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DESIGN FOR GENDER – A NEW PERSPECTIVE FOR THE DEVELOPMENT OF MACHINES

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1. Introduction

A new product could have success on the market if it has a high innovation level, fulfils the requirements of the users and comes timely on the market. The requirements of the users gained more and more importance, but to acquire these in a comprehensive mode is not always easy to achieve. That is why the design process is often influenced by the experience of designers, which bring their own ideas about the needs of the customers into the development process.

The increasing presence of women in all life domains led to question the differences and inequalities between women and men, and required measures in order to achieve equal opportunities for all. Beyond the social domain, where the necessity to consider the gender factor was obvious, women's requirements were considered in the past only for the design of consumer goods such as household appliances. Today, advanced researches in many sectors like medicine, IT, residential building and traffic planning are considering the role of gender differences.

In the industrial sector of tooling and machinery this subject is marginally attended. Differences between genders are considered only in the standards for ergonomic design and usually the design efforts are conducted into a presupposed gender neutral design of new machines, because of the difficulty to predict who will operate it. Furthermore, a specific design for women of industrial machines is considered a high risk. Nevertheless, the increasing participation of women also in the industrial domain generates a diversification of requirements for tooling and machinery. Taking into account gender specific requirements during product design will become imperative and enterprises have to cope with such requirements from their customers, in order to keep their position on the market.

As we know, in most European countries design people from the industrial sector are predominantly male and consequently, the requirements for a new product are defined by men during the design process, even if more women than men will operate the designed machine. More than that, if the company decides to design machines for women they often use stereotypes about the behaviour or requirements of women regarding these machines. Usually design people have their own experience and conception about how a machine should work, what functions should be fulfilled by it and how it should be operated, and are tempted to design according to their own preferences and personal experience [Rommes 2012]. This experience represents on the one side a huge advantage but on the other side the real requirements of the customer could be omitted involuntarily.

In order to identify and define more precisely gender specific requirements of the users the actual research project was initiated, where the existence of gender differences in operating the laser cutting and engraving machines will be investigated by means of different methods like questionnaire, discussion groups, participatory design. The information gained by these investigations should offer the basis for a critical design for gender. The laser cutting machines have been selected considering the relative high number of female operators.

Compared with consumer goods like household appliances, cars, IT-features, where a high emotional relationship could be identified, the key feature in the actual project is represented by a supposed low emotional relationship between the operator and the laser cutting and engraving machines, which should mainly fulfil a technical function. That's why the harmonization of these two features represents the challenge of this project.
The project aims to set the basis for gender sensitive product development in the industrial sector of tooling machines with emphasis on design for gender of human machine interfaces.
Based on the investigations a new approach for the design of industrial machines will be presented in this paper. We will show how gender should be understood in engineering design and how it could be brought into engineering design.

2. How to understand gender in engineering design?

To discuss gender specific demands for the definition of the human-machine interface it is important to ask first, what do we understand about the meaning of gender in the production of technology. To generate a user specific profile of machines it is necessary to reflect on the gender of the users. This is not because on could determine generally specific gendered needs, it is because gender is meaningful in our society in many ways. To understand this, we have to reflect on the history of the research on gender and technology.
It is widely agreed that as historical moment for technoscience studies which view women and technology not anymore in an opposite position, the ‚Manifesto for Cyborgs' by Donna Haraway [Haraway 1986] counts as the key publication: The figure of the cyborg (cybernetic organism) is discussed in this programmatic text at the same time as border transcending everyday – possibly life threatening – experience as well as a conscious, responsible and joyous blurring of dichotomies – nature/culture, female/male, animal/human, object/subject. This confusion of boundaries is joyous because these dichotomies are analyzed as power related and as the basis of current social hierarchies in the way that the latter part is not only regarded as more valuable than the former but also in charge to govern it. In a society in which technology plays an important role, it is considered therefore important for all members independent of their gender to become technically competent. Moreover, it is necessary that all members take part in the responsible shaping of technological developments. Further, all members should become able to judge for whom a technical development or product is helpful and from whom not. A further milestone in the research on gender and technology is the deconstruction of technology as a masculine culture to be a powerful cultural myth [Wajcman 1991]. Instead, technology can be analyzed as a social process open for change. Moreover, as a social construction, technology can be understood as form of social knowledge, social practices and social products. This means that technical products are designed, developed, produced and distributed by persons in social contexts. In these processes images of the potential producer, user, and consumer are integrated, especially on their gender and culture. In this sense, gender is constructed or shaped by diverse technological developments and technological developments can be understood as shaped by gender relations, exactly because it is taking place in social relations.
Studying the development of the microwave oven, it was discovered, that within the technological development, different and possibly contradictory processes of gendering take place – of apparatuses, of areas of production, of persons and products [Cockburn 1993]. Within these processes the gender identity can be questioned and defined in a new way. The microwave technology, for example, was first considered as an innovative new technology - and therefore masculine. Later, in the sale process, it was aligned with household technology which was considered as feminine. In the same way, persons involved with the design and production of new technologies, can work in fields which do not conform to ascribed norms for gender identities. They can be confronted therefore on the social level and accused to counteract to their ascribed gender identities, but on an individual level they are able to widen their area of agency. This points to a fundamental underdetermination of the category of gender and therefore to a broad field for potential experimentation.
This way of studying gender in technological processes and productions is informed by a theory of gender that does not presuppose gender as a given binary dichotomy. This means that we often take for granted that persons exist as women and men and we believe to know which tasks they should or

could take on, which ideas, abilities, rights and duties they would have. In contrast, gender studies show, that it is historically open to change how persons are defined as a certain gender [Scott 1999]. On top of that, it is not ‚nature' but social norms, education, traditions and habits, media and law as well as everyday individual interaction to determine the identity and agency of persons as women and men [West 1991], [Lorber 1994] and [Butler 2004].
As a result, the production of technology shapes our culture which is structured by a gendered social order. Therefore, it is the way in which technological developments take place and the way technology is designed and produced, including each person involved in the process, what is open to change.
Consequently, the human-machine-interface is a dynamic process of materialization, in which meanings can change. This means, although newly developed technological objects need to be recognized in their envisioned cultural environment, they always carry the possibility to lead beyond the replication of accredited norms. Here, machines are not understood as finite objects: "*Rather than fixed objects that prescribe their use, artifacts – particularly computationally based devices – comprise a medium or starting place elaborated in use.*" [Suchman 2007: p. 278]. In the same way, persons who are involved in human-machine-relations, should not be understood as autonomous subjects: "*The person figured here is not an autonomous, rational actor but an unfolding, shifting biography of culturally and materially specific experiences, relations, and possibilities inflected by each next encounter – including the most normative and familiar – in uniquely particular ways.*" [Suchman 2007: p. 281]. This means, gendered subjects and objects can experience in interaction new practices and new meanings of them, including their gendered meaning.
On the practical level, this implies the following consequences for the research in design for gender: First, it is important to take into account the perspective of technology development, i.e. persons involved in designing. It can be interesting to investigate, if a certain "I-methodology" shapes in a more or less unconscious way the designing process [Alhutter 2008]. This means that the designer might generalize her or his own individual competences and preferences for the shape or function of a specific technological product. This generalization leads to a too narrow and possibly wrong design in that it ignores the diversity of potential users. Given the present gender relations in the designing of technology, meaning that there exists an overwhelming domination of those jobs by men, this might lead in a culture which is still shaped by dichotomous gender norms and identities to a construction of technology which might neglect the competences and preferences of women. Second, when the potential users are taken into account in the designing process, ideas on their competences and preferences are often shaped by gender stereotypes. Therefore, it seems to be important to investigate the preferences and competences of potential users of a technology in the design process more systematically.
Studies in "participatory design" show that it is possible to involve present and potential users in the design process using questionnaires and other methods of investigation. To get some valuable information it seems to be helpful to combine diverse methods, since given that our culture is still structured by implicit and explicit gender stereotypes and gender hierarchies, persons are neither always completely conscious about their preferences and competences, nor is it always possible to verbalize them spontaneously. A combination of "saying, doing, making and performing" [Joost 2010], which includes self-observation, idea workshops, prototyping, role plays and focus group discussions seems to be promising in the research on participatory design. As a consequence, such a combination seems to be especially interesting for a critical design which takes given gender relations into account and at the same time works to overcome the gender stereotypes and gender hierarchies which are fundamental to it.

3. How to bring gender into engineering design?

3.1 Design for X

Machines and technologies are developed in a complex design process, where specialized teams come in interaction with each other in order to perform this creative process (Figure 1). In this linked process gender considerations should find their application in order to obtain a higher performance in

the design process, which should lead to products or machines, which better fulfils the requirements of users.
In this complex process various design methods are applied like Design for X (DFX), which is an emerging philosophy that helps to improve the decisions during design by simultaneously examining the interrelationship between design processes and their results (Figure 1).
It is an umbrella term for a variety of effective design techniques during product development, including Design for Assembly, Design for Environment, Design for Manufacturing or Design for Cost among others. For example Design for Control - being a central aspect for mechatronic systems – is a target which can easily be included in this concept. To minimize the number of iterations during the development process, it is necessary e.g. for the mechanical engineer to consider the possibilities of automatic control when dimensioning the plant. This results in a modification of the traditional design process.

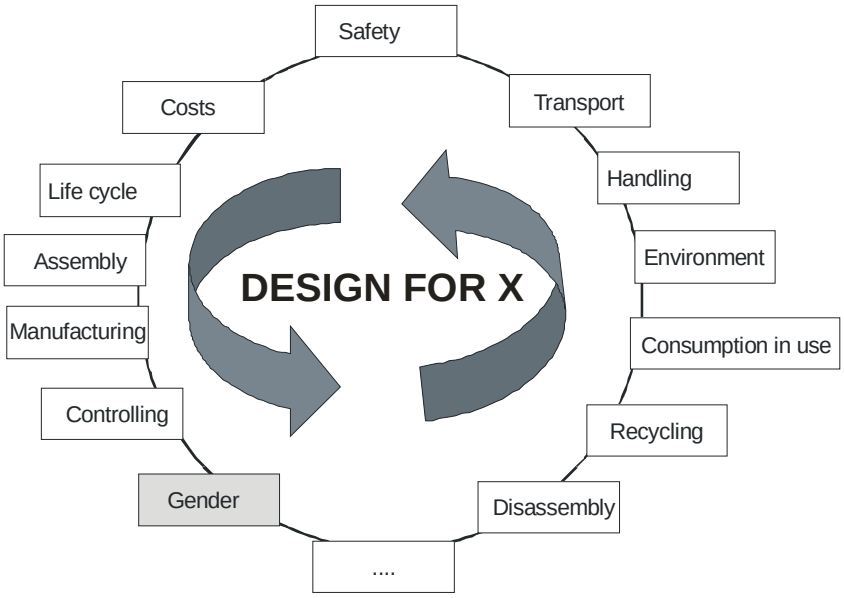

Figure 1. Design for X

The (weighted) consideration of the main criteria for establishing the main characteristics helps the design engineers to make the designs and review their work in complete and efficient manner. In the literature (e.g. [Pahl 2007]) some basic rules are represented, such as instructions for the design of products in form of guidelines. Many of these design guidelines are treated extensively on specialized areas. In this way, developers with a broad technical knowledge have a good basis for product design. In accordance with the definition of DfX, the actual paper brings into discussion the idea of Design for Gender and shows how to address this.
In Engineering Design Research aspects of gender are currently in consideration with focus on the achievement of suitable knowledge to proper handle this challenge. A promising approach to more "gender-sensitive design" is the concept of "doing gender" [West 1991], which emphasizes gender (sex) as a product of performative activities. This direction is established by cross-cultural studies, which recognized, that the social categories of "man" and "woman" are very heterogeneous and that there are very few properties that are shared cross-culturally. Gender is no longer considered as an internal property of a person, as it is the case in former theories of socialization. A working group of UNESCO pointed out that gender is not discrete (woman / man), but that in between some intermediate differentiation must be considered, [Schroeder 2010]. Furthermore, various dimensions of gender in product design have been showed by this group, which should be analysed to make more women friendly tech-products:

1. 1. the value dimension
2. 2. the function/benefit dimension
3. 3. the interaction dimension

4. 4. the aesthetic dimension
5. 5. the communication dimension

An extension of gender aspects of the involvement of the cultural environment is also important. This is enhanced when examination is influenced by demographic consideration [de Vries 2010].
An approach for a design strategy for cookware products with analysing the impact of different cultures was shown by Kalita in [Kalita 2008]. Figure 2 outlines this approach, which can be the basis for Design for Gender.

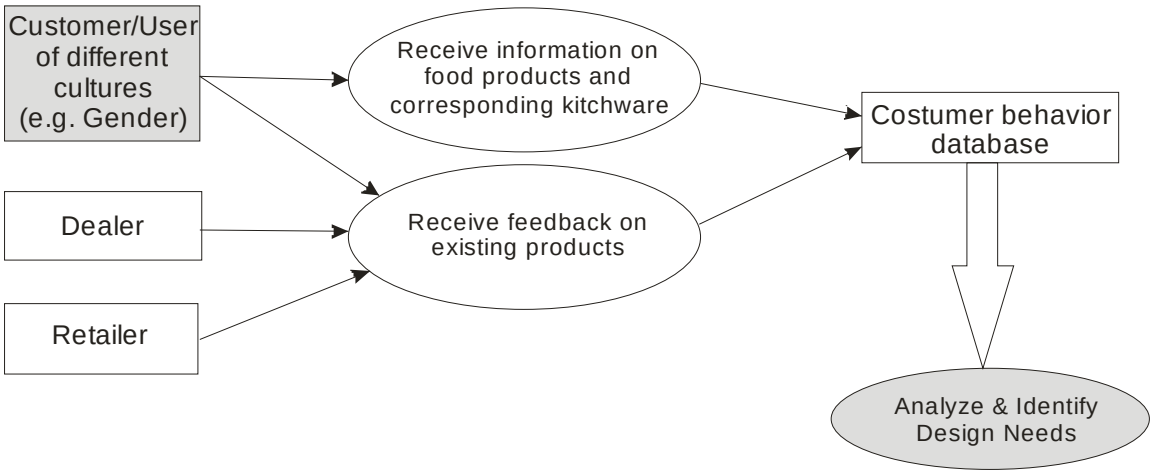

Figure 2. Design strategy for cookware products [Kalita 2008]

3.2 Levels of investigation

So far the importance of gender requirements is accepted, to achieve for investigations could be started on the existing machines. In the actual project investigations were conducted on laser cutting and engraving machines, but how it can be seen the procedure could be applied also on another industrial machines.
To achieve for users requirements a target group has been defined consisting of end-users of the laser cutting/engraving machines. The recruiting of them followed voluntary paying attention to a balanced representation of both gender. Three levels of investigations have been identified considering recommendations from literature like [Bohnsack 2000], [Flick 1995] and the experience of the investigators achieved in other case studies. Additionally to the investigations conducted with the target group, information about the existence of gender stereotypes in companies by work's scheduling on the investigated machines should be inquired. The existence of gender stereotypes could influence the handling of users and implicit their experience with the machines. This could become important for the interpretation of the statistical data.

6. 1. **First level of investigation.** At this level the investigation is primary conducted by means of a questionnaire. The questionnaire includes parameters such as gender, age, origin and education level. Furthermore technical and ergonomics requirements are considered for predefined interfaces of selected laser cutting and engraving machines like command panel, software and hardware. Operation sequences, labour organization and working environment influences are also evaluated. In order to become relevant information at least thirty operators are investigated. The analysis and interpretation of the answers will be carried out applying statistical methods and coding schemes [Flick 1995] on predefined user groups, considering the gender, ergonomic and technical parameters for each investigated machine. On this way a gender specific requirements profile for each investigated machine can be built, although the method reveals only the direct, conscious and evident problems. In addition to the questionnaire, observing the operators while working should offer supplementary information about user's handling with the investigated machines. Depending on the results of such an analysis, next steps are necessary in order to achieve also for non explicit needs of the users.

7. 2. **Second level of investigation.** On this level another method of investigation is applied, that is discussions in predefined groups, consisting of no more than eight operators. Because the needs and requirements of women are the main target of this project, it is recommended to build gender homogeneous groups, such as a female group and male group, in order to avoid influences on the female users and vice versa on the male users and to offer them an adequate frame for discussions. Discussions in groups should offer the possibility to expose and to analyse in a social environment the estimations and decisions of concerned persons. Very important in this case is to create appropriate conditions for discourse's developing, so that the group gets the possibility to define the topic alone [Bohnsack 2000].
8. 3. **Third level of investigation.** On a third level of investigation prototyping as well as participatory design should be also taken into consideration, [Joost 2010]. The investigations on this level should offer a large overview on the requirements and preferences of the users.

We not intend to discuss the results of our investigations in this paper, so far we are not completely covered all three levels of investigations. With our contribution we like to show in which manner the investigations of gender requirements should/could be done and the gained information should be considered in the design process.

The proposed investigation levels offer to the investigators not only the preferences of women and men reported to the handling with laser cutting machines, but also the diversity within gender groups. The information achieved on the three investigation levels offers an instrument for designers to take into account the real gender requirements and at the same time to overcome gender stereotypes in the design process. Considering this approach we intend to leave the classical way to solve a specific problem, that being technical, ergonomic, etc., consisting from finding a specific solution in order to assure the functionality of the system, machine etc., see Figure 3.

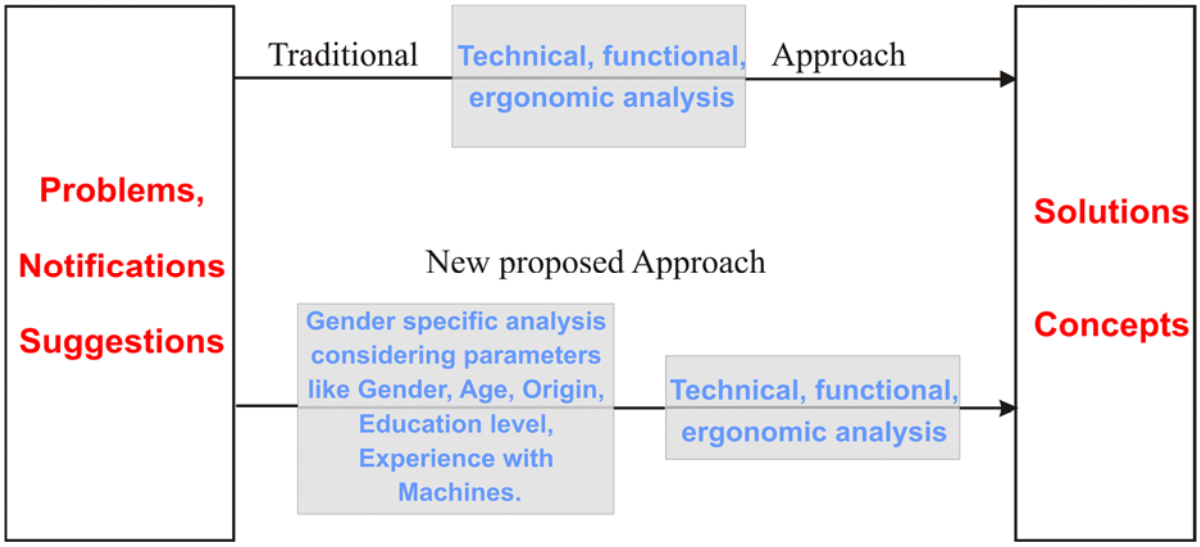

Figure 3. Investigation's ways for a complete solution

In the classical approach the experience of the specialist was the mean and only factor considered to design a machine: the so-called "I-methodology". What we propose is a new approach, where the user's requirements are considered before a decision is taken. On this way the interaction between technology designers and users is present and the design process becomes an open and interactive process.

3.3 Guidelines for Design for Gender

Quality Function Development (QFD) is an overall concept that aims at an enhanced consideration of the customer's voice in every step of the product design process. QFD is a matrix-based approach to improve the customer's perception of the ratio between benefit and cost of a product. Due to the orientation on the voice of the customer, QFD leads to fewer changes in product development projects. Furthermore, the method promotes a high integration of the various highly specialized company

departments during the product development process [DGQ 2001]. The development of the House of Quality (HoQ) data comprises several steps, the results of which are documented in the according fields. So the HoQ aims at "Product Planning", which means to translate the customer wishes and their priorities ("voice of the customer") into a description of the product in a technical, quantifiable manner ("language of the engineer").
Afterwards the classical development/design process can be usually structured into four phases (according [Pahl 2007]):

- Problem Definition:
  Analyzing and defining the needs and requirements of a new product results in a design specification (list of requirements) which has to be updated continuously according to the new information gathered during the development process.
- Conceptual Design:
  Determination of the product's overall function, of its most important sub-functions (main functions) and their interactions lead to a functional structure. For the main functions solution principles, making use of physical, chemical or other effects are established. These solution principles can be combined to one or more basic (principal) solutions for the overall product. The utilization and proper combination of solution principles from different mechatronic disciplines allow for an extended variety and quality of principal solutions.
- Preliminary Design:
  During this step physical modules have to be found being able to realize the above solution principles. This will end up with a modular structure showing the physical main modules of the solution including their interaction and interfaces. Now preliminary mechanical, electrical, electronic and software design of these relevant modules is carried out in order to meet the requirements and optimize the properties and performance of the product.
- Detailed Design:
  All modules of the solution have to be fixed in detail which results in a complete documentation of the product.

Mechatronic systems (e.g. machine tools) consist of components from different disciplines, such as mechanical engineering, electrical engineering, automatic control and information science, each of them contributing its own specific functions to the design of the product. So in a mechatronic design process especially the conceptual design stage is crucial. Here the functional interactions between domain-specific subsystems are determined and have to be investigated carefully therefore. This implies that during the phases of conceptual and preliminary design the designer should be able to quickly and accurately evaluate the system performance due to design changes in the mechanical part as well as in the other parts (electronics, software etc.).
In the new proposed approach gender specific aspects should be considered in all phases of the design processes. Figure 4 shows how gender requirements could be considered into the different phases of the design process. One crucial step in a "New Product Design" is the definition of the list of requirements based on the information obtained at each of the three levels of investigation, which have to be considered at the beginning of the design process.
In "Re-Design" projects in this phase the actual situation and usage of the considered product will be analyzed. Afterwards the required properties of the system (product, machine, component) have to be fixed. Nevertheless in each stage of the design process it should be examined if gender requirements should be considered and how they should be considered. In our opinion in the second stage of the design process the important gender aspects of the Human-machine Interaction should be considered to define the major functions and their structures. A main impact of gender will be established in phase four, where the physical modules of the solution including their interaction and interfaces to the system boundary will be fixed. There the main handling of the machine tool will be realized according to the inputs of the user-specific needs. In the later design phases the Human-Machine-Interface will be fixed, considering the ergonomics of the user in more detail.

One possible method for implementation of the described impacts is the usage of gender-specific check-lists during the design process of the implementation of these rules in a computer-aided design software tool.

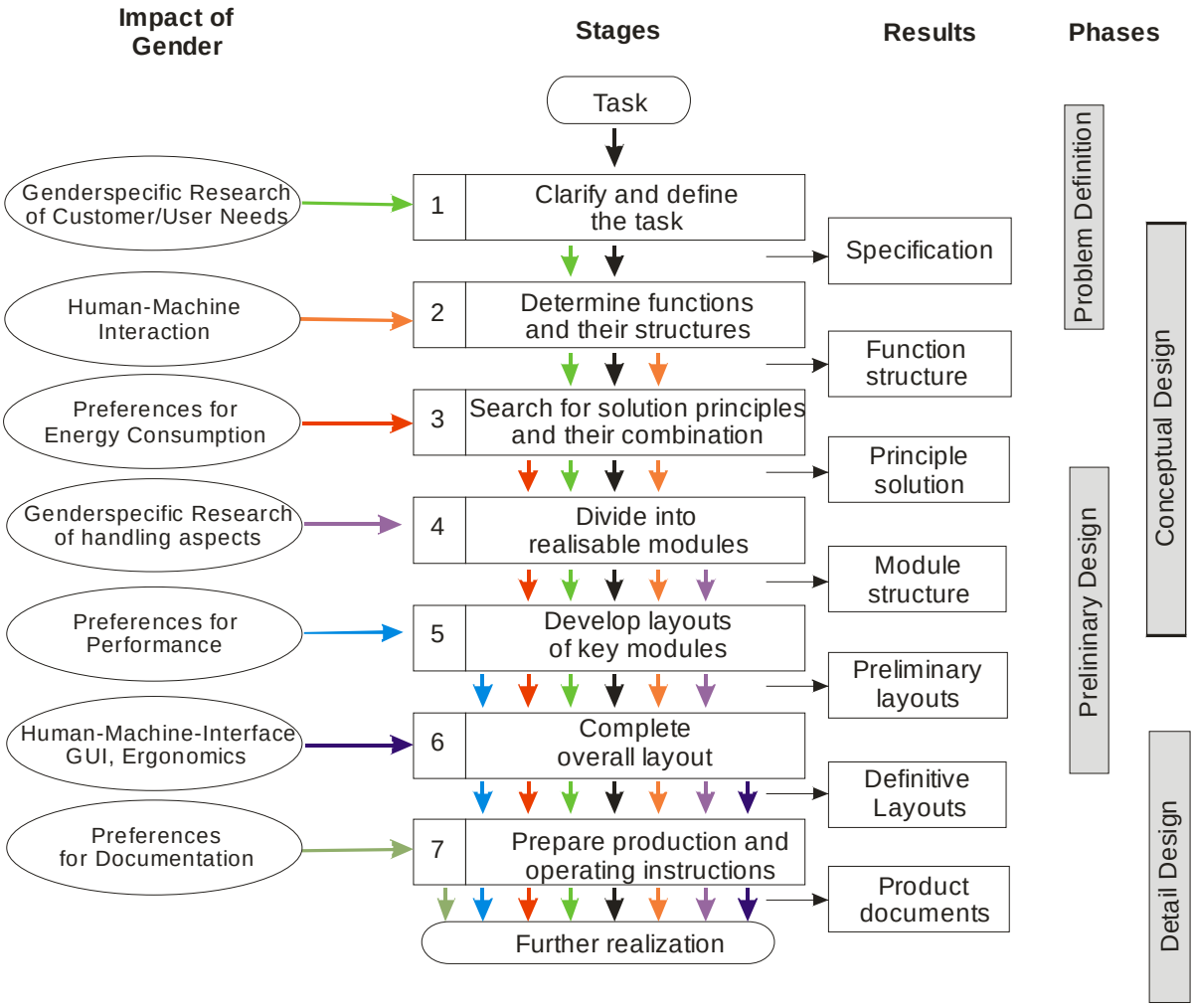

Figure 4. Impact of gender in the design process

4. Conclusion

Systematic studies of women's interests, preferences and requirements will add new dimensions to the process of innovation in machine development, because they have been neglected so far. Producers and designers of machines have not taken into account that women are an important group of users of industrial machine tools in a non-stereotypical way. The scientific confirmation of this hypothesis will have impact on both developers and decision makers and will represent a decisive step towards turning a gender specific approach into a standard into a machine's design. It is important to understand, that such a gender specific approach is not meant to provide stable norms of gender, but rather the insight that gender is contextual and situative. Therefore, women's interests, preferences and requirements cannot be taken for granted once and for all, rather they have to be investigated for each specific machine to be designed and therefore the study of them has to be an integral aspect of every technological development and design process. So, what can be standardized are not differences or specifics of gender needs or preferences, but rather methods how to gain and include knowledge about the interests, preferences and requirements of all genders as potential users. According to the results of these investigations it is possible to define guidelines for "Design for Gender", which can be growing up to a new paradigm in engineering design.

Further investigations will be conducted in the project's frame to asses for the impact of including gender specific aspects on the development and on the quality of the machines and to set the basics for gender critical product development with emphasis on the gender critical design of the human machine interface. The gained knowledge will be used to draft a guide for considering gender specific aspects in the development process of new machines. It is important to evaluate the benefits for the company considering these aspects, nevertheless the outcome will be increased safety and productivity and reduced failures and training costs. Changing or adapting the machines afterwards should be reduced or eliminated.

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