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Concept development for the verification of the didactic competence promotion for the Learning Factory on Global Production

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Abstract

Professional action-related competence of employees plays an increasingly important role for globally operating manufacturing companies to remain competitive. Furthermore, the Bologna process calls for a paradigm change in higher education by placing greater emphasis on the learning process and learner. In order to meet both requirements within the framework of academic teaching and further education, a novel training concept was developed and utilized at wbk's practical and engineering-oriented Learning Factory on Global Production (LGP). The concept aims promoting professional and methodological competencies. Based on specified teaching and learning objectives, indicators are defined to make the promotion of these competencies ascertainable.

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Keywords: Learning factory; global production; competence promotion

1. Introduction

At the beginning of the 21st century, all globally acting companies are challenged by shorter product life cycles, an increasing variety of products and the growing complexity of production processes. In order to face these challenges within a global production environment, the staff's professional competence plays an important role beside the classical competitive factors [1]. In addition, the Bologna Process calls for a transformation of the higher education system moving the learner and the learning process more into focus [2].

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To meet these requirements in university courses, realistic learning environments in the form of learning factories are established at some university institutions dealing with production technology. They aim at enabling students to act in a self-determined and goal-oriented way in a global production environment while promoting the related competencies and skills [2].

However, a comprehensive concept is required in this context, ensuring not only the definition and realization of teaching and learning objectives but also the performance testing. This implies designing a concept to make the promoting of competences measurable.

At the wbk Institute of Production Science of the Karlsruhe Institute of Technology (KIT) a Learning Factory on Global Production (LGP) has been built up where courses and lectures are organized and offered as modules consisting of one e-learning unit and/or an attendance phase, for which a concept has been developed to demonstrate the didactic competence promotion. This concept is based on a didactic-methodological concept for the learning factory and its defined teaching and learning objectives and on the associated competence atlas [2]. The idea of this approach is to address competence promotion with regard to knowledge acquired prior to the course in the context of e-learning units, activities during the attendance phase and interactions between the participants. From the above mentioned aspects, a concept can be derived that represents a recommendation for executing success monitoring as part of the course at the wbk Institute of Production Science. The sequence of the multi-level approach is illustrated in figure 1. In the following section, definitions relevant for the structuring of the aforementioned concept are are outlined.

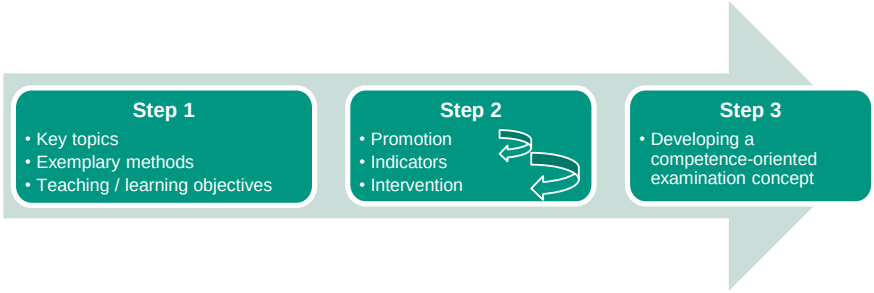

Fig. 1. Sequence of the multi-level approach to finally derive a competence-oriented examination concept.

2. Theoretical bases

2.1. Professional action-related competence

To clarify the term of professional action-related competence, the meaning of action and competence must first be defined before these two words can be merged.

Taking the definition of [3], actions are defined as target-oriented executions with a known inner structure that generate a tangible result. Moreover, [3] points out that an action should not only be understood as a direct practical activity but also as a mental reconstruction. Another structural characteristic of an action is its multidimensionality. According to [4], action is performed multidimensionally, i.e. acting requires a combination of multiple skills. The level of multidimensionality in a specific professional context can vary but the focus is basically always on the interaction of these competence facets.

According to [5], competence is the capability of a person to use a system of rules such as the one of a language with the objective of performing well in the most different contexts. Furthermore, competencies are often described as dispositions for self-organizing physical and psychological actions [6]. For [7] this means that competencies cover all skills, abilities and knowledge portfolios of a human being which enable that person to act in his or her professional environment. Furthermore, [7] differentiates by giving four facets of competence: professional, methodological, social and self-competence. This differentiation into four competence facets is taken as a basis by the wbk for the LGP [2]:

- Professional competence includes task-specific knowledge, professional skills and expertise as well as the capability to recognize and solve problems in that particular field.
- Methodological competence comprises skills that can partly be applied independently from the specialist fields for analyzing problems in a structured manner and for taking decisions in a targeted manner, in some cases also cross-situationally.
- The social competence involves the ability to have social interaction and to act in a cooperative and communicative way. This also includes the collaborative development of goals and plans in a specific department.
- Self-competence comprises the ability for self-evaluation (reflection) as well as the ability to develop one's own personality. Especially the personal, motivational and emotional aspects are at the forefront here.

In an international environment, these four competence facets can be expanded to intercultural competences, if the cooperation between people from foreign cultures integrates their specific concepts of perception, thinking, feeling and acting [8].

According to [9], the professional action-related competence is defined as a competence related to situations in the working environment. The action competence always results from the synthesis of both elements action and competence. In simple words, it can be defined as the ability and readiness of an individual to act in a certain professional context.

2.2. The recording of competencies

Competence is not measurable but it appears when coping with challenging situations and, also known as performance. In order to be able to grasp the professional action-related competence, appropriate criteria need to be developed for the four facets: professional, methodological, social and self-competence. These criteria, their specification and operationalization through teaching and learning objectives and the behavior descriptions may finally indicate the presence of an appropriate competence [10].

An important contribution to the assessment of the four defined competence facets is given by an observation procedure for objective measurement of professional action-related competence. In this respect, indicators are derived based on the defined criteria which describe the criteria in more detail by means of observable behavior and finally allow to record the respective competence facet. For this, the use of an observation form is recommended as a tool [10].

2.3. Layout of success controls

The competence recording as a proof of performance can be done by measuring the written, oral or practical performance. A distinction can be made whether a question should be answered freely or if an answer must be chosen from a given number of response options. The more a task is freely formulated, the more difficult it is to objectively record or assess it. At the same time, a high cognitive level can barely be tested with multiple choice questions [11]. Additionally, it needs to be considered from a test-didactical point of view that many types of examination are related to each other and can be combined. Frequently, there is no clear differentiation between the individual tasks of these examinations. It is more common that single functions overlap [12]. Figure 2 provides an overview of common types of examination at universities [11].

2.4. Quality criteria of exams

One central problem of the examination system consists in the fact that the result of an exam does not only depend on the knowledge, skills and abilities of the candidate but also quite often on subjective and situative factors [13]. In order to avoid this scenario, certain test quality criteria should be used as an evaluation scale for performance

assessments [12]. Regarding the university context, four requirement criteria are presented by [14] for an examination. These are: objectivity, reliability, validity and economy, as shown in figure 3.

Basically, these criteria always need to be fulfilled for all testing procedures and performance measurements, but in practice they can never be maximized simultaneously. The challenge lies in finding an optimum and to balance the four demands in a way that is appropriate to the given exam situation. This can turn out very differently depending on general conditions, objectives and the function of the examination [11].

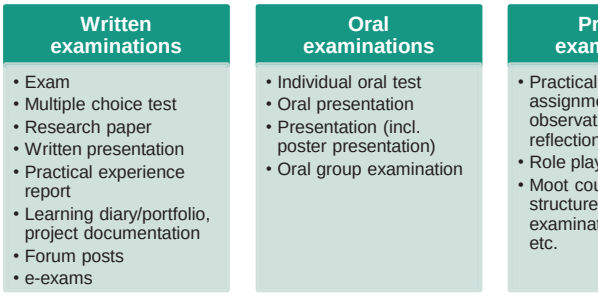

Fig. 2. Examination methods at universities.

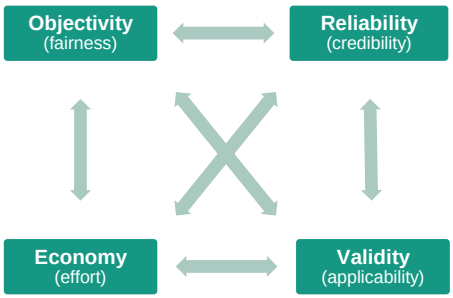

Fig. 3. Interplay of quality criteria of exams.

3. Learning Factory on Global Production at the wbk

The multistage training concept of the LGP is divided into six teaching modules making a distinction whether a module just contains an e-learning unit or an e-learning unit combined with an attendance phase. Above all, the focus is on the development of professional and methodological competence.

The participants work through the e-learning units in the form of a self-study and the materials are provided by the wbk on the e-learning platform called ILIAS, the German abbreviation for Integrated Learning, Information and Work Cooperation System. Subsequently, the level of knowledge needs to be examined with the help of online tests.

In reference to the attendance phases, it should be noted that they consist of multiple theory phases, group work and action rounds in a specific sequence. In designing and performing these courses, an electric motor for seat adjustment in different variants is involved as a real product. The theoretical training phases serve above all the purpose of communicating scientific contents provided by the instructors of the learning factory at the wbk. Participants should become familiar with the procedures for implementing, optimizing and analyzing the assembly process of an electric motor. During group work, participants discuss and outline possible approaches in small groups and present the result to the other participants before applying and testing these skills in an action round in the LGP on site.

The objective of the learning factory mainly lies in acquainting the participants with the chances and challenges of global production as well as in increasing their professional competence in this realistic demonstration environment at the wbk. Since this concept shall be offered as a graded course, it is imperative to record and assess the competence advancement.

4. Concept development for the verification of the didactic competence promotion for the LGP

4.1. General conditions of competence promotion

The analysis of the didactic parameters shall aim at identifying the already existing prerequisites for the individual modules. The wbk has previously determined key topics, exemplary methods and learning objectives. The key topics describe which areas enjoy the main emphasis and thus reflect the event's core subjects. Furthermore, they exemplarily state the methods that shall be applied. Even greater significance is attached to the definition of the learning objectives.

The wbk has therefore specified the level of knowledge the participant must entail after completing the respective module. This shall now exemplarily be illustrated in figure 4 by developing the teaching module ‘site-specific production planning’.

Key topics	Examplary methods	Learning objectives
• Production line and material flow planning • Production control	• Value stream mapping and design • Material flow optimization and layout planning • Production control • Shopfloor management and continuous improvement process (CIP)	• Participants should understand the fundamentals of lean management and should be able to transfer them to practical applications. • Participants should be able to implement an assembly planning strategy for a small series with multiple variants under expert supervision. • Participants should be able to understand and apply the basic methods of factory planning.

Fig. 4. Key topics, exemplary methods and learning objectives of the LGP module site-specific production planning.

4.2. Development of the overall concept

Building on these framework conditions, the aspects have successively been defined with respect to advancement, indicators and intervention. Advancement refers to the competencies that shall be boosted in the individual phases of the module. Furthermore, the question arises which features, so-called indicators, reflect that didactical competencies have been fostered in a targeted manner. Intervention usually deals with how instructors can interfere in the participants’ learning process to prevent undesired phenomena from arising in the learning process and person [15].

Figures 5 and 6 illustrate the advancement, indicators and intervention for the learning module on the topic of site-specific production planning using the example of professional and methodological competence. This teaching module consists of an e-learning unit as well as of a two-day application phase. The indicators are based on the advancement, whereas the intervention is based on the advancement as well as the indicators (figure 1).

	Professional competence		
	Promotion	Indicators	Intervention
Comprehen-siveness of specific trouble-shooting	Participants learn the fundamentals of lean management.	Participants can identify the problems of lean management.	The instructors recommend that the participants take notes for performing the tests when elaborating the learning units on the topic of site-specific production planning in ILIAS.
Comprehen-siveness of subject-specific solution handling	Participants are familiarized with basic methods of factory planning (e.g. value stream mapping and design, material flow optimization and layout planning, production control, shopfloor management and CIP).	Participants can assess the basic methods of factory planning.	Also in this case, the instructors suggest note taking while participants work on their learning units on site-specific production planning in ILIAS in relation to the tests that will take place later.
Subject-specific application orientation	Participants learn to practically apply the basic principles of lean management, i.e. planning under guidance the assembly for a multi-variant small series of a real product such as the electric motor as well as applying the basic methods of factory planning.	With the help of the learned theoretical basics of lean management, participants can perform under guidance an assembly planning for a multi-variant small series of a real product such as the electric motor and can apply the basic methods of factory planning.	The instructors explicitly demonstrate the participants examples of applied methods of factory planning in the teaching units of ILIAS as well as in the theory phases on site. Furthermore, the instructors support the participants in planning the assembly of electric motors by guiding them.

Fig. 5. Professional competence promotion, indicators and intervention in the LGP module of site-specific production planning.

	Methodological competence		
	Promotion	**Indicators**	**Intervention**
Analysis of inter-disciplinary problems	Participants learn to analyze cross-situational problems of site-specific production planning and how they are linked to each other.	Participants can analyze cross-situational problems of site-specific production planning and, they are able to link them with each other.	The instructors remind the respective participants during group work and action rounds of the previously discussed approaches and strategies for a structured analysis of problems in site-specific production planning if the instructor believes that the phase is not proceeding according to plan.
Creating problem-solving processes	Participants learn to transfer known methods for planning, executing and controlling the factory planning to new contexts.	Participants can transfer the learned approaches and strategies for planning, executing and controlling the factory planning to new contexts.	Participants are made aware of the previously learned methods of planning, executing and controlling the factory planning by the instructors during group work and action rounds if the phase does not meet the instructor's expectations.
Applying problem-solving techniques	Participants learn to transfer their knowledge to group work and action rounds closing the gaps in knowledge regarding the process of applying the methods for planning, executing and controlling the factory planning.	Participants can transfer their knowledge to group work and action rounds and close their gaps in knowledge regarding the process of applying the methods for planning, executing and controlling the factory planning.	The instructors point out the methods for factory planning and their appropriate use to the participants during group work and action rounds if the phase develops differently than expected. Moreover, the instructors ask participants to actively participate and act appropriate to the situation if they fail to do so.

Fig. 6. Methodological competence promotion, indicators and intervention in the LGP module of site-specific production planning.

4.3. Recommendations for competence-oriented examination

In the following, an examination concept shall be derived based on the learning objectives and the competence atlas. The learning units of the e-learning phase shall be dealt with first. Subsequently, the application phase shall be referred to. The wbk sees the focus of the e-learning phase on promoting professional competence, upon which the success control shall be based on as well. Written and oral forms of examination are particularly suited to measure and evaluate the systematic didactic promotion of professional competence based on the specified indicators. According to figure 2, several options are principally available. In addition to the conventional written examination, it is also suggested to use the web-based learning concept on ILIAS for testing the performance. The correction effort could substantially be reduced by using the web-based examination, exclusively comprising of multiple choice questions with its subsequent electronic evaluation. However, answers to multiple choice questions are generally a product of chance or stem from competencesleading to the conclusion that competencies cannot really be tested with it. Consequently, the examination should consist, at the most, of a mix of open ended and multiple choice questions.

Measuring and evaluating the competence facets of the theory phases, group work and action rounds shall be discussed for the application phase. The various competencies of the application phase call for dividing the examination according to these facets.

The main focus of the theory phases lies on the promotion of professional competence by the lecturers of the wbk. Consequently, an examination concept for the theory phases primarily concentrating on professional competence shall be derived. Again, written and oral forms of examination are principally conceivable if the tasks are formulated in a competence-oriented manner. An oral examination is recommended for generating a methodological mix. Above all, adhering to the principle of objectivity is to be regarded as critical in this context, however, it also entails the benefit of being able to individually respond and communicate directly with the examinee.

It is suggested that the group work and action rounds focus on acquiring methodological competence as well as social and self-competence since they are emphasized here. Furthermore, it shall be noticed that tasks and questions practically relevant to engineering are addressed in the group work and action rounds and are tested at the learning factory. It is thus reasonable to opt for a practical form of examination whereupon a practical work assignment with

observations is recommended. Based on defined indicators, the students' behavior shall be observed and assessed afterwards for evaluating the above-mentioned competencies. Using a categorized observation sheet as a tool is recommended for this purpose.

However, it is also demanded that the targeted didactic promotion of competence facets must form part of the teachings at the wbk before it can be addressed with the application of the indicator-based examination concept.

5. Summary and outlook

Today, vocational competence is gaining ever-increasing significance in the global production environment as well as the university education system. In order to meet this challenge, the wbk has placed its focus on the targeted didactical promotion of professional and methodological competence in the LGP whereas fostering the social and self competencies is largely neglected. Verifiable conclusions about the promotion of the competence facets can be drawn with the help of indicators based on the previously defined learning objectives. The desired promotion of competence and its indicators have been defined for the areas of the e-learning units as well as for the theory phases, group work and action rounds of the application phase of the six learning modules. Furthermore, interventions have been determined where instructors deliberately interfere in the participant's learning process to prevent undesired phenomena.

Subsequently, a concept for the competence-oriented examination has been derived for the LGP. It must be noticed that only those competencies can be captured and evaluated whose promotion has previously been subject to teaching. In this respect, a recommendation is pronounced suggesting a written examination, an oral group test as well as a practical work assignment with observations and appropriate weighting. For the latter, an observation sheet has been elaborated serving as a tool for assessing the competencies with the help of indicators.

It also needs to be considered in which form the social and self-competencies can didactically be promoted in a systematic way. Above all, an adequate engineering-specific promotion of social competence is suggested, also for justifying the assessment of this competence facet in relation to the competence-oriented examination in the LGP.

In addition to these aspects, the whole concept consisting of the six learning modules also considers the global working environment. Above all, it means that intercultural professional and intercultural social competences are part of the LGP which also will be promoted more in the future.

Furthermore, the elaborated evaluation sheet should be pretested for the purpose of validation in order to identify, if necessary, required adaptations of the present design. In addition, it is suggested to observe at various points in time to identify and evaluate the participants' competence-oriented development throughout the course.

Moreover, it shall be mentioned that competence-oriented vocational training for industry participants is also conducted at the LGP in addition to university education which calls for an individual adapting of the elaborated concept.

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References

[1] Tisch M, Hertle C, Cachay J, Abele E, Metternich J, Tenberg R. A systematic approach on developing action-oriented, competency-based Learning Factories. In: Procedia CIRP. *Forty Sixth CIRP Conference on Manufacturing Systems 2013.* 2013, Vol. 7, p. 580-585.

[2] Lanza G, Minges S, Stoll J, Moser E, Haefner B. Integrated and Modular Didactic and Methodological Concept for a Learning Factory. In: Procedia CIRP. *6th CIRP Conference on Learning Factories.* 2016, Vol. 54, p. 136-140.

[3] Aebli H. *Zwölf Grundformen des Lehrens. Eine Allgemeine Didaktik auf psychologischer Grundlage. Medien und Inhalte didaktischer Kommunikation, der Lernzyklus.* Stuttgart: Klett-Cotta; 2001.

[4] Laur-Ernst U. Handeln als Lernprinzip. In: Reetz L, Reitmann T, editors. *Schlüsselqualifikationen. Dokumentation des Symposions in Hamburg. Schlüsselqualifikationen – Fachwissen in der Krise?* Hamburg: Feldhaus; 1990, p. 145-152.
[5] Nickolaus R. *Didaktik – Modelle und Konzepte beruflicher Bildung. Orientierungshilfen für die Praxis.* Baltmannsweiler: Schneider Verlag Hohengehren; 2008.
[6] Erpenbeck J, Rosenstiel L von. Einführung. In: Erpenbeck J, Rosenstiel L von, editors. *Handbuch Kompetenzmessung. Erkennen, verstehen und bewerten von Kompetenzen in der betrieblichen, pädagogischen und psychologischen Praxis.* Stuttgart: Schäffer-Poeschel; 2007, p. XVII-XLVI.
[7] Wagner C, Heinen T, Regber H, Nyhuis P. Fit for change – Der Mensch als Wandlungsbefähiger. In: *wt Werkstattstechnik online*. 2010, Jg. 100, H. 9, p. 722-727.
[8] Giesche S. *Interkulturelle Kompetenz als zentraler Erfolgsfaktor im internationalen Projektmanagement.* Hamburg: Diplomica Verlag; 2010.
[9] Schwadorf H. *Berufliche Handlungskompetenz. Eine theoretische Klärung und empirische Analyse in der dualen kaufmännischen Erstausbildung.* Stuttgart: ibw Hohenheim; 2003, Bd. 5.
[10] Simon M. Leistungsmessung und -bewertung im handlungsorientierten Unterricht an kaufmännischen Schulen. In: Neef C, Verstege R, editors. *Kernfragen beruflicher Handlungskompetenz. Ansätze zur Messbarkeit, Umsetzung und empirischen Analyse.* Stuttgart: ibw Hohenheim; 2005, Bd. 6, p. 7-33.
[11] Walzik S. *Kompetenzorientiert prüfen. Leistungsbewertung an der Hochschule in Theorie und Praxis.* Opladen: Barbara Budrich; 2012.
[12] Jungkunz D, Litz A. Handlungsorientierte Berufsabschlussprüfungen der Industrie- und Handelskammer – Analyse und Bewertung der ausgewählten Prüfungsform ‚Betriebliche Projektarbeit'. In: Neef C, Verstege R, editors. *Kernfragen beruflicher Handlungskompetenz. Ansätze zur Messbarkeit, Umsetzung und empirischen Analyse.* Stuttgart: ibw Hohenheim; 2005, Bd. 6, p. 35-62.
[13] Lampe M. *Gerechtere Prüfungsentscheidungen. Möglichkeiten und Grenzen der Herbeiführung materieller Gerechtigkeit durch gerichtliche Kontrolle und Gestaltung des Verwaltungsverfahrens.* Berlin: Duncker und Humblot; 1999.
[14] Metzger C, Nüesch C. *Fair prüfen. Ein Qualitätsleitfaden für Prüfende an Hochschulen.* St. Gallen: Institut für Wirtschaftspädagogik; 2004, Bd. 6.
[15] Hussy W, Schreier M, Echterhoff G. *Forschungsmethoden in Psychologie und Sozialwissenschaften.* Berlin: Springer-Verlag; 2013.