Searching for New Ways to Design Landscape: Experience with Parametric Design in Interaction with Computer-Aided Manufacturing Methods in Landscape Architecture and their Effects on the Design Process

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Abstract: Computer-aided manufacturing processes enable the landscape architect to complete the digital workflow from the idea to the physical prototype or the finished project component, not only as a model, but also as a built project. A conceivable workflow progresses from a first idea for a design solution to a digital sketch, e. g. on a tablet, and then to a CAD drawing or a digital three-dimensional model. This design can then be physically produced using computer-aided manufacturing processes – such as additive or subtractive manufacturing – in order to create the desired model, prototype, or finished project component. The fact that these physical-digital technologies continue to expand and grow suggests that it is also time to take a closer look at the design process. On the basis of a case study, I will examine how the existence of physical-digital technologies can affect the processes followed by designers. This paper discusses both benefits and risks. It deals with a formal aspect of design and must therefore be seen in a broader context of design activity (reflection, perception, thinking, expression). On the basis of the practical case study, it is possible to illustrate the potential of computer-aided manufacturing methods in landscape-architectural design processes and make this potential available through the applied method of analysis.

Keywords: Model, physical-digital, method, tool, design process

1 Background

Landscape architecture is based on the development, communication, and realization of ideas for the designed exterior space. The landscape architect's central task – ideally derived from target-oriented ideas – is to create designs showing a solution for the respective design job.

This process, as the decisive and crucial component of finding a design solution, is influenced by a variety of factors, oscillating between the poles of subjectively personal and objectively pragmatic decisions, experiences, and perception. Inspired by Otl Aicher's insight "We have to move from thinking to doing and learning to think new" (AICHER 1991, 76), I endeavored not only to examine my own design process and the noticeable influence of tools on the results of my work in the field of landscape architecture, but also to look at the effects in a more general manner, providing guidance for designers from other design disciplines throughout their design process.

In this paper, the terms *design tools* and *tools of design* are understood in the sense of the definition given by Gänshirt: "'Design tools' are not tools in the same sense as a hammer or a screwdriver. The term is a metaphor, transferring the image of a hand tool to complex states of affairs" (GÄNSHIRT 2011, 94).

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With regard to the constantly growing range of tools for the design process, it is important that the effects on the designers and the findings resulting from them be examined under prescriptive consideration. The methods guiding the process (such as sketching and modeling) operate simultaneously as carriers of information and tools.

Taking the above-mentioned developments as a starting point, I focus on landscape-architectural design and its process and identify the growing number of computer-aided tools for the development of models and project components. From my point of view, these include above all computer-aided additive and subtractive production methods. This also involves methods for digitizing physical objects, allowing a change in the approach to the design work based on the model. These computer-aided manufacturing methods include

- 3D printing (additive),
- subtractive methods such as CNC milling and water-jet or plasma cutting, and
- the digitization of physical objects using 3D scanners and processing, along with the appropriate software.

The effects of these "design tools" on the landscape-architectural design process have never been empirically investigated. This fact justifies the need to devote attention to the subject in light of the saying "the hammer forges the blacksmith" – especially considering the constantly changing digital possibilities. A number of empirical and non-empirical studies have already been conducted on the theory and method of the landscape-architectural design process. These include, in addition to those cited in this paper, the book *Design-Based Research* (edited by Jürgen Weidinger). The impact of different computer-aided manufacturing and digitalization processes on the work of landscape architects and especially on their design work – such as finding solutions on a model – have yet to be sufficiently investigated. In this context, reference can be made to Barbara Wittmann's observations and contemplations on design tools.

> The portraits of design tools assembled here explore the exteriority of designing, forming, and thinking both thematically and methodically: on the one hand, in relation to the concept of the tool, which is undergoing a critical revision; on the other hand, in relation to the concept of designing as a practice that characterizes and justifies the artist, architect, engineer, and scientist, and in general the future-oriented subject of the modern age (WITTMANN 2018, 1).

In addition, Gänshirt examines general processes during the design process (design cycle). He describes and analyzes the significance of various tools, such as drawing, model, or video. The work of both authors laid the groundwork for the study presented in this paper. Although my approach is based on the understanding and knowledge these authors imparted, I will begin by focusing on (more) formal aspects of the design.

2 Question

In principle, this paper deals with the thesis of creating, or facilitating the creation of, new forms through a "changing approach" to the digital and analog model with the help of computer-aided design methods in landscape architecture. In this context, the following question arises:

What influence do computer-aided manufacturing methods, combined with digital practices, have on design?

This paper is part of a series of further studies concerning the influence of physical-digital practices on landscape-architectural design.

The term "changed approach" in reference to the model as a design method specifically describes the emerging or already existing orientation of model making in landscape architecture. The creation, or the utilization and processing for design purposes, turns away from its analog counterpart in the context of the design and decision-making process, moving instead towards the completion of the digital workflow (Fig. 1).

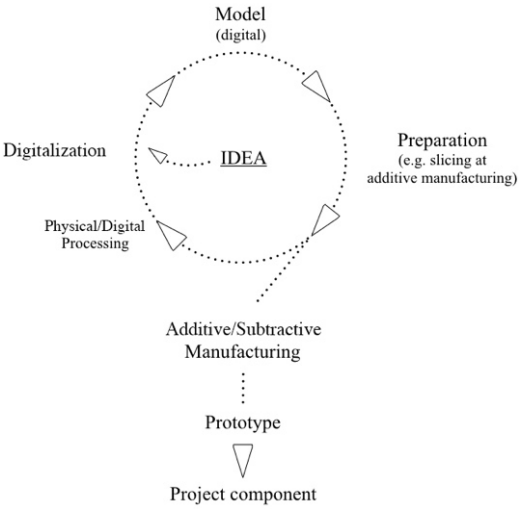

Fig. 1:
Possible digital workflow from analog to digital and from digital to analog (leveling) up to the model, prototype, or implemented project component (Source: own illustration)

Computer-aided manufacturing processes, such as additive and subtractive methods (Fig. 2), and the intertwining of software solutions differentiate the physical model from analog manufacturing techniques within the design and execution process (cf. THEIDEL 2020). This paper focuses on the influence and impact of these manufacturing techniques and the resulting relevance of the digital model for design in landscape architecture, illustrated using a practical example. Decisions are crucial within the design process and require separate consideration.

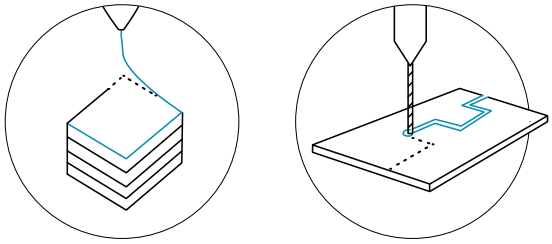

Fig. 2:
Additive (left) and subtractive (right) manufacturing processes as a schematic representation of their functionalities
(Source: own illustration)

Parametric software solutions are an example of this. Changeable models are generated based on numbers and ratios. However, the selection of parameters that shape the design and the task will always be the responsibility of the designers. Therefore, these (parameters) are determined by the design attitude and defined by the awareness of the personal design process (BIELEFELD & KHOULI 2007, 14 f.).

3 Goal

This paper aims to use a practical example (Bryum/Pocket Park – Basel)

- to illustrate the changed approach in the landscape-architectural design process through the model as a design method,
- to record the significant experiences of the designers with regard to the physical-digital practices being used, and
- to put them up for discussion.

Expert interviews were chosen as a method of visualizing decisions and influences. They provide conclusions regarding the use of specific digital tools as well as physical-digital practices in the examined design process. The ideas shared in this paper are introduced and supported by my publication "Model / More than visual communication method considering a changing approach" (in the anthology "Methods of visual communication in spatial planning" by the University of Kassel), which presents the thesis that the changing approach to the digital and analog model in the design process is facilitating the emergence of a new formal language.

The case study under consideration is representative of other projects that were also developed using specific practices and tools. In this way, the paper aims to both initiate a further, exploratory research approach and point out possible systematic studies in this character.

4 Case Study

The Pocket Park in Kaiseraugst, Switzerland, was chosen as the subject of this case study owing to its special type of development, its formulation in relation to the formal language of the ground covering (Fig. 4), and the great precision of its execution. It was clear, even when viewing the project from the outside, that the collaboration between the designers, the client, and the executing agency in the context of the created result would be relevant for the investigation and possibly innovative on different levels. Throughout the development of the project, various digital practices and production methods were used, which also proved to be useful for the practical implementation. These practices included parametric software, which was capable of reacting to changing influences such as tree locations, and additive manufacturing processes, such as 3D printing. Furthermore, the project had received the "European Award for Ecological Gardening 2019" as part of the master plan for the campus area of the pharmaceutical company Hoffmann-La Roche Ltd., located near Basle. The jury's positive rating was based on not only the innovative approach to the factors of man and nature within the master plan (Fig. 3), but also the parametric design of the Pocket Park located in the center of the campus area (Fig. 4). "The project is a groundbreaking implementation of parametric design in Landscape Architecture" (COMPETITIONLINE 2019). In the Pocket Park, unlike in the overall concept, the visitor is not considered a "silent" observer or a part of the ecosystem, who is mostly interpreted as a disruptive element, but instead is brought into the foreground due to their usage requirements (gastronomy etc.), whereas nature moves into the background.

The master plan aims to develop a system that implicates humans as a "disruptive element" and sees them as part of succession and development (WEINSBERG 2020).

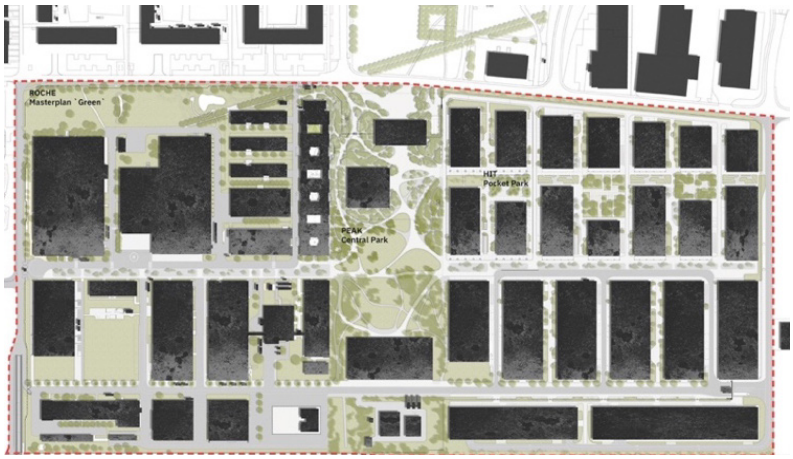

Fig. 3: Master plan for the campus area in Kaiseraugst (Source: WEINSBERG (2018, May 13), personal communication May 13, 2018, Image © BRYUM)

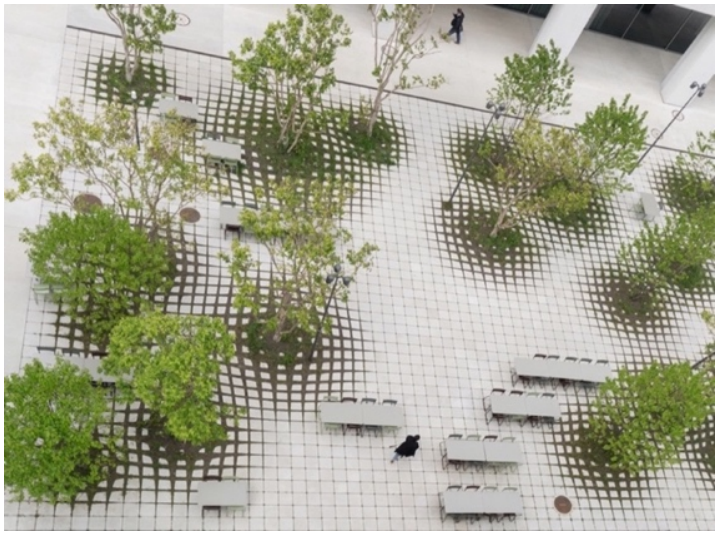

Fig. 4: Surface of the Pocket Park on the grounds of Hoffmann-La Roche AG in Kaiseraugst, Switzerland (Source: WEINSBERG (2018, May 13), personal communication May 13, 2018, Image © BRYUM)

5 Method

In order to investigate the link between the design process and the tool, guideline-based expert interviews were conducted with various people who were involved in the design process.

The qualitative content analysis method described by Mayring makes it possible to structure and analyze the collected statements using deductively formed categories (Mayring 2015,

20). The analysis provides information on how the work of the designers was influenced, not only by the model as a design method but also by digital practices and computer-aided manufacturing processes in particular. The deductive categorization via 1. the definition of the categories, 2. anchor examples and 3. the coding rules enabled me to structure the captured content and evaluate it as described below (MAYRING 2015, 97).

At a personal meeting, the questions were addressed to the people involved in the design by BRYUM, landscape architects from Basle, Switzerland. The answers from the recorded interview were transcribed and used for the content analysis in point 6. The following questions were relevant to this study:

1. How would you define the term *design tools*?
2. Which design tools did you use during the design phase of the project (Pocket Park)?
3. Are there any design tools that are particularly helpful to you in the development of "new forms"*?
4. What advantages and disadvantages do digital models offer you compared to analog models in your design process?
5. What influences (other than the given task) guided you during the form-finding and design process?
6. How did you deal with computer-aided manufacturing methods in the design process?
7. Define the influence of computer-aided manufacturing processes on your design work within this project and on your design work after this project.

* Definition "new forms" / form finding:

The terms "form finding" and "new forms" (developed through form finding) can be summarized by means of the definition of form language. Form language describes the constellation and combination of basic elements such as bodies, lines, and colors to and with each other to create a defined impression of a room. The way of getting there or the actor's search for this constellation and combination of the various elements can be described as form finding and produces new forms (c. f. VON BORRIES 2019). According to Weber, two overriding/overarching influences or objectives can be identified: Beauty or expression can determine and steer the process in a detached way. A focus is defined by the respective actor or task (c. f. WEBER (1982) 2019).

The transcribed interviews were presented to the designers for review and approval and form the basis for analysis.

6 Analysis

In this section, I will use certain categories as a basis for structuring, analyzing, and summarizing the above-mentioned questions along with the answers that were collected from the designers in the interviews.

The following categories were defined in advance and described in detail with anchor examples and coding rules according to Mayring (Table 1) (MAYRING 2015, 97/113). Only the

respective overarching categories are explained, not their gradations up to level 3 (no agreement or dependence). These are only characterized by a weak expression of the respective content statement. The contents of the interviews were assigned to these categories and further categorized according to their characteristics using an anchor example.

Table 1: Deductive categories for structuring and qualitative content analysis

Category	Definitions	Anchor Samples	Coding Rules
KR.1	High dependency on manufacturing processes in the realization of the project. • Acceptance of digital data from companies for the execution • Realization of special combinations of forms by computer software • - Design and planning parameters can only be changed by outsiders using digital data	"It was the use of computer-aided manufacturing processes that made the realization of the project possible in the first place."	All aspects of the definition must be fulfilled; otherwise encoding towards KR.2.
KE.1	High knowledge of the influence of tools on the individual's own work and the development of designs, and curiosity to learn about other tools • Form, construction, composition developed from the tool, ... • Openness towards unconventional design tools (conventional = sketch) • Reflective use of design tools	"Computer-aided manufacturing processes have led to the development of the significant form of the design in the first place." "There are many ways I can do it and many ways I want to do it." "I'm interested in exploring and learning about new tools."	All aspects of the definition must comply with the view; otherwise encoding towards KEW.2.
KEW.1	• Computer-aided manufacturing processes that can create or edit physical objects from digital models (e. g. additive, subtractive manufacturing processes) • Model, both analog and digital • Computer software (Vectorworks, etc.) • Sketch,are considered relevant and are regularly used	"Knowledge of computer-aided manufacturing techniques and the physical model enabled us to further develop our design."	All aspects of the definition must be considered as design tools; otherwise encoding towards KEW.2.

Category 1: Realization (KR) is defined by a high dependency on computer-aided manufacturing processes based on the transfer of digital data for execution within the project. The statements answering questions 4, 5, and 7 can be assigned to this topic theme because of complete conformability with the anchor examples. Salient for this is the reproduction speed and precision of digital models and their physical equivalents via computer-aided manufacturing processes. The dependency is perceived by the designers. However, at the same time, the technical advantages are exploited and augmented through expert knowledge in order to utilize them for the project. Over the course of the project, the need for reorientation was determined: the production of mold elements for casting the surface covering was changed

from a targeted additive to a subtractive production. This was not considered a failure but rather an increase in knowledge (Figs. 5 + 6).

"We haven't taken the leap yet to really use 3D-printed elements. But considering 3D printing, it probably won't be far off" (THEIDEL 2019, 11).

Fig. 5:
Mold prototypes produced with the help of additive manufacturing processes (Source: WEINSBERG (2018, May 13), personal communication May 13, 2018, Image © BRYUM)

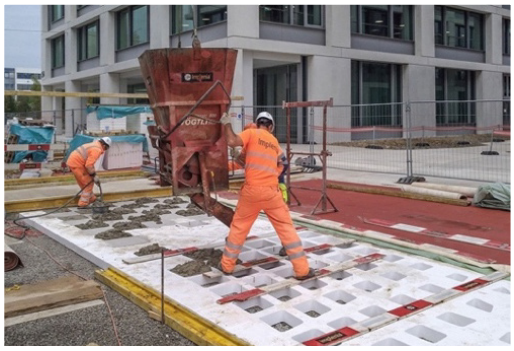

Fig. 6:
Mold prototypes cut from polystyrene with a water-jet cutter (CNC-controlled) (Source: WEINSBERG (2018, May 13), personal communication May 13, 2018, Image © BRYUM)

Category 2: Design (KE) is paraphrased by the designers' high level of understanding of the influence that tools have on their own work and the development of designs. In this context, open-mindedness and the general and reflective use of design tools are significant. The answers to questions 2, 3, 4, 6, and 7 apply to the definition of this category to the full extent. They indicate a reflective use of digital practices and computer-aided manufacturing processes. Parametric software has proven to be particularly capable of creating "new forms"* (see definition above), but only if it can be actively influenced. Furthermore, the knowledge of how to produce physical models or prototypes from digitally created models is (very) important, requiring additive and subtractive computer-aided manufacturing processes such as 3D printing or CNC. However, the decisive factor is the designers' aspiration not to copy or imitate, but to creatively apply the extension of the technical possibilities up to realization.

Category 3: Design Tools (KEW) are defined by the research horizon of the paper and include computer-aided manufacturing processes (additive, subtractive), models, sketches, and computer software. Answers to questions 1, 2, 3, 4, 5, and 6 can be categorized into first or second quality, due to the fact that the designers had not identified computer-aided manufacturing processes as design tools. Nevertheless, the additive and subtractive manufacturing processes and the knowledge of the possibilities proved decisive for the project process. The computer-

aided manufacturing methods had also been questioned throughout the project, but never entirely rejected, as the advantages for the implementation of the basic design idea outweighed the disadvantages. New knowledge was generated regarding the manufacturing processes, both additively and subtractively, e. g. by experimenting and working together with experts from other disciplines.

> From the [external 3D printing expert who was supposed to make molds for Bryum] we actually learned that 3D printing can be more than just prototyping; it can be mass production. […] And not just on a small scale, but that you can actually theoretically use it 1:1 (THEIDEL 2019, 14).

7 Results

The summary and analysis of the interviews (Section 6) form the essence of the recorded material. In this section, the findings of the interviews will be considered and reflected upon in the context of the previously generated question.

Most of the answers given by the interviewed designers can be classified into the previously defined categories KR.1, KE.1, and KEW.1. Accordingly, the following findings can be identified for the Pocket Park project and the interviewed designers involved in the design and implementation process:

1. Digital practices influence the designer.

The use and knowledge of specific design tools, particularly computer-aided manufacturing processes and the corresponding software, influenced the design of the Pocket Park in Kaiseraugst (Switzerland) in a significant way. Without their knowledge and combined use of different tools and computer-aided additive and subtractive manufacturing processes, it is clear that the designers would not have considered the concise forms of the square surface (see Fig. 3). In this context, the software knowledge of the individual designers is of subordinate importance. They were able to recognize and communicate all important aspects of the knowledge they had gained, in terms of both design and technology.

This fact is particularly apparent in the answers to question 2:

> There you come up against limits (in terms of working with the industry standard software solutions, e. g. Vectorworks, Rhinoceros, Grasshopper). If you are only able to work with 2D and CAD, you stop and think: “This is not plannable” (irregular expansion of the surface covering). But if you know that there are tools, then it is somewhat different. You don’t have to be able to do it yourself. You don’t have to be able to use Rhinoceros or Grasshopper, but you have to know that they exist and that there are people who can do it and who can help you (THEIDEL 2019, 3).

This statement suggests that there is a perceived direct relationship between tool, design process, and result.

2. Computer-aided manufacturing processes may encourage the renunciation of standardized results.

In this context, the question of whether the use of computer-aided manufacturing processes enables or creates "new forms"* (see definition above) needs to be considered in a more differentiated manner. Despite the (at least) theoretically smooth interaction between software solutions and the materialization of the data generated through them, the designer still remains the decisive factor. She pools all the information. She interprets the knowledge and transforms it into a design solution. The appearance of this solution is dependent on many factors – not only subjective factors related to the designers but also objective ones. Bryum's Pocket Park serves as an example demonstrating that computer-aided manufacturing processes encourage the abandonment of standardized design components, in this case ground coverings. This is how these processes have been able to contribute to the creation of a designed landscape with greater variety.

3. Curiosity and openness lead to innovation.

The open-mindedness of the interviewed designers towards technical innovations, in combination with the standards they set for themselves and the existence of an open-minded, solvent (building) contractor made it possible to enter new territory and generate new knowledge beyond the scope of the project. Throughout the process, knowledge was consistently contributed by the participants. The created space is a very highly frequented site, according to the number of users, and therefore attracts the interest of experts.

4. New styles can result from digital or physical-digital workflows.

With respect to the question asked at the beginning "What influence do computer-aided manufacturing processes in combination with digital practices have on design?", it became apparent that the digital workflows are intertwined, (consequently) leading to a new style. This fact is demonstrated by the individuality of the space and the renunciation of standardized components. In the spirit of Aicher, it can be said that "technology (...) sets free a wealth of new aesthetics" (AICHER 1991, 86).

Although similar parametric digital models are not uncommon, the Pocket Park stands out among similar projects owing to its implementation. Only when a project has been implemented can it be innovative. Otherwise, it is only fiction and, in my view, less relevant.

The design approach refers to the formal design and production of the surface of an (outdoor) space using parametric software and computer-aided manufacturing processes. The approach of the designers was also included in the design process. However, the use of digital practices – such as a digital parametric model and the creation of digital and physical models through computer-aided manufacturing processes – does not provide any information on how the designers arrived at the basic form of the area's surface. Only the repetition, modification, and production of this form is addressed and facilitated.

8 Discussion

The discussion will be divided into two parts: method and results.

First, the applied method will be considered.

With the aim of generating specific knowledge on the basis of a practical case study, experts were interviewed, and their answers were deductively categorized according to Mayring's

qualitative content analysis. The qualitative content analysis method was supplemented by a content summary, which was again verified by the interviewees. In my view, this approach made it possible to take into account aspects that are generally difficult to identify through design research. The recorded facts have been counterchecked by the interviewees to ensure a higher level of reliability.

The applied method of project analysis through guided interviews combined with a final analysis of these interviews is in principle well-suited for application in similar projects.

Methodical risks arise if existing knowledge cannot be correctly captured by the guiding questions prepared in advance. This problem can be prevented by asking the questions in a generally less rigid interview, which allows for more flexibility in reaction to unforeseeable situations.

The results are based on the case study as well as the interviewed designers. They will require further consideration, especially from the field of landscape architecture, in order to derive generally valid conclusions regarding design processes. Projects like the one used for the case study are still rare. Due to the ongoing prototypical intertwining of computer-aided design and computer-aided manufacturing – from the model to the implementation of projects – I would argue that examples of related design-based disciplines should be taken into consideration as reference objects. The ETH Zurich project "Urbachturm" for the Garten Schau Ramstal in Switzerland (Fig. 7) can be seen as a relevant example. The created forms are based on a computer-controlled process of drying the wooden panels that are being used.

Fig. 7: The "Urbachturm" for the garden show in Ramstals, Switzerland (Image © ICD/ITKE University of Stuttgart; Source: https://www.holzbauaustria.at/architektur/2019/06/selbst-ist-das-holz.html (30.12.2020)

These technology-based possibilities point the way to formal opportunities that may be inherent in the use of computer-aided design practices and manufacturing processes. In the presented context, it would seem reasonable to make certain processes possible by automating and thereby accelerating them. Furthermore, based on the specific results of this study, it is possible to derive research interests that also have a bearing on the subject of the design

process. This raises the question as to whether the use of computer-aided manufacturing processes and the associated closed digital workflow leads to a higher frequency of reflection in the design process and thus to "better" results.

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