based on a study of children's Making in a formal elementary science classroom context, the goal of our work is to provide empirically-based understanding of the research questions below:

- **RQ1:** *What do children perceive as fun in Making in a formal educational context?*
- **RQ2:** *What do children perceive that they learn through Making in a formal educational context?*
- **RQ3:** *What are the manifestations of fun during Making in a formal educational context?*
- **RQ4:** *What are the manifestations of learning during Making in a formal educational context?*

Given that Making is typically used to teach topics (e.g., computer programming, 3D modeling, electronics) that are more directly related to the materials and processes of Making, it is necessary to clarify what we mean by learning. We understand learning here to refer to a broad variety of topics that may include the learning of science concepts, electronics knowledge, technical vocabulary, etc. RQ1 and RQ4 precisely relate to what kinds of learning students gain through making their own science experiment artifacts, and how.

6. Study Description

6.1. Participant Population

We conducted a study that integrates Making into the science curricula of 3rd, 4th and 5th grade classes and within the structure of a local public elementary school classroom. Specifically, the study lasted one week and took place in 6 classrooms, 2 of each of the 3 grades. Each classroom was led collaboratively by the elementary science class teacher and a support person (a technically trained member of our research team), both assisted by 2 helpers who provided logistics support. Each class lasted an average of 65 minutes. The number of students in each class ranged from 16 to 25, with a total of 124 participants in our study (40 in 3rd grade, 32 in 4th grade, and 52 in 5th grade).

6.2. Apparatuses and Materials

Each day of science class during the week included one curriculum-integrated Maker activity. The Maker activity generally involved the students working in pairs to build an artifact that would help them conduct a science experiment. The curriculum topic addressed during our one-week study was that of ‘mixtures and solutions’, a core elementary science unit in the school district’s learning standards. The learning goals for that particular standard is that physical states of matter can be tested, observed, and recorded. Physical properties of matter include temperature, mass, magnetism, and the ability to sink or float. A mixture is created when two materials are combined such as gravel and sand and metal and plastic paper clips. A first Maker activity for 3rd grade for example, consisted of the students building an electronic mixer (see Figure 1 Day 1) to create a mixture and a solution. The mixer comprised of a basic electronic circuit with a geared rotating motor as the load. A 3D-printed mixer head is attached to the motor through a dowel rod so that the student can insert the head into a mixing container and activate the motor. A second Maker activity for the 3rd grade students was to build an electric sifting tool to separate the individual parts of a mixture (see Figure 1 Day 2). This comprised of a simple hand-held sieve with a vibrating motor attached to it. Activating the vibrating motor by depressing the card switch would shake the sieve to separate its contents. Table 1 outlines the complete set of Maker activities and associated science learning goals for 3rd grade for each of the 5 days of the study. The activities varied slightly on Days 4 and 5 to adjust to the different science learning goals of 4th and 5th grades. Figure 1 shows pictures for the Maker activities for each day.

Table 1. Curriculum-based Maker activities in study

Day	Maker Activity	Science Learning Goal
1	<ul style="list-style-type: none"> • <i>Artifact built:</i> Electric rotational mixer • <i>Materials:</i> Rotational motor, 3D printed mixer head, copper wires, battery, paper switch • <i>Science experiment:</i> Make a glitter and salt mixture 	Recognize that a solution is a type of mixture in which one or more of the ingredients, when mixed, goes through a change in physical properties.
2	<ul style="list-style-type: none"> • <i>Artifact built:</i> Electric sifter • <i>Materials:</i> Vibrating motor, binder clip, off-the-shelf sifter, copper wires, battery, paper switch • <i>Science experiment:</i> i) Separate salt and water; ii) Separate glitter and water 	Recognize that with a mixture, the ingredients can be separated.
3	<ul style="list-style-type: none"> • <i>Artifact built:</i> Electric vibrating mixer • <i>Materials:</i> Vibrating motor, plastic cup, binder clip, copper wires, battery, paper switch • <i>Science experiment:</i> Mix sand, iron fillings and glitter. Separate the elements using different tools (tweezers, magnets) 	Recognize that with a mixture, the ingredients can be separated using their physical properties.
4	<ul style="list-style-type: none"> • <i>Artifacts built:</i> Another electric vibrating mixer, Another electric sifter • <i>Materials:</i> Vibrating motor, plastic cup, binder clips, copper wires, batteries, paper switches, off-the-shelf sifter • <i>Science experiment:</i> i) Mix legos, sea shells, glitter and water; ii) Mix salt, iron fillings and wooden toothpick pieces. Separate the elements using different tools (electric sifter, tweezers, magnets) 	<p>Recognize that a solution is a type of mixture in which one or more of the ingredients, when mixed, goes through a change in physical properties.</p> <p>Recognize that with a mixture, the ingredients can be separated using their physical properties.</p>
5	No maker activity Administration of post-questionnaire

Figure 1. 3rd grade Maker activities for each day of the study

6.3. Procedures

The curriculum-based Making activities were developed several weeks before the study in an informant design process (Scaife, Rogers, Aldrich, & Davies, 1997) that used the science teachers as the informants. The teachers provided the specific learning goals for each Science class, which our research team used to brainstorm an initial Maker activity and associated science experiment. The researchers and teachers then discussed ways to adapt the science experi-

ment and design the lesson plan for each day. Finally, the teachers and researchers met again to rehearse the classroom instruction and procedures for each day.

Students provided assent prior to participating, and parents provided written informed consent for their child to be observed and recorded during class. The science class with the Maker activity consisted of 5 main parts: i) initial instruction by the teacher; ii) Making instructions by the support person; iii) students' engagement in Making; iv) science experiment; v) post-experiment notetaking and discussion led by either the teacher or the support person. In the initial instruction, the teacher reviewed content previously covered, and introduced the students to the science concepts of the day. The support person then took over the class to provide guidance as to how to build the artifact, materials needed, and how the artifact were to be used in the science experiment to be performed. Outside of instruction times, the students were allowed to work relatively autonomously and in freeflow interactions. They were able to ask for help from the logistics helpers throughout the Making process. The teacher or the support person provided instruction for the science experiment, after which the students were asked to write down their observations in their notebook, and a classwide discussion was initiated. On the last day of the week, students were administered surveys during class that asked questions about their experiences in the Maker activities during the week. Figure 2 shows pictures of the students engaging in the study.

Figure 2. Students in the study

Figure 3. Data capture setup in classroom (faces blurred for privacy)

7. Data Collection and Analysis

All classroom sessions were audio and video recorded, with one audio recorder and one camera per table to capture a group of 4 to 6 students (see Figure 3). At the end of the week, a questionnaire was administered to all the students. The questionnaire was only distributed at the end of the study/week because given the time constraints for each subject matter in the formal context of the public school, it was not possible for us to administer a questionnaire at the end of

every day. We made use of the last day of the week when no Maker activity took place (see Table 1 Day 5) to administer the questionnaire to the students.

For this research, we are mainly interested in 4 questions from the post-questionnaire: i) a Likert scale rating of ‘It was fun to do this activity’ using the smileyometer (Read & MacFarlane, 2006), a pictorial measure adapted for use with children. We note that although MacFarlane, Sim, and Horton (2005) found little correlation between smileyometer ratings and children’s rankings as measures of fun, the authors acknowledged that the question asked for the smileyometer measure was in terms of “how good” the activity was, instead of “how fun” the child had that the ranking question asked. Our smileyometer measure asked directly how fun the activity was; ii) “What are some things you liked about this week’s Maker Activity?”; iii) “What are some things you didn’t like about this week’s Maker Activity?”; and iv) “What did you learn from this week’s Maker Activity?”. These questions were used in several of our Maker workshops that we had conducted with children of the same age group prior to this longitudinal study (see S. L. Chu, Quek, Saenz, Bhangaonkar, and Okundaye (2015) for example of one of the workshops), and we found that the children were able to answer the questions independently, significantly, and relatively quickly.

To answer RQ1 (*What do children perceive as fun in Making in a formal educational context?*) and RQ2 (*What do children perceive that they learn through Making in a formal educational context?*), all answers were collated from questions ii) and iii) taken from the questionnaire administered to the 124 students who participated in the study. Two types of coding were done on the students’ given answers by a coder: the first identified the thematic content addressed in the responses (i.e., what discipline or domain does the response relate to?), and the second identified the type of responses given (i.e., does the response indicate an action, a process, an object, a person, etc?). The same coding processes were done for question iv) on things learned. Since this coding process was straightforward and did not require extensive interpretation, we did not engage in a multi-coder analysis. The single coder consulted with two other researchers when the coding of a response was unclear.

RQ3 (*What are the determinants of fun during Making in a formal educational context?*) and RQ4 (*What are the determinants of learning during Making in a formal educational context?*) were to understand the intimate experience of the child Making with the goal of learning in the classroom, and were answered through close analysis of video data from 6 children. The 6 students were selected as follows: the children’s self-reported fun rating scores from the smileyometer were entered into a spreadsheet and analyzed. The standard deviation for the scores was small (0.564). Previous research has indeed shown that the smileyometer is subject to extreme results, with children tending to rate high on all prompts (e.g., Van der Sluis, Van Dijk, and Perloy (2012), Zaman, Abeele, and De Grooff (2013), Kam, Rudraraju, Tewari, and Canny (2007)). Nevertheless, the scores provided us with a guide to select students for video analysis, which is the main emphasis of this work. We divided the scores into two groups of ‘high’ (scores of 4 or 5) and ‘low’ (scores of 3 and below), and 3 cases were selected from each group. This gave us 6 focus students.

In-depth qualitative video analysis was performed for the 6 students as follows: for each student, one day was chosen randomly out of the 5 days that the study ran. Video and audio recordings for each focus child for the chosen day were retrieved and synchronized. Video-based analysis was performed using the qualitative data analysis software MaxQDA by 3 coders at 2 levels:

I. We followed the coding method outlined by Saldaña (2012). Saldaña’s approach for qualitative inquiry prescribes a cyclical model that moves from codes to themes to categories and eventually theory. In his method, methods in the first-cycle coding involve a more direct description of the data, and second-cycle coding methods entail more analytic processes such as classifying, abstracting, etc. This is an inductive process, which in contrast to other qualitative inquiry methods such as Mayring’s (2000) that put forth a more deductive approach guided by a specific theoretical framework at the onset. A first-cycle coding process was done on each video, whereby descriptive codes were assigned to video segments to describe the content (i.e., explicit happenings and identifiable behavior units) of each segment, and relevant speech transcribed with timestamps. Each of the 3 coders coded one high fun rating and one low fun rating case. They met periodically during the first-cycle coding to establish common ground as to the granularity and type of descriptive codes to use. The intercoder reliability for this first level of coding was above the 70% generally required agreement threshold. A second-cycle coding process was done, whereby descriptive codes were analyzed to generate category or thematic codes. The second-cycle coding process was done collaboratively by all 3 coders;

II. Each video segment was coded with a predetermined framework labels of ‘positive affect’ (happenings that appeared to affect the child positively assessed based on behavioral and speech indicators – smiles, thumbs-up, positive comments, etc.), ‘negative affect’ (happenings that appeared to affect the child negatively – disgusted look, sigh, negative comments, etc.), ‘potential learning episodes’ (instances when it appeared that the child could have gained knowledge or understanding), and ‘potential distraction episodes’ (instances when it appeared that the child was distracted from the intended activity that he/she was meant to be engaging in at that moment in time). For potential learning episodes, we also coded the thematic content (discipline or domain addressed) that each episode related to. Essentially, we coded for happenings, affect, and possible outcomes (learning/distraction).

8. Study Findings

We structure the findings around each research question asked.

8.1. Research Question 1

Understanding for RQ1 (*What do children perceive as fun in Making in a formal educational context?*) was obtained from self-reported open-ended responses of things liked and disliked from the students. Figure 4 shows the counts of responses coded by type, and by topics or themes. 107 responses mentioned that the student did not dislike anything in the activities, and 2 indicated that the student liked everything. Most of the liked items listed referred to a specific *object* or artifact, e.g., “the mixer”, “the vibrator”. A significant number of liked items also pertained to a specific *activity* that was performed, e.g., “mixing glitter and water”, “making solutions”. Nineteen responses re-

Figure 4. Things liked and disliked

lated to a general *process* that the child engaged in during the sessions, e.g., “making notes about what we learned”, “building”, “being creative”. *Knowledge* refers to specific content items mentioned, e.g., “learned about electricity”, “how to make a mixture”. Other non-pertinent responses included *adjective* (simply characterizing the experience, e.g., “it was cool”, “nice”), *don’t know*, *liked all*, and *other* responses that were not classifiable.

In terms of the content topic of the responses, most of the responses were of *Making* (e.g., “made a blender”, “the shaker”) and *science* (e.g., “magnet”, “saw salt dissolve”). Some responses related specifically to the domain of *electronics* (e.g., “battery”, “when we worked with circuits”). In items disliked, 6 responses also pertained to the *flow* of the activities (e.g., “that we’re leaving”, “stopping”), and to the level of *involvement* in the activities (e.g., “didn’t get to do too much”, “Jacob not letting me do anything”). Responses indicating *don’t know* or *liked all* are not included in the topics chart.

8.2. Research Question 2

Answering RQ2 (*What do children perceive that they learn through Making in a formal educational context?*), Figure 5 shows the counts of students’ self-reported responses of things learned based on the topic/theme mentioned, as well as the type of item reported as learned. Most of the learned items listed described a *process*, characterized by students reporting they gained an understanding of the method used, such as “I learned how to make a circuit,” “I learned how to make a blender,” “I learned how to separate a solution.” Reported *objects* included the items that were used (e.g., “wire”), artifacts produced during the Maker activities (e.g., “mixer”), or products used during science experiments (e.g., “mixture of sea shells and legos”). *Concepts* represented knowledge learned from the Making activities, including what was discovered during the science experiments when the artifacts built were put to use (e.g., “that if you put salt in water you can separate it by putting the water and the salt on a hot plate”). Reports of *identity* learned were described as new understanding about preferences (e.g., “I liked the circuit”), abilities (e.g., “you can make anything if you just believe”) and future opportunities (e.g., “you can become a scientist”). *Other* types of responses were null responses, non-descriptive responses (e.g., “some stuff”), or additional statements about the experience (e.g., “that this is a good thing”).

Additionally, we were interested in the topic or theme represented in reported items learned. Given the collaborative nature of the Maker activities and the use of electronics and making procedures to enhance the understanding of the science curriculum, it is reasonable that a relatively equal number of items were reported as learned from each of the instructed topics. *Electronics* items reported referenced the electronic materials used during Making (e.g., “I learned how to make a circuit”). *Making* items included items that mentioned Making procedures or artifacts (e.g., “mixer”). *Science* items included observations and final results from the science experiments (e.g., “when you put water and salt and evaporate the water, the salt is still there”). *General* behaviors included reported items pertaining to behavior that was asked of students by teachers and support people (e.g., “being very careful”).

Figure 5. Items learned

8.3. Research Question 3

RQ3 (*What are the manifestations of fun during Making in a formal educational context?*) was answered through video-based analysis of the classroom sessions of 6 specific students. A total of 303.05 minutes of video were analyzed, resulting in 1433 unique descriptive codes generated in the first-cycle coding, and 27 category codes were derived in the second-cycle coding for affect. 20 of the category codes, shown in Table 2, were labeled with ‘positive affect’, and 13 of them, shown in Table 3, were labeled with ‘negative affect’. Six of the category codes had both positive and negative instances (italicized in Table 2 and Table 3). The category codes were grouped by general type (relating to the Making activity – 41%, to some form of social interaction – 40%, or to behaviors non-related to any topic of our interest – 17%). 83% of coded segments labeled with ‘negative affect’ were from children who self-reported low fun ratings. For coded segments labeled with ‘positive affect’, it was almost equivalent with 49% coming from children reporting high fun ratings, and the other 51% from those who reported low fun ratings.

Table 2. Manifestations of Positive Affect

Type	Category Code	Count	% of All Coded Segments
Activity	Experimentation	77	11.4%
	Novelty	49	7.3%
	<i>Wanting involvement</i>	28	4.2%
	Accomplishment	18	2.7%
	Fantasy	12	1.8%
	Wanting to get it done	10	1.5%
	<i>Absorbed in activity</i>	9	1.3%
	Vicarious experimentation	5	0.7%
	Real-life	1	0.1%
	SUBTOTAL:	209	41%
Non related	Play	79	11.7%
	Recording devices	7	1.0%
	SUBTOTAL:	86	17%
Social	<i>Ordering</i>	55	8.2%
	Sharing	46	6.8%
	Answering	36	5.3%
	<i>Boasting about knowledge</i>	22	3.3%
	<i>Chatter</i>	22	3.3%
	<i>Instruction</i>	11	1.6%
	Questioning	10	1.5%
	External reinforcement	2	0.3%
	Competition	2	0.3%
	SUBTOTAL:	206	40%

Table 3. Manifestations of Negative Affect

Type	Category Code	Count	% of All Coded Segments
Activity	<i>Wanting involvement</i>	11	1.6%
	<i>Absorbed in activity</i>	2	0.3%
	Motor ability	1	0.1%
	Repetitive practice	1	0.1%

	Breakage	1	0.1%
	Impatience	1	0.1%
	SUBTOTAL:	17	2.5%
Social	<i>Giving instruction</i>	77	11.4%
	<i>Boasting about knowledge</i>	27	4.0%
	<i>Ordering</i>	9	1.3%
	Being ignored	3	0.4%
	<i>Chatter</i>	2	0.3%
	Peer evaluation	1	0.1%
	Engagement out of protocol	1	0.1%
	Intervention from other	1	0.1%
	SUBTOTAL:	121	18%

8.4. Research Question 4

Results for RQ4 (*What are the manifestations of learning during Making in a formal educational context?*) were obtained from coded segments labeled with ‘potential learning’ or ‘potential distraction’. Out of the 1433 total descriptive codes generated from the dataset, 595 descriptive codes indicated potential learning episodes, and were classified into 14 category codes. As to the theme of the learning episodes, 25.9% of the 595 instances related to potential uptake of electronics knowledge, 17.7% to Making knowledge, 13.7% to science, and 0.1% to technology in general (e.g., recording devices). Table 4 shows the category codes that the descriptive codes for learning were grouped into. These are listed in the table based on the primary type of medium that the category code relates to (hands-on, verbal, or visual, or any). 626 descriptive codes indicated potential distraction episodes, and were classified into 9 category codes. Table 5 shows the category codes that the descriptive codes for distractions were grouped into. As in Table 4, the category codes in Table 5 are listed based on the medium type that each category code relates most to (hands-on, verbal, visual, any or passive).

Table 4. Manifestations of potential learning episodes

	Category Code	Count	% of All Coded Segments
Hands-on	Absorbed in activity	96	6.7%
	Experimentation	48	3.3%
	Independent engagement	43	3.0%
	Following instructions	39	2.7%
	Spatial arrangement	1	0.1%
	SUBTOTAL:	227	15.8%
Verbal	Questioning	27	1.9%
	Verbalising	15	1.0%
	Engaging in argument	6	0.4%
	SUBTOTAL:	48	3%
Visual	Observation	91	6.4%
	Listening	64	4.5%
	SUBTOTAL:	155	11%
Any	Giving instruction	98	6.8%
	Answering	30	2.1%
	Problem solving	24	1.7%
	Reflection	13	0.9%
	SUBTOTAL:	165	12%

Table 5. Manifestations of potential distraction episodes

	Interpretive Code	Count	% of All Coded Segments
Hands-on	Absorbed in activity	126	8.8%
	Experimentation	27	1.9%
	Class structure	4	0.3%
	SUBTOTAL:	157	11%
Verbal	Chatter	87	6.1%
	Knowledge self-efficacy	23	1.6%
	Involvement	7	0.5%
	SUBTOTAL:	117	8%
Visual	Environment	184	12.8%
Any	Excitement about artifact	88	6.1%
Passive	Mind wandering	80	5.6%

9. Discussion

The use of Making in education is often justified by the fact that it purportedly integrates or infuses learning with fun. We conducted a study of children engaging in one-week long curriculum-integrated Maker activities in the classroom, and analyzed select children's observed and self-reported experience of fun and learning. We describe the most prominent themes and discuss them in the context of prior literature, and with respect to key insights that they inform us about with respect to the child's Maker experience in a formal learning context.

The main codes of positive affect related to the Maker activities in the study were *experimentation*, *novelty* (when the child encountered something for the first time), and *wanting involvement* (when the child asserted her participation in an activity). Main codes for positive affect that related to social interactions were *ordering* others (telling others what to do) and *answering* questions. *Play* instances that were unrelated to the Maker activities also contributed significantly to positive affect during the sessions. The emphasis on experimentation was also somewhat reflected in the children's self-reported liked items. Items reported were mostly of type 'object' or 'activity', and pertained to Making. Weibert et al. (2014) found that *accomplishment* and *sharing* are 2 key characteristics of positive affect in the child's Maker experience within an e-textile workshop setting. These were 2 manifestations that we found as well. Pleasure from the creation of aesthetically-pleasing products however was not found, perhaps because in a formal educational setting, focus was on functionality. Another interesting code was that of *fantasy*. Malone (1980) found that fantasies (evoking images of objects or situations not present) represent a key ingredient of fun learning. We saw a number of interesting cases of fantasy during the Maker activities. For instance, a student pretended that the motor was a curler and wrapped her hair around it. Curiosity is another key ingredient from Malone (1980)'s framework. In curriculum-based Making, curiosity was manifested in terms of exploration behaviors, and behaviors that emphasized the novelty of the situation, artifact, idea, etc.

There were far fewer codes of negative affect, perhaps reflecting the small standard deviation of the children's self-reported smileyometer fun ratings. The most prominent negative affect codes were *wanting involvement* and *giving instruction*. Experiencing negativity in involvement was indicative of the difficulty of the students to work together on the Maker activities and

science experiments. In informal or workshop settings, it may not be essential that children are able to work in teams. In fact, in summer camps, children often sign up without knowing each other, and complete the program without having the time to develop teamwork skills. In school, students spend each day in the same class, and teamwork is a critical factor continuously encouraged. It may thus be worthwhile to investigate how to support the child's collaborative Maker experience within learning contexts.

Absorbed in activity, questioning, observation and giving instruction were the main ways by which we saw potential opportunities for learning to happen. The Maker experience not only allowed for a diversity of ways to engage knowledge, but we believe it also amplified the likelihood of a particular behavior resulting in some form of learning. For example, *observation* was prominent in our study. The children were often engrossed in watching others engaging in Making (hooking up their circuit, building their mixer, etc.), experimenting with different methods of mixing the glitter and water, and creating fantasy scenarios, etc. While it may be true that such opportunities for learning can also be found in typical science hands-on activities, we argue that Making renders the same behaviors more meaningful because of its inherently more unstructured nature. For instance, a child observing others performing exactly the same science experiment as himself with exactly the same industrially-manufactured instruments may not learn as much as a child observing others making their own instrument and then performing the science experiment. The Making process itself, and the results of the experiment as well, may have variance, given the custom-made instrument with all its Making nuances and deficiencies. We note that it is rather encouraging that the items learned as reported by the children addressed almost equally science and Making issues.

For episodes that potentially distracted from learning, two main codes are of significance, apart from *play* that pertained to playful behaviors related to neither the Maker nor science activities. Given that having the children engage in the Maker activities within the classroom structure resulted in much more action and happenings than during a typical class, the continuous flow of activity in the child's *environment* sometimes detracted him/her from focusing on what was being taught. Furthermore, the Maker activities required materials and *artifacts* to be placed in front of the students throughout most of the science class. This resulted in the children being too excited and unable to wait to interact with the artifacts, sometimes simply because these were laid out, fully accessible and persistent in front of them.

Finally, given our findings, it is interesting to ask whether there are any common manifestations of fun and learning during Making in a formal educational context. Some prior literature (in non-Maker contexts) on the relationship between determinants of fun and learning are not encouraging. For instance, MacFarlane et al. (2005) reported no significant correlation between observed fun and learning in a study of children using 3 different desktop software. They provide the possible explanation that children may not "see a product that is fun as being 'suitable' for classroom use". However, the findings of our Making study are more optimistic. Comparing descriptive and category codes labeled with 'positive affect' and 'potential learning episodes', 5 key codes can be found to overlap to various degrees. Absorbed in activity, experimentation, giving instruction, questioning and answering were the recurrent codes. *Absorbed in activity* was when the child engaged in repetitive behavior or in a behavior continuously for an extended period of time with an artifact, for example, pressing the switch repeatedly, tapping the vibrating motor continuously. Absorption in the activity created an opportunity for the child to gain embodied knowledge and a sense of the material. *Experimentation* was when the child en-

gaged in explorative behavior. This was manifested mostly in the form of hypothesis-testing – the child appeared to have formed a hypothesis, e.g., which object is magnetic?, and attempted to test his/her hypothesis, e.g., placing the magnet on different objects to see whether they would ‘stick’. *Giving instruction* was an interesting theme. In the Maker activity, children sometimes found pleasure in explaining procedures to others, and in so doing potentially reinforced their understanding of the concept through explanation. The same theme however was sometimes associated with negative affect, when the child was irritated or frustrated at having to instruct someone else. This seemed to happen in 2 main scenarios: i) when the child wanted to complete her own or others’ activities at higher standards than the other child wanted to; and ii) when the child was not able to perform an activity herself, and had to tell others how to do it. *Questioning* and *answering* were both themes with evident learning potential. They were tied to positive affect in the sense of the satisfaction that they generated for the child upon either finding something to ask about, or being able to provide an answer to a question asked.

10. Limitations and Future Work

Our work is limited by a number of factors that we highlight here. Only 6 children out of the 124 who participated in the study were studied through video analysis. This limits the generalizability of the themes uncovered in the findings. We believe nevertheless that the qualitative nature of our study enabled us to obtain much richer and textured meaning than would have been possible with only quantitative results. Even though only 6 children’s videos were analyzed, our analysis was in-depth, coded at the level of micro-behaviors. Moreover, there are different ways of operationalizing a Maker activity. We developed our science Maker activities using participatory design with a design team and elementary school teachers. It is possible that an entirely different operationalization of curriculum-based Making may result in different students’ behaviors and responses. As of now however, there are relatively few studies on Making in formal school contexts, and so our work contributes significantly in this area.

Future work will attenuate the generalizability concerns raised above. In-depth video analysis of more students in the current study will be performed to validate the occurrence of the themes. Another curriculum-based Making study using a different science topic (other than ‘Mixtures and Solutions’) will also be performed so that we can compare and contrast findings. Last but not least, given the limitations with the use of the smileyometer, our future studies may explore the use of different assessment instruments of fun with children (e.g., the fun sorter (Sim et al., 2006), the laddering method (Airey, Plowman, Connolly, & Luckin, 2002), etc.).

11. Conclusion

This article has contributed to our understanding of the child’s experience of fun and learning within curriculum-integrated Maker activities in the elementary school classroom. Our analysis of data collected in an in-the-wild study was qualitative in nature, but highly detailed and in-depth. In summary, the contributions from our findings are that: i) we found key behaviors that are indicative of positive affect (e.g., experimentation, ordering others) and of negative affect (e.g., wanting involvement, giving instructions), and key episodes that provide learning opportunities (e.g., asking questions, observing others) and those that distract students from learning during Making activities in the classroom (e.g., absorption in the Making process); ii) we saw that curriculum-based Making allows for a variety of types of knowledge to be gained (electronics knowledge, Making process, science concepts, general technology, etc.), iii) we provided evidence that behavioral themes common to both learning and fun can be found in formal

Making contexts, contrary to previous findings in the literature; and iv) we validated findings from prior work that children's self-reported fun ratings from the smileyometer is of limited usefulness by itself.

The child's Maker experience in a formal educational context is exceedingly complex with many institutional structures, environmental factors, and social dynamics, exerting influences. It is not sufficient to say that we will make learning fun in the school by bringing in Maker activities. The question that still requires further investigation is how learning in the classroom may be made more aligned with Jago (2009)'s concept of 'deep fun'. As with all qualitative studies, our findings may be limited in generalizability. However, we believe that the value of this work is in its *in-vivo* deployment of Making in an actual classroom, and our close analysis of the children's experiences.

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