A concept for integrated, adaptive course planning for professional industrial training with a case study on a collaborative robot

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Abstract

We present a concept for course planning that is integrated, i.e., developed together with a company and adaptive, i.e., continuously tailored to the participants requirements using their feedback during the course. We also present a case study, applying this concept to online (hybrid) training in a SME industrial environment with a simulated collaborative robot (CoBot).

Key Words: Course Planning, Industrial Training, Collaborative Robots, SME, Agile Work.

1 INTRODUCTION

Often, training courses are generic and do not sufficiently match the requirements of the participants or the industrial context. They are also often static and cannot adapt to emerging needs during the course.

We present a concept for course planning that is integrated, i.e., developed together with the company, and adaptive, i.e., continuously tailored to the participants requirements using their feedback during the course.

An important part of the concept is that the course is based on a use case, preferably using examples that are close to the company's application. The presented concept also supports a low threshold learning start and adapts to more complex content that is tailored to the requirements.

We also present a case study, applying this concept to online (hybrid) training in a small and medium enterprise (SME) industrial environment with a simulated collaborative robot.

The case study is about building the competency of employees in robot programming. The course is based on a real use case: the use of the collaborative robot (CoBot) with a press brake for bending sheet metal. This use case is exemplary and generalisable for other and future scenarios.

We argue that, with somewhat increased preparation time and effort for the instructors, a greatly improved course success and benefit for the participants and company can be achieved, compared to conventional, static courses.

1.1 Context

This work is part of the large interdisciplinary project DigiNet.Air (www.diginetair.de), consisting of the education and aviation associations Hanse Aerospace, HIBB, HCAT+, HECAS, nordbildung, and the universities HAW Hamburg and TU Hamburg. The project promotes and ensures the necessary competence of SMEs in digitization. It is supported by the German Federal Ministry of Education and Research (www.bmbf.de), and the European Social Fund in Germany (www.esf.de).

2 DIDACTICS AND PROCEDURE MODEL (LITERATURE REVIEW)

We will now present the didactic basis for this training course concept and the regarded learning approaches, social constructivism and connectivism, as well as the procedure model for deriving case adaptive education modules.

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2.1 Didactic Concept: The Six Questions for course planning

Our initial didactic concept was tailored to our target group's requirements based on the six didactic questions for course planning (Schlutz, 2006). Figure 1 shows the questions/aspects that should guide course planning according to Schlutz. How this is applied in our concept and in the case study will be presented below.

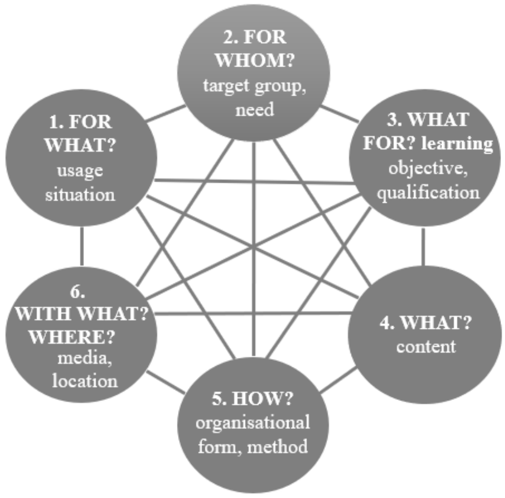

Figure 1: Six didactic questions for course planning, Translated from (Schlutz, 2006)

2.2 Social constructivism

From the social constructivist approach:

1. The Learner is provided a democratic and critical learning experience which serves to open boundaries through inquiry, not through unquestioned acceptance of prevailing knowledge. In a learning community grounded in constructivism, learners mediate knowledge within a social context (St. Pierre Hirtle, 1996). This is promoted in our course concept a) through different representations and demonstrations and b) above all by hands-on practice.

2. Learning is an "intersubjective process of knowledge" in the group (Kergel & Heidkamp-Kergel, 2020). Our course concept aims to promote cooperation, mutual support, and a good working atmosphere.

2.3 Connectivism

According to connectivism (Siemens, 2004), learners form a (digital/hybrid) learning society (Kergel & Heidkamp-Kergel, 2020). In our concept, we emphasize recurring motivation of participants to exchange ideas inside and outside the group.

In connectivism, every learner is also understood as a provider of knowledge who can bring knowledge into the community (Pfeiffer-Bohnen, 2017). There is benefit in participants presenting their solutions and they should be encouraged to do so. If possible, feedback from employee's daily work should be integrated into the couse.

Learning is done by actively connecting content and other resources, both technically and socially (Kergel & Heidkamp-Kergel, 2020). In our concept, the use of different modalities, such as presentation, demonstration, hands-on exercises, and social exchange among attendants is emphasised.

2.4 Procedure Model (previous work)

In one of our previous papers we have explained the procedure model that was developed in DigiNet.Air (R. Isenberg, K. Gutiq, L. Schell-Majoor, 2018). The final results of the procedure model are case adaptive education modules for university and industry. Our concepts in this paper are located and derived in the steps (see Figure 2):

5. Target-process and transformation concepts
6. Prototyping with learning projects and

9. Development of case adaptive education modules.

In DigiNet.Air case studies presented in that paper, we are using the procedure model to derive these learning modules for Industry 4.0 by building demonstrators using collaborative robots and digital twins (R. Isenberg, K. Gutiq, L. Schell-Majoor, 2018).

We focus on the substantial difficulties handling necessary changes of digitization/industry 4.0 which small and medium enterprises (SME) are facing in particular. Especially in the aviation industry, many SMEs are working as suppliers for a few large original equipment manufacturers (OEMs). This calls for fast changing competence requirements.

A commonality with this paper is that in both cases the training uses CoBots and serves as inspiration for business process improvements.

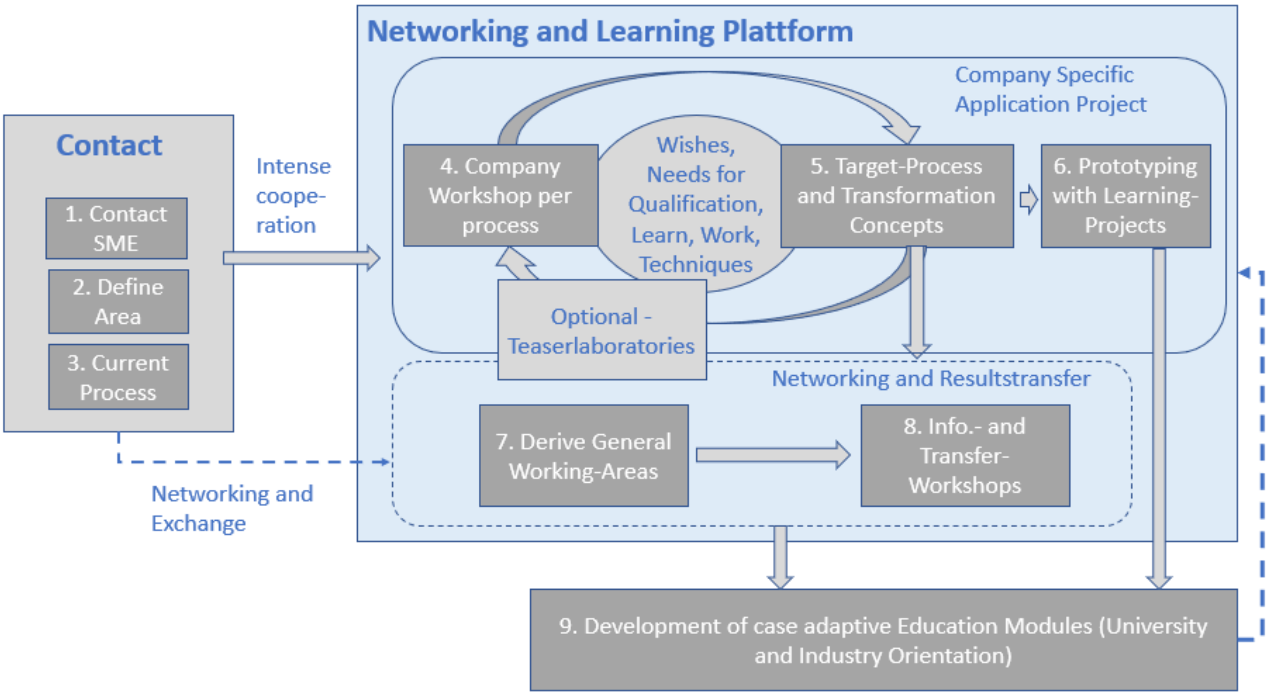

Figure 2: Procedure model DigiNet.Air for deriving case adaptive education modules. Translated from (R. Isenberg, K. Gutiq, L. Schell-Majoor, 2018)

2.5 Individual knowledge and organizational knowledge

Nowadays, knowledge is mainly tied to institutions and employees and, in the form of employee experience, has an important meaning for companies. The connection between employees and knowledge is essential for many companies in order to achieve business success. However, it can be found more and more often that knowledge is being lost with leaving employees (Cruz, 2017).

Organizational learning is a collective term for approaches that enable a company to transform individual knowledge into organizational knowledge (Basten & Haamann, 2018).

2.6 Extension by the presented concept

Some of the presented didactic aspects can be realized in conventional, generic, and static training courses. However, the benefit for participants and company can be greatly increased by tailoring the content to a specific, real use case close to employees' daily experience and adapting to participants' (emerging) requirements by continually integrating their feedback. The following section will present our concept and elaborate on this.

3 COURSE PLANNING CONCEPT

3.1 Didactic concepts

Table 1 shows how the didactic aspects by (Schlutz, 2006), as shown in Figure 1, are applied in our concept and in the case study.

Table 1: Course planning aspects after (Schlutz, 2006) in the presented concept and in the case study

	Aspect	**In the concept**	**In the case study**
1	Usage situation	• industrial training for a specific use case	• application of collaborative robots in the industry
2	Target group	• company employees ○ possibly from different departments ○ possibly with different prior knowledge	• SME employees ○ From different departments with ○ different prior knowledge
3	Learning objective	• build employee competence within the use case • facilitate transfer of knowledge and innovation	• re-setup of the robot after an interruption • understanding and adapting robot programs • ability to recognize possible applications ○ including limits
4	Contents	• lessons based on realistic practical problems	• robot usage, programming, as well as security, technical and ergonomics aspects
5	Learning method	• presentation • demonstration • hands-on exercises	• presentation • demonstration using simulator • hands-on exercises using simulator
6	Media, location	• online • on-site • depending on the use case	• hybrid setting ○ participants on-site ○ instructors online

3.2 Goals

The first goal of a training course is to build participants' competency in the subject matter. This not only enables them to perform better in the specific use case, but potentially to transfer the acquired knowledge to other areas or even to come up with innovative approaches, all of which are of benefit for the employees as well as the company (Dostie, 2017). Innovation is an important competitive factor for improving SMEs performance and for their survival on the market (Dimoska, Nikolovski, Gogoski, & Trimcev, 2014).

A goal for the instructor(s) should be to adapt and improve their courses, i.e. both contents as well as teaching methods.

3.3 Integration

The company should be closely involved in all steps of planning and execution of the course. A thematic roadmap is drawn up at the beginning and coordinated with the company. This roadmap is then continuously adapted to the requirements, based on the input of the participants. (Planning steps according to (Wiegrefe, 2011))

The course should be developed based on real use cases to ensures the relevance and benefit for the company and the participants.

3.4 Feedback

Participants‘ feedback is essential to improve the course. In our concept, it is the basis for adapting the course to the requirements. Especially since requirements can be unknown to instructors as well as participants at the beginning of course planning. Thus, feedback should be encouraged throughout the course as well as collected at the end of sessions. Having a questionnaire helps to elicit initial responses.

3.5 Adaptivity

We extend and integrate the presented didactic methodology and the case-adaptive learning modules from the procedural model with an agile mechanism, by continually adapting the learning principle based on the input of the participants and their practical experience (see below for details).

This approach also allows for a low threshold learning start and adapts to more complex content that is tailored to the requirements.

3.6 Generalisability

While using specific company examples focuses the course for a use case, it can also serve to improve the usability for other industry practitioners, and thus support generalisability. This should be considered during course planning.

3.7 Hands-on Training

An important method are frequent hands-on practice exercises for participants to do on their own or collaboratively. This approach improves knowledge transfer and retainability, as well as acceptance of the course (Sisson, 2010).

4 CASE STUDY

The concept was applied in a case study, comprised of a training course for collaborative robot (CoBot) use and programming for an SME.

4.1 *Participants*

Four participants took part in this course. They were employees of the SME with varying degree of prior knowledge regarding the CoBot, ranging from the head of construction to employees starting to work with the CoBot at the time of the course, to beginners.

4.2 Feedback and adaptation

Participants were encouraged to ask questions throughout the course. Exercises included prompts to do so. Feedback was also collected after every session, first freely, then followed by questions, e.g. on exercise time and difficulty, to encourage participation.

The participants' varied competency allowed for varied, concrete feedback during the increasing course difficulty. Especially participants starting to work with the CoBot gave valuable feedback and posed questions from their daily work experience.

This feedback led to new exercises and topics that were continuously integrated into the course content in between sessions.

4.3 Teaching methods

4.3.1 Collaborative visual annotations

One Method to facilitate collaboration and interactivity during our course was the use of the annotation tool in zoom calls. Participants could visually annotate slides to answer questions, demonstrating and discussing their solutions. Figure 3 shows an example, illustrating the calculation of the gravitational center point of a tool gripper and object combined.

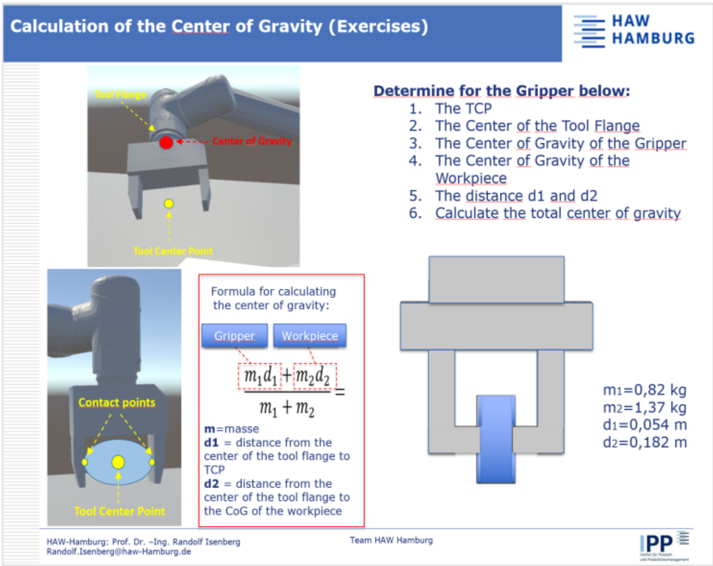

Figure 3: Course content example, calculating the center of gravity for a robotic gripper and grabbed object. As a teaching method, the annotation feature of a zoom call was used by participants to present and discuss their solutions.

4.3.2 realistic examples

Realistic examples were chosen wherever possible, especially to make abstract programming concepts more graspable. See Figure 4 for an example.

4.3.3 Hands-on training

We included frequent hands-on practice. Many topics, such as program commands, included examples and exercises for participants to do on their own or collaboratively. This mostly utilized the UR offline simulator (Universal Robots, 2021). Figure 3 and Figure 4 show example slides for a programming command including a hands-on exercise.

This greatly improved learning and retainability, as well as acceptance of the course. It was one of the aspects that got the most frequent positive feedback. For more on hands-on training see e.g. (Sisson, 2010)

4.4 Motivation and use case

The initial reason for the cooperation with the company was to support a process using a Universal Robot Cobot with a press brake to bend sheet metal. This process needed to be re-established due to loss of an employee's individual knowledge leaving the company. Due to the lack of written instructions from the previous work, we've performed an extensive case analysis for a better understanding of the complex robot program. This use case is exemplary and generalisable for other and future scenarios.

Following this, a need was identified for building and improving the competency of employees in robot programming. This was also considered an innovation driver: employees should be enabled to develop scenarios for new robot use cases.

4.5 Robot Process, business process

The robot process was not regarded in isolation, but the business process in which it is embedded was analysed to improve understanding and possibly find optimization approaches. However, this is outside the focus of this paper.

4.6 Workshop Goals

The main goal was competency building for the robot use case.

Since some employees had varying prior experience with the CoBot, one of the goals of our course was to facilitate a form of organizational learning (see above), to help the company to transform individual knowledge into organizational knowledge, by giving course participants a basis and platform for knowledge exchange.

Another goal was to improve the company's knowledge management for this use case through documentation such as course handouts.

Specific content goals were:

4.6.1 Setup of existing robot process after interruption

For the content of the course, an overarching goal was to enable participants to reactivate a robot process after an interruption, e.g., after the robot has been moved away from the machine. This involved understanding and setting up different coordinate systems in the simulator.

4.6.2 Adaptation of existing process to a changed process

Another overarching goal of the course was to enable participants to adapt a Process/Program to different conditions, such as different bending forms. This required an understanding of many programming commands and procedures.

All of this is to further the use of the robot by employees and their ability to innovate, benefitting them and he company.

4.7 Workshop Content Overview

The Workshop has been designed to master the basics, improve the skills needed to program and deploy the CoBot from beginner to confident robot technician.

4.7.1 Robot basics

An introduction to Universal Robot, terminology, basic programming commands, hardware overview and previous university work with application examples were presented at the beginning of the workshop session.

4.7.2 Configuration of the End-effector

Focus of this workshop-unit were how to set up and connect the Tool and the sensors, as well as how to find and configure the Tool Center Point and how to calculate and teach the center of gravity and the payload. See Figure 3 for an example excerpt of this unit.

4.7.3 Safety and ergonomics

Safety is one of the most important aspect in all press brake (automated) metal bending process. The high tonnage on the moveable traverse poses a great risk of injuring the hands between the punch and the die. In this case the use of a CoBot also serves as a safety measure.

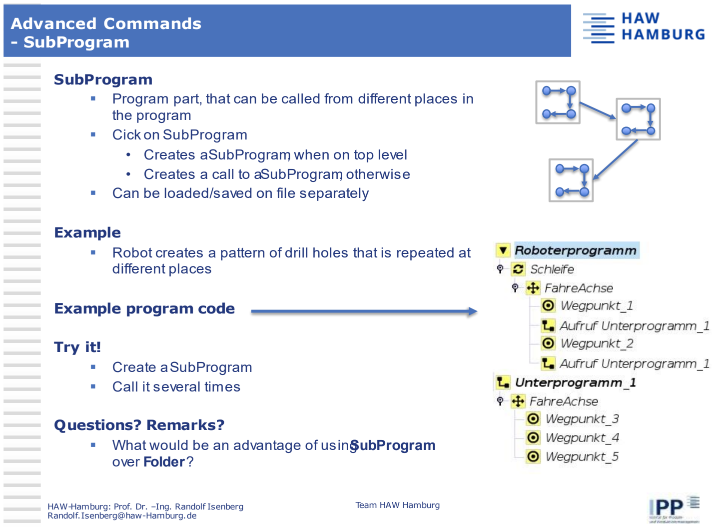

Figure 4: part of a programming command lesson, containing command usage instructions, realistic application example, example program code, hands- on exercise, and prompts for feedback.

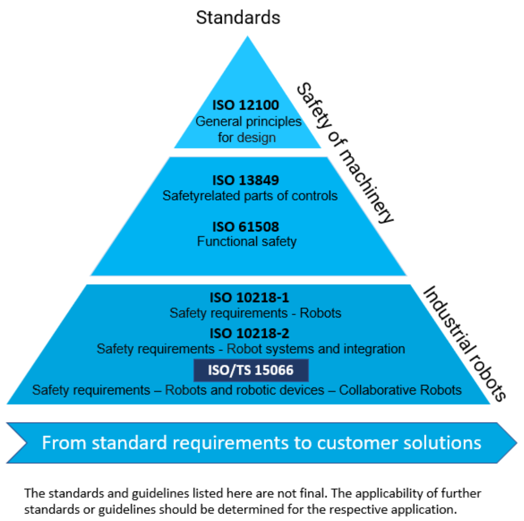

Figure 5: ISO Standards for Human-Robot Collaboration. Translated from (Schunk, 2021)

The importance of the international standard ISO/TS15066 (Figure 5) that determines the technical rules for safe human / robot collaboration has been emphasized in the workshop (Schunk, 2021). The Universal Robot models of the e-Series have a total of 17 TÜV-certified safety functions, the most important of which have been elaborated in the course.

4.7.4 Programming

Programming content ranged from basic commands, like setting waypoints and movement types, to more advanced programming concepts like loops and if conditions, as well as specialised CoBot features.

Program commands always included realistic application examples and exercises for participants to do hands-on on their own or collaboratively, using the UR offline simulator (Universal Robots, 2021). Figure 4 shows an example slide for a programming command including a hands-on exercise.

5 DISCUSSION

5.1 Relevance

The concepts high relevance and benefit to companies is ensured by the didactic concepts and learning methods, and especially by the close collaboration in selecting a relevant a use case, planning and conducting the workshop as well as by the continuous integration of participant feedback and the courses consequent adaptation.

This was validated during and after the case study by very positive feedback, especially on the hands-on exercises and the integration of feedback and suggestions.

5.2 Requirements

This method poses an increased requirement of preparation time and effort from the instructors, not only before the course, but continuously between sessions. However, the result is a greatly improved benefit for the participants and course success.

5.3 Future Work

An application to other use cases in other contexts suggests itself and is considered promising.

We feel that the increased time and effort for preparation is justified by the significantly improved benefit for the participants and company. However, a comparative study, testing our approach against other methods has not been done yet.

5.4 Conclusion

We presented a concept for course planning that is integrated and adaptive, i.e. it is developed closely together with a company and continuously tailored to the participant's requirements using their feedback during the course.

Using specific application examples focuses the course for a use case, but it can also serve to improve the usability for other industry practitioners, and thus support generalisability.

We also presented a case study, applying the concept to a workshop with a specific use case in an industrial context. This proved to be very successful, regarding the benefit for participants and company, as per their feedback.

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