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THE RELEVANCE OF SELF-FORMATION IN TEACHING STRUCTURAL DESIGN

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Summary. The paper discusses the relevance of teaching Self-formation processes using active bending only for the form-finding, whereas the long-term load-bearing structure is determined from a number of hybrid solutions. The Research & Development Project *Neuschneewolke* serves as a vehicle to develop a method for a dialogue based workflow between Architects and Engineers, which has the capacity to bridge the gap between computational design and practical implementation.

1 BACKGROUND AND INTRODUCTION

The ongoing collaboration between the Architect Walter Klasz and Format Engineers has its origin in the commissioned and realised research & development project *Neuschneewolke* [1]. This publicly funded project aims at developing a multifunctional light-weight structure to provide space for the artificial generation of snow-flakes for usage in sustainable winter-tourism. The shell was intended to be constructed in the landscape with a minimal impact on the environment and with the challenge to achieve a high level of aesthetic quality.

Following on from an earlier experimental structure in this context – The Cloud for fresh Snow [2] – there were identified three representative bent typologies [3], where material change can happen without affecting relevantly the long-term load bearing capacity of the structures. Figure 1 shows Photos of the assembling process of those structures using scaled models.

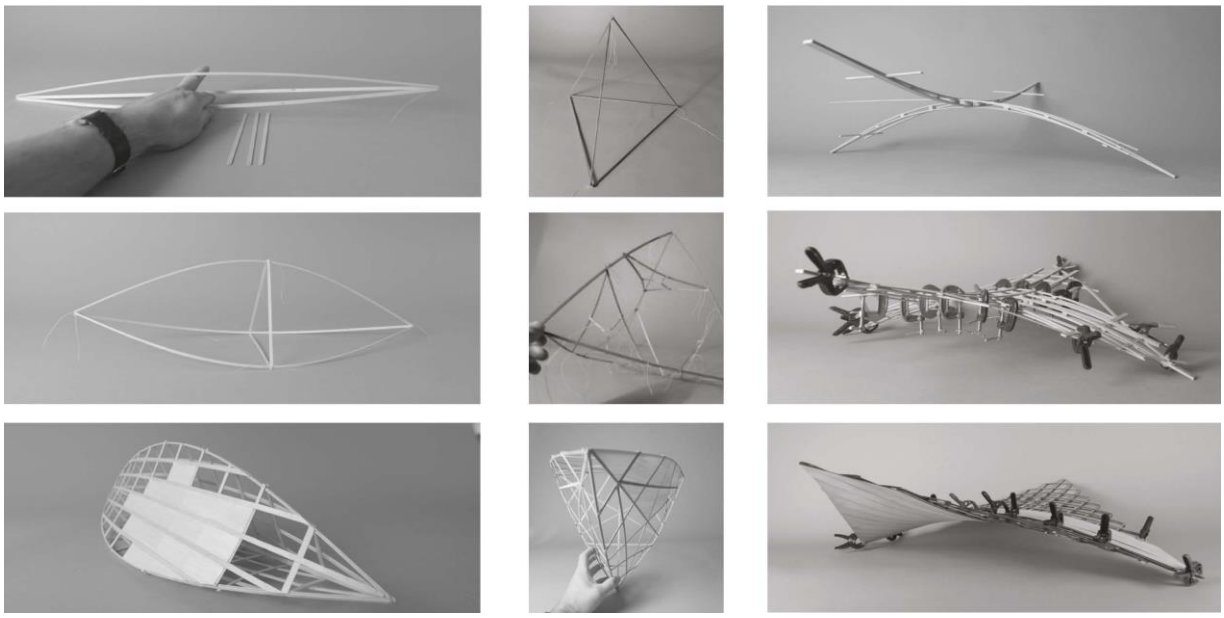

Figure 1: Photos of physical Assembling Studies of the three Typologies: left to right: Onion, Spherical Tetrahedron, Self-formed Composite Shell

Instead of following the idea of the anticlastic wooden membrane, the four surfaces of the Neuschneewolke-Lüsens present synclastic bent surfaces. On-site assembled wooden double T-Beams provide the necessary stiffness of the structure. The phenomenon of Active Bending is used mainly to find the form and to simplify the assembling. The pre-tensioned edge beams create the initial form and give the structure its primary form. In the final hybrid configuration, active bending has no structural relevance.

The following research investigates the relevance of Self-formation in teaching structural design. There are discussed different aspects of Self-formation. That is why the next chapter deals with the terminology.

2. TERMINOLOGY OF SELF-FORMATION

2.1. SELF-FORMATION IN THE CONTEXT OF ENGINEERING

In 2013, Engineers used the word Self-formation process to describe the phenomenon of active bending: "… structures, where bending is used as a Self-Formation Process" [4]. Since then the internationally growing scientific community use the word Self-formation mainly in the context of active bending. Wooden (or even aluminium, carbon fibre etc.) members can be bent to a predictable shape, with a built in prestress, and then continued to be bent with control over the final geometry. It is a repeatable and describable process to produce complex curved forms easily. The new aspect in the context of Form-finding consists in the fact, that the designer focuses on the boundary conditions and on the parameters and not on the form itself. The first internationally recognized realized architectural project in this context is the Theme Pavilion Expo Yeosu by soma-architecture. The parametric software K2E was developed by Cecile

Bandt-Olsen in close collaboration with Format-engineers [5]. It enables the real-time development of three-dimensionally bent structures in relation to the used sections and to the E-Moduli of the materials. Figure 2 shows the sequence of the self-formation process of one conceptual option for the spherical tetrahedron of the Project *Neuschneewolke Lüsens*.

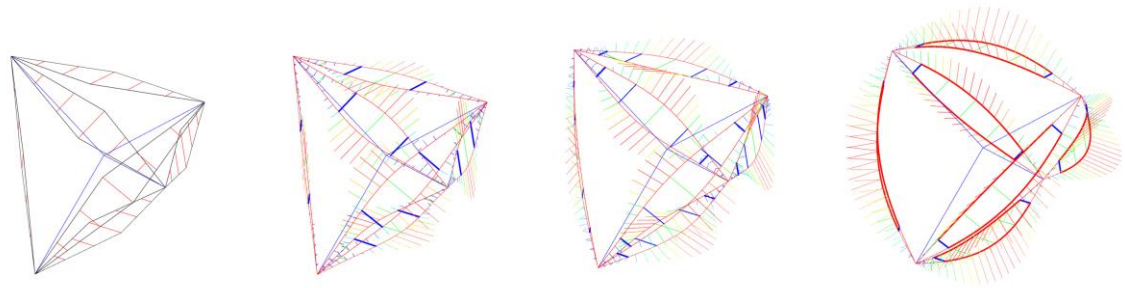

Figure 2: Pre-studies for the Project *Neuschneewolke* in parallel to the physical Studies by the Architect: Parametric Bending Simulations with the Software K2E by Format Engineers

2.2. SELF-FORMATION IN NATURE

In Nature, Self-formation is the norm. Forms emerge out of the boundary conditions in a self-forming process. Consequently, there is always a strong relation of forms and their boundary conditions.

Figure 3: Meandering Water (Photo W. Klasz in Auckland), Snow-flake (Photo Michael Bacher), Snow-Drift (Photo W. Klasz)

In this context, the example of water is exemplarily chosen to present the variety of forms emerging out of one material due to different boundary conditions. Figure 3 shows a meandering river, a snow-flake, and a snow-drift against the wind direction. All forms are completely different, but in every form there can be identified a typical implicate order. A snow-flake has always six spikes, which is linked to the molecular structure of water. In homogenous conditions, a meandering river finds its inherent form of a sinusoidal-curve with the proportion 1:11, which was observed and investigated by researchers in California [6].

2.3. SELF-FORMATION IN AUTOCHTHONE ARCHITECTURE

Human settlements and buildings interact with nature. The conception of Self-formation could help to understand the deep relationship of architecture without architects in complex boundary conditions. Looking at such autochthone architecture, this close relation to the surrounding is obvious from the usage of local materials to the logic in the forms. In the context of teaching, architects and engineers can learn from the relevance of the close relation between both disciplines and the resulting aesthetics. Farmers worked intuitively based on experiences and knowledge.

Figure 4: Photo by Josef Dapra in the Book by Raimund Abraham: Architectonics, P.22

Contemporary tools like K2E allow architects and engineers again to work intuitively, while calculating the structures in real-time. Intuition is a human inherent resource to get a Form-finding-process started and controlled in the holistic context, which is discussed in the following chapter 2.4.

2.4. HOLISTIC SELF-FORMATION IN A COMPLEX FORM-FINDING PROCESS

This paper introduces the new term *Holistic Self-formation*. It implicates a physical and a metaphysical aspect of Self-formation. In the Book *On Dialogue,* the Physicist and Philosopher David Bohm describes the analogy between formation processes in quantum physics and the Form-finding happening during a dialogue in the spirit of David Bohm. The words *Holistic Self-formation* describe a method of dialogue-based collaboration in a complex architectural form-finding process (see the following Chapter 3). In contrast to the accepted convention, that the architect defines the main form as the leader of a multipart team, this new approach considers the Architect responsible for ordering the boundary conditions and to define the relevant parameters in a process. The initial intuitive input in form of a sketch or a concept model serves as a seed or a nucleus of a crystallization-process in an interdisciplinary working-group.

3. THE R&D PROJECT NEUSCHNEEWOLKE LÜSENS AS A VEHICLE TO DEVELOP A TEACHING METHOD FOR SELF-FORMATION

The Form-finding process itself was and is the core competence of architects. Instead of guiding this process hierarchically, the project Neuschneewolke is a successful case study to prove the efficiency of a Self-formation process on both levels: Physical Self-formation with bending wood and holistic Self-formation in the interdisciplinary group including the engineer, the client, landowners, tourism experts and users.

Figure 5: Collage with relevant Snapshots from the Form-finding-Process Neuschneewolke; Photos W. Klasz

The intuitively built physical concept model (see Figure 5) served as a first step for the application of the public funding and in a second step to get the professional Form-finding process started. The whole group met only twice physically in two-day workshops. The role of the architect was mainly to organize the parameters and to give the relevant people at the right time the word to contribute to the common solution. Instead of debating different positions, Holistic Self-formation holds the emerging solution in suspension. It gives a freedom, to let things happen. This is reflected not only in the detailing of the structure but also in the concept of interacting in the environment. The architect and the engineers visited the location together to choose the appropriate rocks. Then they immediately adapted the

structure using the parametric script. Later users of the fresh snow, which is generated by Neuschneewolke, shaped the snowskate-lines themselves, which is seen in the aerial photo of Figure 5. Figure 6 presents an abstract organigram of the Self-formation process from the very beginning to the final integrated design solution in avant-garde winter-tourism. Comparing the physical Self-formation and the holistic Self-formation in the second part of the process, there are identified the same soft boundary conditions, which are confidence, empathy, peacefulness, time and pleasure. The digital parametric toolbox consists mainly of K2E and Karamba (a finite element structural engineering analysis tool). The metaphysical parametric toolbox names firstly the Bohmian Dialogue. This communication tool is contemporarily used in organisational development but not yet in architectural form-finding. Analogies between physical Self-formation and the Bohmian Dialogue are discussed in a separate paper [7].

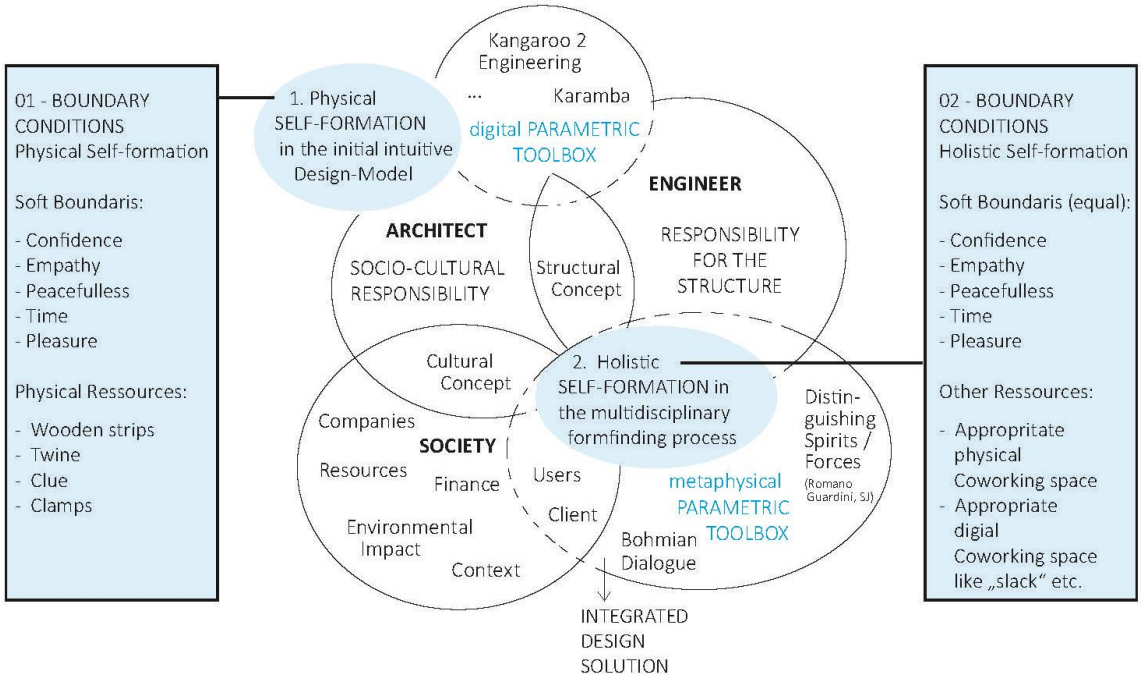

Figure 6: Abstract Organigram and Workflow of Physical and Holistic Self-formation

In the research team of the Neuschneewolke, there are two students involved, who work on the same eye-level with the other experts. The key issue of success in the ongoing project is the focus on the common vision and mission. The clearer this is, the less structured organisation is necessary. Members of the team know on their own what to do and how and when to contribute. The common vision intrinsically motivates team-members. Intuitive physical modelling, digital parametric modelling and experimentations go hand in hand enriching each other. The architect guides this process focusing on the boundary conditions and keeping the common mission in the centre of the conscience. An important new aspect of the method is that the client plays a creative but listening role in the process. He has to be open to get something unexpected. The client takes part - less demanding solutions but rather contributing and reacting creatively in the process. Figure 7 shows the framing of teaching Self-formation processes. Firstly, teachers

and students work on eye-level. The client frames the Form-finding concerning the link to society. Generally, constraints are not charged as negative limitations but as potential parameters for creative form-finding.

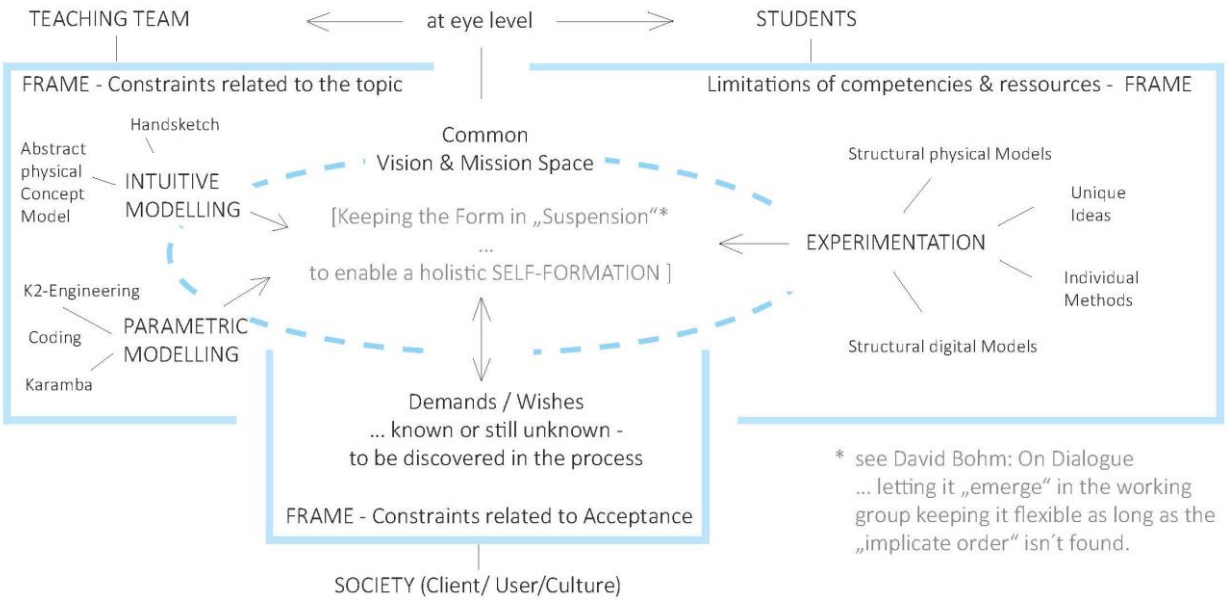

Figure 7: Framing the Teaching of Self-formation Processes

On the one hand, teaching Self-formation is characterized by a not hierarchical structure, but on the other hand, there is a clear method to develop physically self-formed structures. Figure 8 shows ten steps of the emergence from the first intuition to the final product or building, illustrated with photos and images of the project *Neuschneewolke*: Intuitive Modelling / Parametric Modelling / Scaled physical Detail Models / Physical Testing of 1:1 Elements / Scaled physical Over-All-Model / Site Specifications / Detail Specification / Production of the Components / Test-Assembling of selected Parts / Transport and Assembling. These ten steps can be seen as a proposed framework, but they want to be customized to individual projects. It is up to the teaching team to select the relevant steps during the process, keeping the common vision and mission in mind (see Figure 7). Especially the ongoing experiments of the students in the different phases of the project can contribute to new solutions in the overall conception as well as in detailing innovative solutions. The teaching team should frame these experiments in the relevant field trying to keep creativity lively and to keep the development focused at the same time.

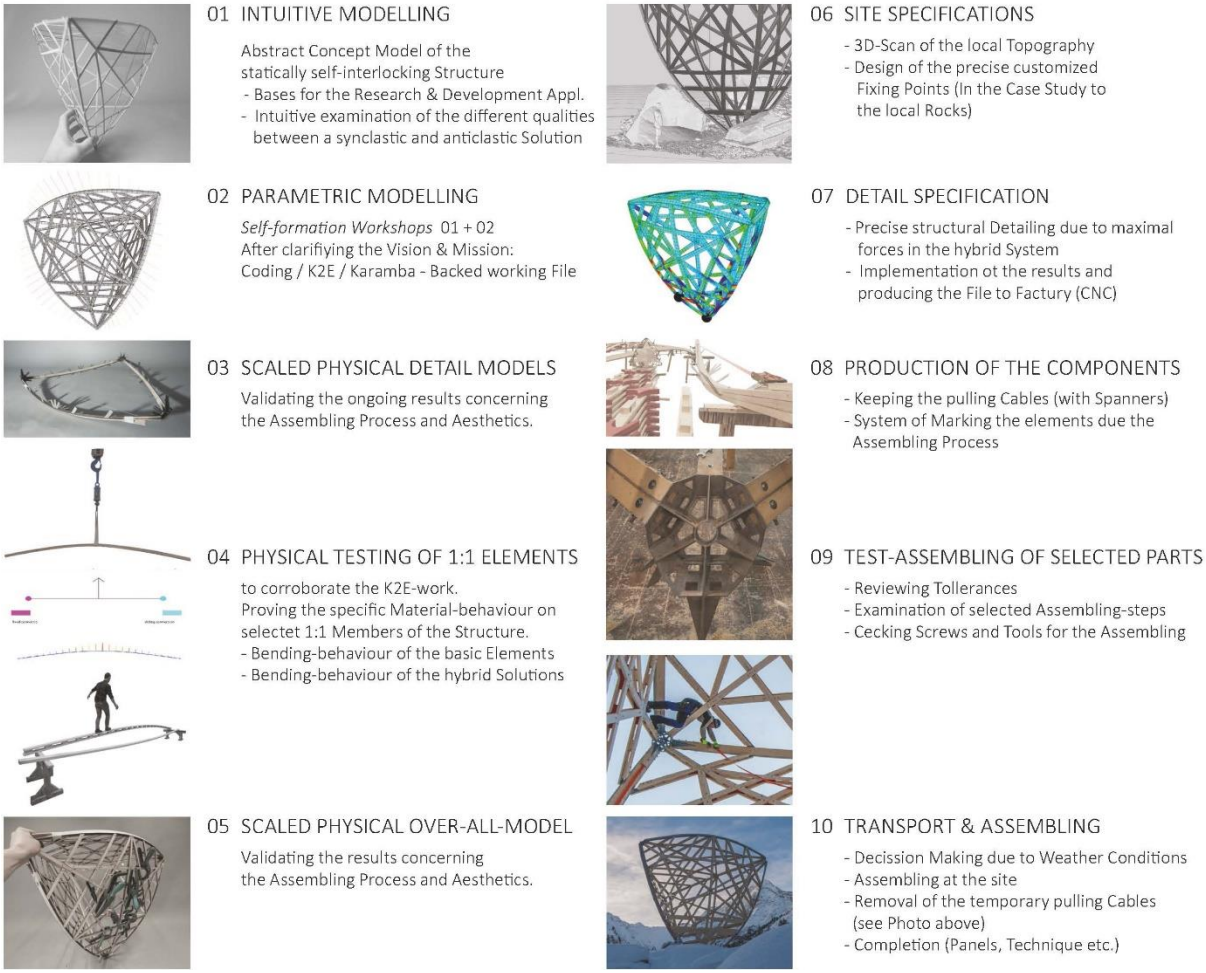

Figure 8: Ten Steps to develop Self-formed Structures from the first intuitive Modell up to the Implementation to the Market

4. EXPERIENCES IN TEACHING SELF-FORMATION

The teaching team tries to provide the soft boundary conditions mentioned in Figure 6. Students receive the following physical resources: Wooden strips, twine, clue and clamps. After receiving a briefing on the design topic, they get started to experiment freely. At the beginning, students try to focus mainly on the sculptural quality of their work and less on functions. During four years of teaching experience, it is found out that intensive one day workshops are very efficient to achieve interesting solutions in the concept phase. Students learn from each other and the emerging atmosphere stimulates them to get more out of the given resources.
Concerning the collaboration with real clients or partners from industry, two experiments of one semester each were performed. In 2017/18 Klasz was invited to teach one semester at the TU-Vienna at the Institute of Art and Design. The traditional furniture company Thonet was

invited as a sponsoring and collaborating partner. In the final Jury, at the beginning of the Vienna Design Week, Mr. Thonet was positively surprised about the huge variety of new concepts developed in Self-formation processes using active bending. The emerging sculptural quality of the majority of the wooden projects was convincing on an aesthetical but less on the functional level. The team understood that it would have been better to involve the furniture expert more deeply during the process. On the other hand, the distance allowed the students to work freely and to risk suggesting very unconventional ideas. One main result of this experimental research was, that the clients should be constructively involved taking part to risk together with the team to develop new ideas.

The second collaboration-experiment was carried out with 18 students at the University of Innsbruck at the Institute of Design in the department of Structure & Design in 2017/18. The Tyrolian Company Sunkid was an industry partner to help develop new ideas for outdoor structures in bent wood. Figure 9 presents two projects of high aesthetical quality. The involvement of Marco Pellegrino from Format Engineers during the design process helped guiding the design evolution towards realistic dimensioning and proportions. In the ongoing collaboration with the University, Sunkid wants to realize a full scale Prototype with a local client in the team.

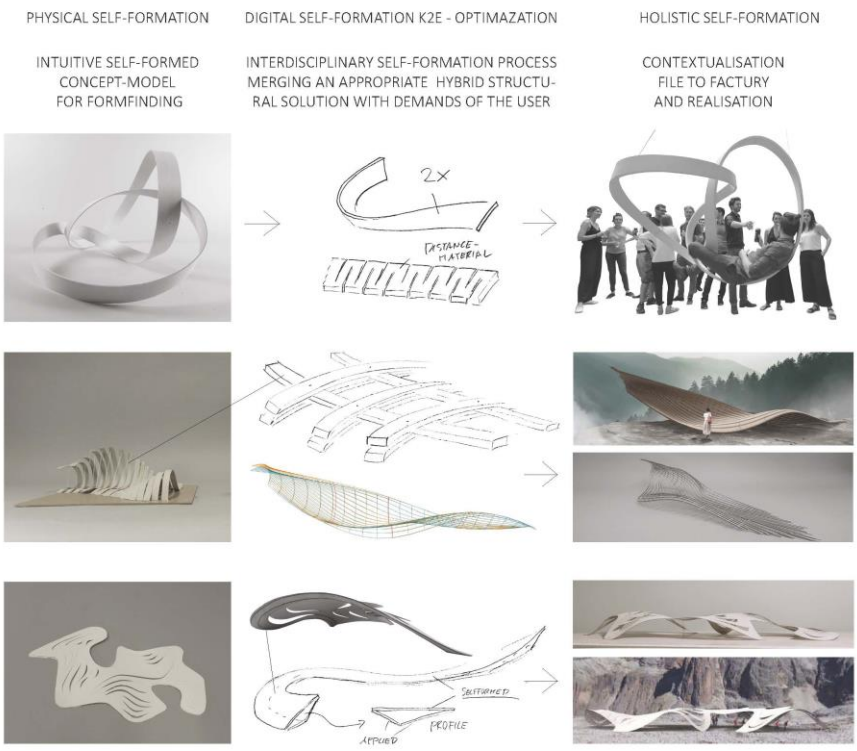

Figure 9: Three Student-projects developed with the presented Method to teach Self-formation processes using bending wood and collaborating with commercial partners at the University. On Top: Project *Bondage* by Johannes Fandl and Laurenz Greger; In the Middle: Project *Wooden Wave* by Bernard Blaschette; On the Bottom: The Project *Ray-fish* by Sandra Camini

12 CONCLUSIONS

- Self-formation plays a relevant role in teaching structural design. On two different levels, students learn to develop and to realize free forms: On a structural level, active bending is used for Form-finding. On a holistic level, students, teachers and clients find together hybrid structural solutions to match all requirements of a project.
- The method of Self-formation implicates a useful training for students to sharpen their intuition for choosing the appropriate tool at the right time bridging the gap between computational design and 1:1 production.

13 PERSPECTIVE

In order to get new results and to sharpen the method of teaching Self-formation in the future, there will be organized an experimental winter-school in Tyrol for international students. The whole course should be financed by a commercial partner in a fair win-win situation. This could be further developed as a way of funded academic teaching without losing independency of the university. It may interconnect economy, research and teaching in a deeper way [8].

REFERENCES

[1] Klasz W. Bacher M., Ressl M.: *Sustainable Winter-Tourism: The Project Snow Cloud*; In: Agathón – International Journal of Architecture Art and Design 2/2017 (with Peer Review); Palermo University Press ISSN online 2532-683X

[2] Klasz W. Greiner S.: *Active Bending to facilitate the installation process of membranes in statically self-locking spatial structures*; Conference Structural Membranes, Barcelona, October 2015

[3] Klasz W., Grasser A., Flach M., Sevela P.: *Wooden Membrane with integrated flexible PV-Foil; Conference on Advanced Building Skins*; Bern, October 2016; ISBN: 978-3-98120539-8; p. 68-76

[4] Julian Lienhard*, Holger Alpermann, Christoph Gengnagel and Jan Knippers: *Active Bending, A Review on Structures where Bending is used as a Self-Formation Process*; University of Stuttgart, Germany; 2013

[5] Cecilie Brandt-Olsen: *Calibrated Modelling of Form-active Structures*, Master´s thesis in Architectural Engineering, Technical University Denmark, 2016 – Supervisors: S. Melville, J. Solly

[6] Christian A. Braudricka,1, William E. Dietricha,1, Glen T. Leverich and Leonard S. Sklarb: *Experimental evidence for the conditions necessary to sustain meandering in coarse-bedded rivers*; Department of Earth and Planetary Science, University of California Berkeley, Berkeley, CA 94720;

[7] Klasz W.: *Self-formation as a Method for integrated Design – Form-finding Analogies to the Bohmian Dialogue*; 5th International Multidisciplinary Scientific Conference on Social Sciences and Arts SGEM 2018, Best Speaker Award, Conference Proceedings, 2018, ISBN 978-619-7408-33-1, p. 299 - 306

[8] Ulrich Pfammatter: *Building the future*: Prestel Verlag, ISBN 3-7913-3334-8