Digital Methods of Academic and Professional Training in Industrial Engineering.

Abstract: This paper presents the current results of our project which deals with virtual learning in industrial engineering. The aim of this project is to develop learning scenarios which ensure better teaching of theory and practical application through use of virtual reality. Therefore, the new methods which are to be learned are immediately applied in practice. Especially in educational fields (e.g. post-secondary institutions) there is often no “real“ work system. For this reason we aim to use virtual reality technologies to close this “gap“ to facilitate the transfer of methods and knowledge in operational practice. In this report we present current results of this project.

Keywords: learning, industrial engineering, virtual reality

1. How to close the gap between theory and practical application

Industrial engineering is a subject heavily defined by its practical application. Therefore, learning plays a crucial role at work and within work systems. In the following we present our current results of our still ongoing project “Close the Gap“ which deals with virtual learning. This project is a cooperation of the post-secondary institution Duale Hochschule Baden-Württemberg, Mannheim and the campany kreatiVRaum GmbH, Karlsruhe.

The aim of this project is to develop learning scenarios which further close the gap between theory and practical application through use of virtual reality (VR). With this project we aim to achieve for freshly learned methods of (industrial) engineering (e. g. value stream analysis and design, planning of assembly areas etc.) to be immediately applied in practice.

Often there is no “real“ work system when it comes to teaching (e. g. in post-secondary institutions due to financial reasons). Therefore, we aim to use virtual reality technologies to close this “gap“. This is beneficial for the students as it simplifies transferring knowledge and methods into operational practice.

2. Current state of teaching without virtual reality

Industrial Engineering is a subject heavily defined by its application in practice. This involves the economic design of work systems as well as their adaptation to human needs. Therefore, learning plays a crucial role at work and within work systems (e. g. REFA 1993). An ideal state of knowledge transfer in industrial engineering (Fig. 1) could look as follows: You are in the lecture ”Industrial Engineering“ and discuss a method (e. g. Value Stream

Mapping, Value Stream Analysis and Design; cf. Erlach 2010). After the theoretical introduction (theory), this method is consolidated/reinforced by an exercise (training). Afterwards you introduce your students to a real work system and apply what you have learned (practical application). In this scenario, there is less of a “break“ between theory, exercise and practice. The students can immediately apply what has been learned and thus it can be practically tested and didactically reinforced/consolidated.

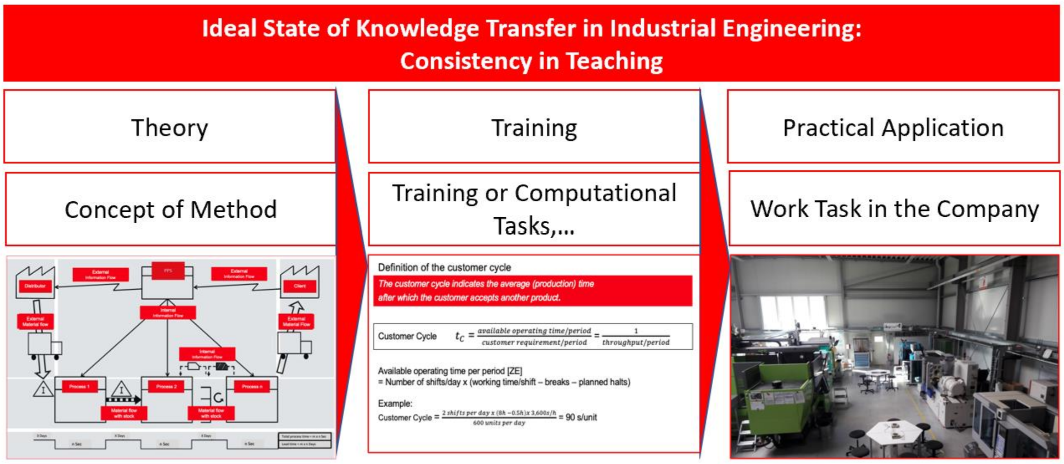

***Figure 1**: Ideal state of knowledge transfer in industrial engineering (Fig. on the basis of Erlach 2010; Picture: Th. Gamber)*

Often, the process of knowledge transfer as described in Figure 1 is not easily (or not) possible in many post-secondary institutions. There are various reasons:

- There is no (costly) production equipment at the post-secondary institution.
- Production equipment is only used for knowledge transfer in production engineering. It is not planned to treat works organizational or labor scientific contents of teaching.

- During the organizational analysis it would need to be ensured that the machines operate. This would mean that machine operators and material etc. were necessary. This way is very investment-intesive and costly
- etc.

In the following we describe the actual condition of knowledge transfer in industrial engineering (Fig. 2): In the theoretical part, methods of industrial engineering are well described and explained and reinforced/consolidated by suitable exercises. However, students often do not get the opportunity to apply these methods in practice (at least at post-secondary institutions) or rather not at a desired scale. Experiencing and applying the methods in practice remains reserved for a real work task and thus “practice“ at a later time. It is known that it is the little things that cause the big problems. This can also be applied to (practical) application. In this area we often observe a didactic gap which we aim to close by our project with digital methods.

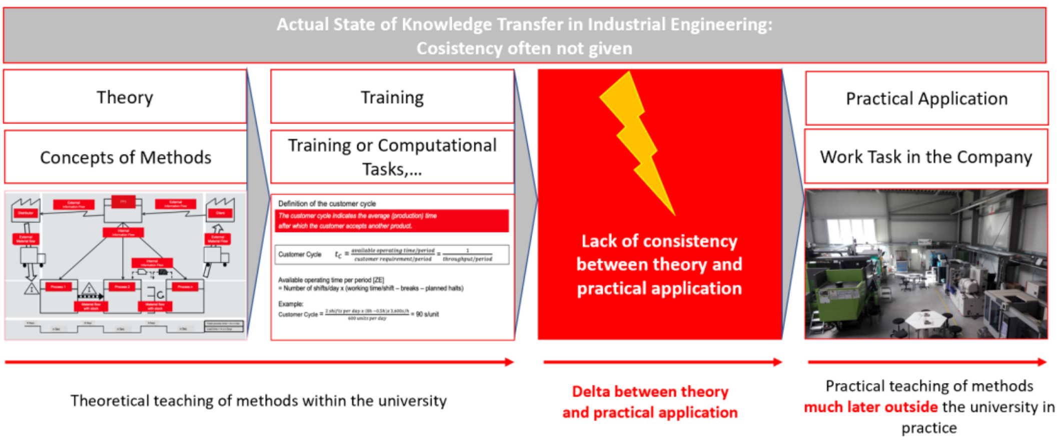

***Figure 2**: Actual state of knowledge transfer in industrial engineering (Fig. on the basis of Erlach 2010; Picture: Th. Gamber)*

3. Desired state of teaching with virtual reality support

In the following, we describe the nominal condition of knowledge transfer in industrial engineering (Fig. 3) which is also the objective of this project.

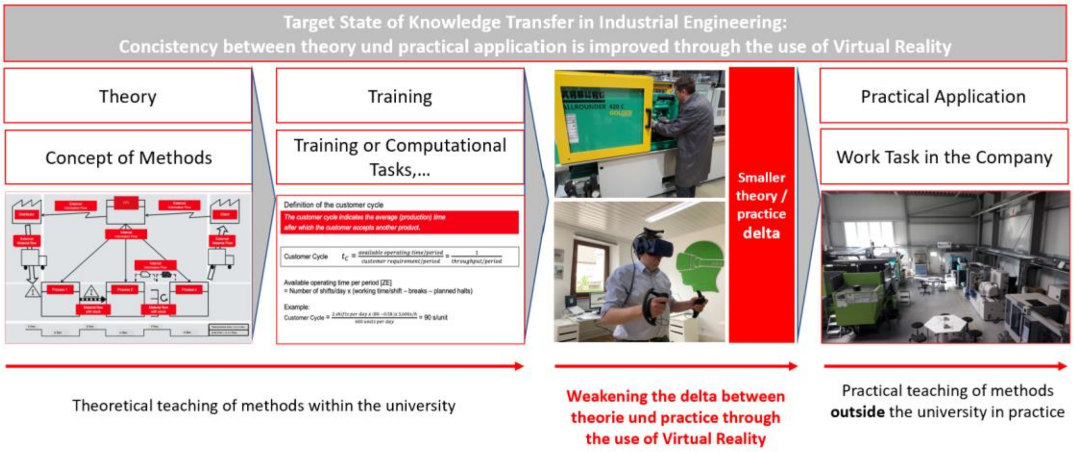

***Figure 3**: Target state of knowledge transfer in industrial engineering (nominal and target condition of knowledge transfer in production (Abb. On the basis of Erlach 2010; Picture: Goppold; li.o.; Knecht li.u.; Gamber,re.)*

To achieve the ideal state (Fig. 1) is, due to financial reasons, is not possible in most post-secondary institutions. Therefore, this project aims to deliver a solution which combines following benefits:

- Minimizing the delta between theory and practice through use of virtual reality technology (knowledge transfer between theory and practice).
- Immediate and practically oriented testing of newly learned methods. Reinforcing

learning content through immediate subsequent practical application in virtual reality.

- Identifying problems in applying methods in practice.
- Faster readiness for use of the methods learned in the later real-life practical case.

Superordinate objective therefore is the completeness of the learning exercise. The goal is to follow the taxonomy levels of Bloom 1972 (1. knowledge→2. understanding→ 3. application→ 4. analysis→ 5. synthesis→ 6. evaluation).

The idea is to close the gap between theory and practice by not allowing any gap to appear. The following table (tab. 1) gives an outline of how this is to be done. Exchange, collaboration and discussion among the students about the issues are essential elements.

Table 1: *Learning modules of the project*

VR-No.	**Subject**	**“Close the GAP“ via VR**
1	Engineering-scientific **basics**	technical mechanics, theory of strength of materials, statics, bending and force distribution
2	Evaluation of the **work system** (REFA 1993) and the **working environment influences** (Schlick et al. 2010)	**noises** (headset VR), **light** (production of shadows, reflections), **haptics** (vibration feedback through controller)

3	**Anthropometry** (Schlick et al. 2010)	Anthropometric analysis
4	**5S / 5A** method (Teeuwen &; Schaller, 2017).	Carrying out the method at a virtual work-place
5	**Value stream** analysis and de-sign (Erlach, 2010)	Observation of a VR-simulated and visual-ized factory process, implementation of pro-cess recording on the work system
6	**Time recording** and **perfor-mance** assessment according to REFA (REFA 1993)	Work processes can be observed in virtuality, time recording exercises are carried out
7	**Work sampling** (REFA 1993)	Work processes can be observed in virtuality, work sampling exercises are carried out
8	Assessing and correctly setting up **screen and office work-stations**	Assessment and set-up of different VR work-stations
9	Assessing and correctly setting up **assembly workplaces**	Assessment and set-up of different VR work-stations

4. Current state of the project, present results

For demonstrational purposes, we deal in the following with the learning modules:

- “Engineering-scientific basics (1)“
- “Assessing and correctly setting up screen and office workstations (7)“.

First, we teach the students the basics of the subject. Together with their teacher, they then can use the virtual environment in multi-player-mode simultaneously and collaborative. Both teacher and students are portrayed as personalized avatars – they can see each other, communicate with each other and move freely in the room. For the time being, it is possible to convey the theory on a virtual blackboard or any other projection surface, just like in a traditional lecture. The special feature here is that this "lecture room" can also be designed directly with a possible later application reference. In the following figure (Fig. 4) we chose a machine hall in which a corresponding task could be carried out. Afterwards, students and teacher discuss and calculate the exercises together in a virtual room. Subsequently, the students carry out a practical task and change individual parameters of the task and carry it out again.

Fig.4 serves as an example from the engineering-scientific basics, here the field of technical mechanics, theory of firmness of materials. The figure depicts a simple girder (bended steel profile) which lies on two supports. All relevant parameters of the assignment are live and individually alterable by the teacher or the students. Example: cross-section profile, elastic modulus, material (steel, wood, concrete etc.), support distance. The students have short-term visual feedback based on practice and can discuss the effects of the changes directly with each other or with the teacher.

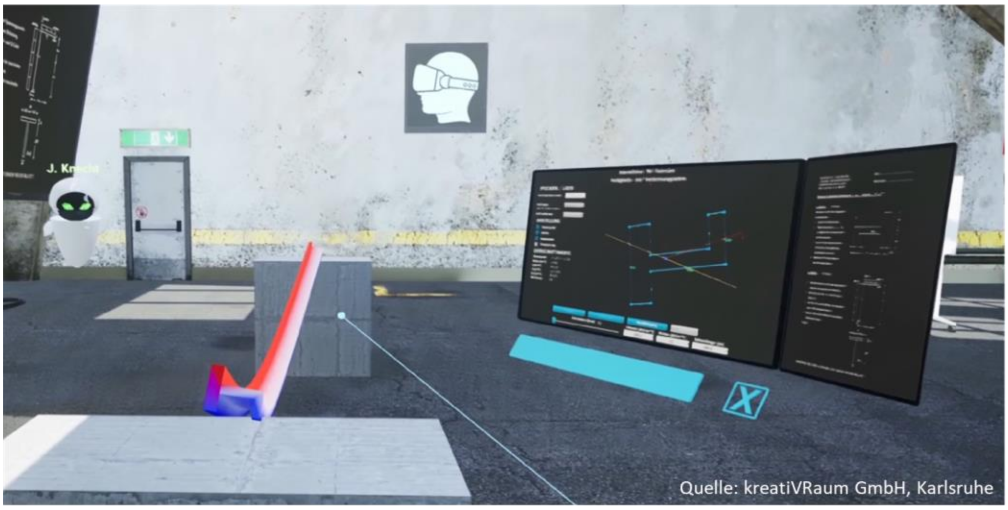

***Figure 4**: Illustration of basic engineering-scientific “theory of strength of materials“ in virtual reality*

In order to illustrate the range of possible applications, we will describe in the following another example from the field of labor science. We explain to the students in advance what they have to pay attention to when setting up office workplaces. The students know which design aspects have to be taken into account.

The following illustration (Fig. 5) shows a screen or office workplace. The students analyze the work systems with regard to technology, ergonomics, human behavior (e.g. disturbances by other people) and organization. In this context, it is didactically useful to discuss workplace regulations and other relevant legal sources. One focus is on the influences of the working environment on the work system. Here, for example, it is discussed to what extent a subjectively perceived "brightness" corresponds to the actually measured values and thus to the legal and occupational science requirements for a particular activity.

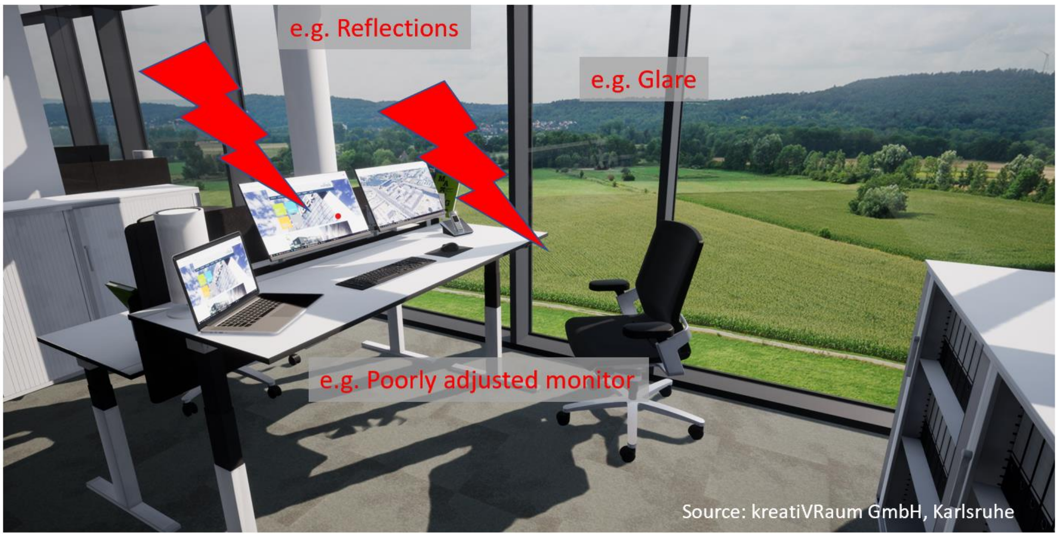

Figure 5: *Illustration of a workstation in virtual reality*

5. Prospects

Once the "Close the Gap" project is completed, it is possible to meet with students collaboratively in the virtual world in multi-player mode and to convey teaching content. The technology used is cloud-based. VR goggles will be used as the output device. It will also be possible to participate in the virtual lectures using an existing desktop PC or laptop. This location-independent setup is a forward-looking feature of the technology used, especially in view of current hygiene requirements. It will be possible to have a joint look at the different virtual work systems and to discuss and evaluate improvement and implementation alternatives from an ergonomic and organizational point of view in the student group. Design improvements in the work system can be made directly and individually or mock-ups of new work systems and thus additional alternatives can be created live and interactively by the students. The potential future "real" work systems are tested with real spatial understanding and are mapped to scale.

Learning takes place in a holistic relationship to people, technology and organizational design aspects. The learning task does not end with the theory or the task sheet "practice". It rather continues in virtual reality in order to close the "gap between theory and practice" in industrial engineering and perhaps even to overcome it to some extent.

6. Bibliographical references

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