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# Safety Culture in Digital Fabrication: Professional, Social, and Environmental Responsibilities

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## ABSTRACT

This paper addresses the safety culture as a concept in the context of digital fabrication. The aim of the paper is to provide a basis for the understanding and adoption of safety culture in digital fabrication, makerspaces and fab labs. The paper outlines the concept of safety culture in digital fabrication through three dimensions of safety culture: professional, social, and environmental responsibilities. We propose that these dimensions can act as motivators in adopting a correct safety behavior in the context of digital fabrication education.

## CCS CONCEPTS

• Social and professional topics → Codes of ethics; Sustainability; Cultural characteristics

## KEYWORDS

Digital fabrication, Safety culture, Professional responsibility, Social responsibility, Environmental responsibility, Organizational culture

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## 1 Introduction

Safety is a major issue in many industries such as construction, car and airline, mining, and nuclear energy where the focus is on minimizing the risk of accidents and damages (see e.g., [1]). Moreover, safety is also related to well-being in healthcare and

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professional work (see [2]), and social and environmental responsibility, for example, in production settings when a product development can have long-term impact on society and environment [3]. After the Chernobyl accident, the concept of safety culture was introduced in 1991 to highlight the organizational impact on safety consciousness in addition to the traditional organizational safety management [4,5]. Though the issue of safety culture has gained attention in industry [6], there are multiple views on safety culture concept and variations on how it is implemented in practice depending on the context (see e.g., [2,4,5]).

In this paper, we address the safety culture concept in the context of digital fabrication with the aim to provide a basis for further research and discussion to increase the understanding and adoption of the safety culture in digital fabrication. The paper contributes to the outlining of the concept of safety culture in digital fabrication and to the theoretical understanding of safety culture in general by highlighting three dimensions that shape safety behavior: professional, social, and environmental responsibilities. Currently there is no research reported on the topic of safety culture in digital fabrication and the theoretical discourse on safety culture in general is very limited and requires further clarifications [4]. The contribution is relevant in the context of digital fabrication education in that the three proposed dimensions of safety culture, professional, social, and environmental can be regarded and employed as motivators in adopting a correct safety behavior by educators and students alike.

Generally, digital fabrication is safer than traditional fabrication techniques [1], however there are concerns with toxicity of the materials and with sustained exposure to harmful substances that result from the use of digital fabrication and rapid prototyping processes that may negatively impact health and environment in short and long run [7-10]. These issues should be dealt with by designing the workspaces using occupational health standards [10]. Moreover, other safety issues can be managed by adequate training, correct use of equipment and personal protection equipment, proper waste management, and adopting adequate chemical hygienic practices in the lab (including regular hand-washing and keeping the space clean).

The challenge in adopting a correct safety behavior lies in the particularities of the organizational context of digital fabrication. It

can be difficult to define and implement a safety culture especially when the organization within which digital fabrication projects develop is open for public or non-professionals such as in makerspaces and fabrication laboratories. In these spaces, makers can come from various professional, social, and cultural backgrounds and their level of involvement in the product design and development varies, as well as their usage patterns and interests regarding the digital fabrication spaces and equipment. Thus, the makers' adoption of a desired organizational safety behavior is not as straightforward as in traditional industrial settings with contractual employment obligations. From the perspective of safety behavior, we propose three dimensions that shed light on understanding how adoption of the target behavior can be influenced. These dimensions are *professional*, *social*, and *environmental responsibilities* and they can act as extrinsic or intrinsic motivators for adopting a safety behavior depending on the individual values and beliefs.

## 2 Safety as Professional Responsibility

A professional in any field follows a regulated set of professional behavioral standards that are embodied in a commonly accepted professional code of conduct [11]. The concept of safety as a professional responsibility integrates the safety awareness and risk management as cultural norms in the organization, and all levels of the professional organization are responsible for improving and maintaining the common safety culture [12]. Accordingly, the safety performance and improvement should be key performance indicators at both organizational and individual level, and the safety issues must be treated with respect [12]. In this concept, the safety consciousness and concerns are part of the professionalism, and an integral part of personal professional responsibility towards oneself, towards the colleagues and other stakeholders, and towards the society in general [12]. Aviation, space, and nuclear industries are examples of professional fields, where defining, following, and improving the safety procedures form the basis of professional practice and where safety awareness is a cultural norm and a form of professional empowerment.

In digital fabrication spaces, safety as professional responsibility should be incorporated into the general ideal of a professional and qualified 'maker'. The aim is to have makers of digital fabrication to follow the safety procedures as part of their professional conduct in the lab (e.g., to be aware, concerned, and responsible of safety issues). To reach this aim, different approaches can be implemented. There should be role models and opinion leaders promoting safety in makerspaces and fab labs as "the right thing to do". There should be an implicit and explicit professional code of conduct in the makerspaces and fab labs including safety consciousness and issues. This professional code of conduct should be enforced by staff and peers. Gaining the formal and informal status of a qualified "professional maker" should also depend on the knowledge and adherence of safety in digital fabrication. Makers' professional responsibility in digital fabrication can be attained by contributing to setting, updating, and

following the adherence of safety rules in the makerspace or fab lab.

## 2 Safety as Social Responsibility

Organizational social responsibility has been defined as the voluntary integration of social concerns and issues into the organizational decision-making [3]. This voluntary adherence to social concerns can occur due to the prospects of using the social responsibility as a competitive advantage in marketing, genuine concerns of the societal impact of organizational operations, or fears of governmental regulations if there is no effective self-regulation. These social concerns include general working conditions, the impact of work on the long-term health of the stakeholders and stakeholder empowerment [3], and sustainability concerns such as monitoring and displaying the energy consumption [8].

In digital fabrication spaces, the social dimension of safety includes ensuring that the digital fabrication space itself is free of hazards, and that the well-being, long-term health, safety, and empowerment of makers and staff are carefully considered (see e.g., [3]). This means that the operation of machines and materials is done minimizing the risk of hazards and impact on short-term or long-term safety and health of staff and makers. The staff and the makers as stakeholders should be empowered to influence and develop the safety culture including practices and artefacts in the makerspace or fab lab. Integrating social responsibility into digital fabrication would mean to participate in co-creation activities for increasing awareness, concern, and responsibility towards safety issues. Other activities to adhere to safety practices as social responsibility can involve makers to contribute at designing for safety, at monitoring and keeping to a minimum the levels of harmful particles, gases, substances, and noise (see e.g., from construction industry [1]).

## 3 Safety as Environmental Responsibility

Organizational environmental responsibility has been defined as the voluntary integration of environmental thinking into the organizational decision-making [3]. The voluntary integration of ecological thinking can be driven by various factors such as: using environmental responsibility as a marketing strategy, genuine concerns of the environment, or fears of governmental intervention by regulations on waste and pollution if the industry does not self-regulate itself. Environmental responsibility manifests in organizations in terms of safe disposal of hazardous waste [9], minimizing the energy consumption and monitoring it [3,8], managing the impact of the process on climate change and environment [3].

In digital fabrication, safety as environmental responsibility includes optimizing the use of materials, consumables and energy, preferring renewable materials, minimizing the waste, recycling the waste when possible, and disposing the hazardous waste safely. Also providing and adopting means to collaborate and participate in raising awareness, concern, and responsibility on how digital

fabrication process impact environment and climate change can contribute to raising safety culture through environment responsibility.

## 4 Discussion and Conclusion

Organizational cultures are typically built upon shared beliefs and values [2,6,13,14]. However, in any organization there are multiple sub-cultures that are at times competing and conflicting (see [6,14]). As such, safety culture can compete with professional culture and operational culture within an organization which are not always focusing on human values such as fulfilling the users' and society's needs, but on economic values such as minimizing costs (see [14]). However, the reconciliation of cultural conflicts can be achieved through the reorientation of values [14].

In this paper, we identified three types of responsibilities, professional, social, and environmental that can shape the individual and organizational safety behavior. These rely on specific values towards performance, users and society, and environment, respectively. We propose that these types of responsibilities and values can be communicated to makers to create extrinsic and intrinsic motivations of adopting the target safety behavior. Participatory and collaborative approaches are recommended in the literature as providing effective results in raising awareness, concern, and responsibility (see e.g., [4,15,16]). For future work, we suggest investigating how these values and responsibilities manifest in practice and how they can be influenced with participatory and collaborative approaches.

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