TOWARD INCLUSION OF CHILDREN AS SOFTWARE ENGINEERING STAKEHOLDERS

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ABSTRACT

Background: A growing amount of software is available to children today. Children use both software that has been explicitly developed for them and software for general users. While they obtain clear benefits from software, such as access to creativity tools and learning resources, children are also exposed to several risks and disadvantages, such as privacy violation, inactivity, or safety risks that can even lead to death. The research and development community is addressing and investigating positive and negative impacts of software for children one by one, but no comprehensive model exists that relates software engineering and children as stakeholders in their own right. Aims: The final objective of this line of research is to propose effective ways in which children can be involved in Software Engineering activities as stakeholders. Specifically, in this paper, we investigate the quality aspects that are of interest for children, as quality is a crucial aspect in the development of any kind of software, especially for stakeholders like children. Method: Our contribution is based mainly on an analysis of studies at the intersection between Software Engineering (especially software quality) and Child Computer Interaction. Results: We identify a set of qualities and a preliminary set of guidelines that can be used by researchers and practitioners in understanding the complex interrelations between Software Engineering and children. Based on the qualities and the guidelines, researchers can design empirical investigations to obtain deeper insights into the phenomenon and propose new Software Engineering knowledge specific for this type of stakeholders. Conclusions: This conceptualization is a first step towards a framework to support children as stakeholders in software engineering.

1 Introduction

A massive and ever growing amount of software intensive technologies is available today to children of younger and younger age through sites such as Facebook and Instagram, apps, games, and Internet of Things (IoT) devices embedded in, for example, cars and toys. In some cases, the software is specifically made for children, but, in other cases, it is made for the general users, like Facebook and Instagram, and also used by children. In some cases, the software aims at solving a problem, like helping children with reading difficulties to learn how to read [1] or children with obesity to exercise [2]. In other cases, the software’s goal is to enhance children creativity [3], like Scratch [4]. In most cases, software is made for commercial and entertainment purposes, like war games.

With the advancement of technology and the development of new IoT applications, games, and social media sites, it is getting increasingly difficult to keep up with the associated threats and vulnerabilities for all stakeholders, and especially for children. The increasing presence of robotics, automated systems, and AI makes software more and more pervasive at all levels and for all ages. This has ethical and social implications for software engineers and users, especially for a particularly vulnerable category of users like children [5]. In the last few years, we have witnessed a series of problems generated in the digital ecosystem populated by software and children. Children can fall victim to cybersecurity threats like social engineering, cyber bullying, hacking, viruses, and damaging malware, cyber stalking, etc. through search
We observe that the community is producing new software for children to address the problems generated by software. A number of different process and product qualities have been identified as relevant for SE practice and research and a well-being. It is therefore necessary to build a comprehensive quality model for software development when children without considering the problems that the new software will produce. For example, [2] reports about development and evaluation of an exergame based on a shooting game, to improve physical well-being without considering how other qualities (for example mental well-being, or privacy) will be impacted by this new game. This is a classical trade-off in software engineering: when optimizing one quality attribute, for example performance, one needs to be careful not to compromise other qualities, like for example readability and maintainability.

The final research objective of the line of research of our paper is the development of new knowledge which will enable to recognize children as competent stakeholders in Software Engineering.

Existing quality models, e.g., [10] already deal with some of the qualities that are important for children, e.g., security. However, it is not straightforward to figure out whether and to what extent they also deal with qualities like creativity or well-being. It is therefore necessary to build a comprehensive quality model for software development when children are stakeholders. This quality model should be used for several purposes: (1) assess the overall quality of the final software product; (2) assess the quality of the various artifacts produced during software development; (3) allow software stakeholders to make informed decisions about the inevitable trade-offs between all of the relevant qualities during the development of a software product for children; (4) allocate resources in an effective way to reach quality objectives with the available budget.

In this paper, we introduce an initial set of qualities that are relevant to children as Stakeholders in Software Engineering. The main qualities that we propose are: Security, Well-being, Fun, and Creativity. We also provide a preliminary set of guidelines for researchers and practitioners that can help them understand the complex interrelations between Software Engineering and children. Starting from the qualities and the guidelines, researchers can design empirical investigations to obtain deeper insights into the phenomenon and propose new software engineering knowledge specific for this type of stakeholders. Practitioners can use the provided knowledge to better understand children as stakeholders of their software products.

The remainder of this paper is organized as follows. Section 2 presents the relevant background on software quality and quality models. In Section 3 we propose a set of qualities that form a preliminary software quality model when children are primary stakeholders. In Section 4 we propose preliminary guidelines for research and practice. Section 5 provides conclusions and an outline for further work.

2 Software Quality Models

A number of different process and product qualities have been identified as relevant for SE practice and research and a large number of measures have been proposed in the literature for their assessment. Qualities are traditionally divided into internal qualities, such as software size, structural complexity, cohesion, and coupling, and external qualities, such as reliability, usability, and performance [11]. Internal software qualities refer to a software product or process per se. External software qualities refer to a software product or process and to its users/stakeholders. For instance, the size of some software product depends only on the product itself, while its reliability depends on the product itself and the way the product is used.

The distinction between internal and external qualities has practical consequences. Internal qualities have no practical interest per se, while external qualities are the relevant ones from a practical point of view. The number of lines of code
of a software product is simply a statistic, while an assessment of its reliability (e.g., how often it fails) is useful to
developers and users/stakeholders.

However, this is not to say that internal measures are useless. An internal measure has practical value if a model exists
that relates it to an external quality, i.e., if a model exists that can be used to quantify/estimate/predict an external quality
of practical interest [12]. For instance, the number of lines of code is an useful size measure because it is used in several
models for various external qualities, such as reliability, fault-proneness, and reusability.

Software quality models (e.g., those of the SQUARE 25000 series [10]) provide an organized view of a number of
qualities that are believed to be important in the evaluation of software products (and processes). Quality models are
usually general-purpose, in that their objective is to take into account the needs and goals of many and diverse software
users and developers. However, to be practically used, quality models need to be “instantiated” for specific sectors, or
companies, or even projects.

The fact that it was promoted from being a subcharacteristic of functionality in the ISO/IEC 9126-1:2001 standard to
being a full-fledged characteristic in the ISO/IEC 25010:2011 standard shows that Security has become a fundamental
quality for all types of software over the years. Security has five subcharacteristics in the ISO/IEC 25010:2011
standard: 1) confidentiality, i.e., allowing only authorized actors to access data; 2) integrity of software or its data;
3) non-repudiation, i.e., proof of the occurrence of actions or events that have taken place; 4) accountability, e.g.,
traceability of actions, such as transactions; 5) authenticity, i.e., identifiability of the actors interacting with software.

The ISO/IEC 25010:2011 standard also includes a “Quality in Use” model, which includes five characteristics, which
are about how a software product interacts with its stakeholders, namely, 1) Effectiveness, 2) Efficiency, 3) Satisfaction,
4) Freedom from Risk, and 5) Context Coverage. Satisfaction is refined into Usefulness, Trust, Pleasure, and Comfort.
Freedom from Risk encompasses: Economic Risk Mitigation, Health and Safety Risk Mitigation, and Environmental
Risk Mitigation. Subcharacteristic Health and Safety Risk Mitigation is the one that is most related to safety, but it is
quite generic, in that it is related to potential risk to people in the context of use. We can envision physical and mental
risks related to the use of software.

To the best of our knowledge, no quality models have been proposed or specifically tailored for software for children,
which also balance security, the various dimensions of well-being, fun and creativity.

3 Relevant Product Qualities for Children

It is therefore necessary to build a comprehensive quality model for software development when children are stakeholders.

To this end, in addition to being functionally correct, software products must have adequate levels of a number of
qualities that are specifically relevant for children.

It is certainly too early to identify the quality levels (i.e., the thresholds and constraints) that need to be satisfied by
software products for children. However, as a necessary preliminary step, we need to identify the qualities themselves
that are of interest when children are stakeholders.

Quality models were generally introduced in such a way that they could be customized for specific application domains,
for specific users, and for specific goals and needs. However, they were all probably conceived with grown-ups as
stakeholders, and there is no indication that children were included in the set of stakeholders even as an afterthought.
However, given the ever-increasing pervasiveness of software, children are a set of stakeholders that is becoming more
and more important, since software is already affecting children’s lives and will affect them more and more in the years
to come.

We here propose a preliminary set of qualities that are specifically relevant for children, in several classes of applications,
both those explicitly developed for children (e.g., games, etc.) and those developed for the general users (e.g., social
media, etc.), but with children as stakeholders. Some qualities have already been addressed in existing quality models,
but others may be missing or they may not have received sufficient emphasis.

The relation between the software and the child is bidirectional. On the one hand, it is important that the software
exhibit some specified characteristics, but on the other hand is important that the child be empowered with knowledge
necessary to interact with the software so that this characteristic is achieved. For example, for security, on one hand, the
software must be designed and developed so that it does not have security traps. On the other hand, each child must be
empowered with knowledge and awareness about security. The same holds for fun, creativity, and well-being.
3.1 Security

Security is an important characteristic of all software products and gets even more importance when it comes to software for children.

Ensuring secure interaction between children and a software system entails several different sub-challenges. The two most important sub-characteristics are:

- **Cybersecurity** is related to all those threats that may affect teenagers and countermeasures to support teens and their parents and the awareness that teenagers have on the various cybersecurity threats. For example, [6] reports an investigation about teenagers and cybersecurity awareness. A mobile app called CyberAware, destined to cybersecurity education and awareness is reported in [13].

- **Privacy** is related to how to ensure that private information about the children is not made public. Privacy is a characteristic of the software system, that has to be carefully addressed by the software engineers. How to deal with personal information and how to share online, is a skill that children and teenagers have to acquire. [14] reports about the role of parents of influencing children’s willingness to disclose information online.

In this respect, education plays a fundamental role. It is of paramount importance to ensure that children are fully aware of the importance of protecting public data (cybersecurity) and own data (privacy).

The ISO/IEC 25010:2011 standard's sub-characteristic that is most closely related to the above issues is Confidentiality.

3.2 Well-being

Well-being has physical, mental, and social aspects that need to be identified and addressed, as follows.

- **Physical** well-being is addressed for example by the studies about exergames which show how children who suffer from game addiction and obesity [8] may become physically active [2].

  In [15], the authors have studied how healthcare games and applications for toddlers who suffer from respiratory issues. Physical well-being can also be related to safety, like for example, addressing the question of how to ensure that cyber physical systems (like robots, cars, and even digital toys) do not physically harm children safety.
Concerning the mental dimension, [16] reports about how to develop software for motivating adolescents with Intellectual Disabilities to become active.

We define social well-being as the ability to establish and maintain healthy relations to other people. [17] introduces a digital story tool that facilitates the process of connecting human beings and increase empathy as a function of their relation.

There is a SQUARE 25010 subcategory of the Satisfaction characteristic of Quality in Use called "comfort": degree to which the user is satisfied with physical comfort.

### 3.3 Fun

One of the main qualities of software for children is that it should be fun. We define “fun” as the degree to which children enjoy interacting with a software product. Fun can be divided into two main subcharacteristics:

- **Digital Entertainment** is mainly associated with teenagers playing video games online. The interactivity of the medium allows a player to choose settings or the unfolding of a narrative, to participate in the narrative, pursue goals, accept challenges, and experience. The study of the relation between software and children has been dominated by computer games research [18].

- **Gamification** is defined “As a way to use game elements to learn” [19]. Gamification uses game-like features including points and various levels in a way that is not meant to be mere entertainment, but to provide solutions to problems and/or to provide training, practice, and interactions that are engaging while utilizing real-world objects” [20]. Gamification has been defined as a process of enhancing services with (motivational) affordances in order to invoke gameful experiences and further behavioral outcomes. The role of gamification in general software is to add a layer that provides the same psychological experiences as games do.

Since the invention of the digital computer, games have been developed for education in various subjects, like mathematics and foreign languages, by adding a layer of gamification to subject learning, and according to [21], educational games were already popular in elementary and secondary schools in the 70’s. Key influences on the successful use of games to support struggling readers (repetition, feedback, motivation, self-efficacy, parental beliefs) are reported in [1].

Overall, Fun can be seen as related to the Pleasure subcategory of the Satisfaction characteristic of Quality in Use, which also includes the pleasure to use a product to satisfy such as acquiring new knowledge and skills.

### 3.4 Creativity

Digital creativity for children is characterized by creativity support tools and activity designs to assist users engaged in creative work. Examples of creativity measures can be found in [22].

Digital creativity is defined as the creativity manifested in all forms that are driven by digital technologies. Digital creativity can be divided into two subcharacteristics.

- **Creativity for Storytelling**. Digital storytelling tools enable children to develop multimedia stories. As observed by [23], digital storytelling creativity cannot be achieved only by digital device to support the creative process. The software has to be introduced into already existing practices, including the interaction between the child, the teachers, and educational processes.

- **Creativity for Programming**. Since the public launch in May 2007, the Scratch Web site functions as a platform and online community for digital creativity for children, with people sharing, discussing, and remixing one another’s coding projects [4]. Paper [24] explores digital creativity for children and proposes activities that combine art and programming for children.

### 4 Guidelines

We now provide two sets of preliminary guidelines, one for developers (in Section 4.1) and the other for researchers (in Section 4.2).

Common to both research and development is attention to Ethical issues. When developing for children and with children and when researching children as subjects, parents or guardians must grant practitioners and researchers consent to collect and store data. Procedures must be established in accordance with the national authorities for data. When health data are collected, one needs to be even more careful and requests for extra permissions must be
addressed to health authorities. In general, data have to be anonymized and there must exist a precise plan for when
to delete the data after the analysis. Special attention has to be given to ethical issues when children are subjects of
empirical investigations for software development. More refined guidelines must be defined specifically addressing the
involvement of children, similarly to existing guidelines for using university students as subjects in SE research while
balancing research and educational goals [25].

The EU General Data Protection Regulation (GDPR) brought new rights for European residents to have control over
their online personal data. In addition, online data controllers and processors must also take new steps for ensuring
personal data is secured. GDPR[1] devotes one of its 178 recitals (Recital 38 Special protection of children’s personal
data). In the United States, Children’s Online Privacy Protection Rule (“COPPA”) [2] imposes certain requirements on
operators of websites or online services directed to children under 13 years of age, and on operators of other websites or
online services that have actual knowledge that they are collecting personal information online from a child under 13
years of age.

4.1 Guidelines for Development

Based on previous studies carried out about single qualities, like well-being [16] [15], we propose a preliminary set of
guidelines that we outline next.

1. The child and the caregivers should be included as much as possible in the software development process,
including testing. It is not uncommon nowadays that children are invited to universities and to industries to
participate in coding workshops. The ideas developed by the children should be incorporated as much as
possible into the software developed by the companies, especially when the companies develop software for
children.

2. Each of the qualities (and subqualities) should be considered in each phase of the software development
process. If a quality is regarded as not to be of primary importance for a specific software development
project, the software development team should discuss and document why it is not important. Consider for
example fun. It cannot be intuitive to consider fun when developing a system for safety, but studies, see for
example [26], reveal the importance of understanding and measuring fun in software systems that are devoted
to children, which should be fun to use.

4.2 Guidelines for Research

Software engineering is a multi-disciplinary field, crossing many social and technological boundaries. Software
engineering processes are studied by interdisciplinary efforts that combine technical, business, and social perspectives
[27].

Thus, research should be carried out in the context of a general research question that should guide future research in
Software Engineering with children:

• How can Software Engineering knowledge be extended to incorporate knowledge about children as stakehold-
ers?

This general question can be refined in several ways. For instance, if the focus in on software development, a relevant
research question may be

• How to design processes for involving children in Software Engineering development?

As an example, when it comes to software quality, this general question can be refined as:

• What are the relevant qualities of software aimed at children?

We now introduce a few guidelines with the long term aim to develop validated interdisciplinary knowledge about
software quality and children to help answer these research questions (and other related ones).

1. The building of software, whether especially conceived for children or not, must be studied from the point of
view of various stakeholders, such as:

   • children of various ages, skills, and different social and cultural contexts and their caregivers.

[1]https://gdpr-info.eu/
[2]https://www.ftc.gov/enforcement/rules/rulemaking-regulatory-reform-proceedings/childrens-online-privacy-protection-rule
• software engineers who work in software projects that develop software for children.
• software engineers who work in software projects that develop software for all, since, as observed before, children use both specific software and software made for general users.

2. Researchers must be aware of the fact that technical aspects, although necessary, represent only a part of the set of problems that need to be addressed. To understand processes that develop and evolve software systems with children as stakeholders, researchers need to investigate tools and also the social and cognitive processes surrounding them. Research must draw from several different sources and disciplines.

3. Research in this field cannot be purely theoretical or speculative, but it must be carried out via empirical studies. It will be necessary to carry out systematic collections and analyses of empirical data to develop validated knowledge about why and how organizations, teams, and individual software engineers develop software [28] when children are, or should be considered, relevant stakeholders.

4. Data collection should be carried out for specific goals and in the framework of a quality model like the one we proposed in Section 3. For each quality, carefully designed templates should be used to gather information from each stakeholder about:
   • characteristics of the software under development;
   • characteristics of the software process in use, like agile, extreme programming, etc.;
   • the intention of children to participate in Software Engineering activities;
   • the intention of software engineers to integrate children in the Software Engineering activities;
   • relations between qualities and software development phases (Like for example, "in which phase do you work with mental well-being issues?");
   • the reciprocal relations between the network of qualities and their sub qualities
   • the relative importance of the qualities, like fun can be perceived as more important by small children, than by adolescents, or software developers.

   It will be important to translate these questions into a language that is understandable for children, see for example [26] for tools to elicit information from young children. Study [15] reports about data collection about the interaction of toddlers and their care givers with researchers and medical personnel. They have used Affinity diagram to structure the elicited knowledge.

5. More generally, it will be important to define what type of Software Engineering knowledge and education children need to be able to effectively participate in Software Engineering processes.

5 Conclusions and Future Work

We have proposed a model that puts children goals and well-being as an integral part of the software engineering processes, so that the children who use software systems will be offered new possibilities to influence the future of software systems and they will be made aware of threads that can be caused by software systems.

There is no common definition about how to characterize an individual as a child, given her age. Age-related development periods and examples of defined intervals include (according to [29]): newborn (ages 0–4 weeks); infant (ages 4 weeks – 1 year); toddler (ages 12 months-24 months); preschooler (ages 2–5 years); school-aged child (ages 6–12 years); adolescent (ages 13–19). In this work, we have studied children from the perspective of their relation to technology and we have presented related work and background that spans from research about toddlers and technology, like in [30] to research with adolescents, like in [16]. A limitation of our work is that we have not gone in depth into the different age categories and this distinction by age has to be addressed by further work.

We have reviewed studies devoted to understand single qualities, like creativity and guidelines to develop for one quality, but the qualities and the guidelines have not been evaluated in its wholeness yet. The proposed characteristics and sub-characteristics have to be validated by setting up systematic investigations of the literature and of the practice. We have proposed a road map to set up empirical investigations to grasp the perspective of the different stakeholders, including software engineers, children, care givers. The proposed road map (four main qualities and guidelines for practice and research) will enable researchers to set up the empirical investigations interventions in SE with children.

There is consensus in the SE literature about the distinction between qualities and the respective activities to achieve the given quality, like "maintenance" is an activity, but "maintainability" is the corresponding quality. On the contrary, in existing literature about software for children, Gamification is used for both the quality of the software and the activity of gamifying the software. The same applies to creativity. Further work will refine our model and propose increased understanding and better definitions of the qualities and the respective activities. We will also explore the relationships between existing quality models and the qualities of interest for children. For instance, while the Confidentiality of
Security in the SQUARE 25010 standard can be somewhat mapped into our preliminary quality model, the role and relevance (if any) of the other subcharacteristics, i.e, integrity, non-repudiation, accountability, and authenticity, still need to be investigated. In general, further work will establish Software Engineering with children as a sub discipline of Software Engineering with a specific terminology, models, techniques, and methods.

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