Following three years’ experience of piloting large-scale competence diagnosis in electrical engineering, an initial appraisal can be made of the scope and limits of this new instrument for the measurement of vocational competence. The competence levels and skill profiles of test groups from various forms of vocational training can be determined on a comparative basis, which examinations cannot do. The prerequisite is a psychometrically tested competence and measurement model. The collection of contextual data make this procedure an effective instrument for the analysis and design of vocational training processes and structures.

This article introduces the conceptual foundations and findings of the KOMET project conducted at the Institute for Vocational Education and Training (I:BB) in Bremen.

Why competence diagnosis?

Even though the idea of a PISA study on vocational education and training (VET) has become somewhat jaded and has been the target of criticism (Bundesanzeiger No 104/2009), it still serves as a reminder of the value, in terms of education policy and economics, of discovering whether and in what ways investments in VET are cost-effective. The collection of contextual data, for example on training design in companies and vocational colleges, also permits a remarkably detailed analysis of the prerequisites and conditions for good and not-so-good training structures. This in turn can serve as the basis for strategic and political conclusions on the organisation and design of training processes. Large-scale competence diagnosis represents a formidable challenge to VET researchers. Two questions are at the heart of this article, which reports on the KOMET project conducted at the Bremen-based Institute for Vocational Education and Training (see box).

Key data on the KOMET project

<table>
<thead>
<tr>
<th>Aim:</th>
<th>To measure the occupational competence and professional commitment of electronic engineers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test subjects:</td>
<td>Since 2007, 700 test subjects in Hessen and Bremen from the dual system of vocational training and technical colleges; 800 test subjects in Peking from vocational sandwich courses and higher technical colleges, plus 40 instructors</td>
</tr>
<tr>
<td>Consortium:</td>
<td>Hessen Ministry of Education, the Bremen Senator for Education and the RIBB, Beijing</td>
</tr>
<tr>
<td></td>
<td>Academic support by the I:BB Research Group at the University of Bremen, headed by Professor Felix Rauner; psychometric testing by Dr Birgit Erdwien of Erdwien Consulting, Bremen, Dr Thomas Martens of DIPF, Frankfurt, and Dr Lars Heinemann of the I:BB at the University of Bremen; instructors, lecturers in specialised instructional techniques and instructor training: Hessen steering group and Bremen steering group as well as 30 assessors from Hessen and Bremen and 30 from Beijing</td>
</tr>
</tbody>
</table>
1. Can the theoretical and standards-based KOMET competence model (see grid on page 25) be transformed into a psychometric model, and can the latter be used to measure vocational competence?

2. What experiences were gained during the three years of practical testing based on the KOMET methods?

What can and cannot be tested using large-scale competence diagnosis?

The establishment of the German Research Foundation’s Priority Programme on Competence Models for Assessing Individual Learning Outcomes and Evaluating Educational Processes saw empirical educational researchers reach agreement, if they had not done so before, on a pragmatic definition of competence as a basis for empirical skills research (see Klieme and Leutner, 2006). According to that definition, competence is a cognitive disposition to perform in a specific way in a specific context, since areas of competence can, to a certain extent, be generalised by extension to similar situations. Motivational and affective factors are disregarded (Hartig and Klieme, 2006, p. 18). On the basis of this definition, there is a distinction in vocational education and training between the cataloguing of areas of competence on the one hand and the checking of skills on the other.

- Examination (within the meaning of the German Vocational Training Act (Berufsbildungsgesetz)) of the skill requirements defined in the occupational profiles is intended to check all of the skills that are relevant to a person’s aptitude to practise a particular occupation.
- The measurement of occupational competence in the sense of cognitive potential is intended to determine competence levels or profiles, particularly in the context of a comparison between different test groups.

The definition of the function of large-scale competence diagnosis makes it advisable to begin by highlighting what its methods cannot be used to measure (see Table 1).

Measuring occupational competence

CONCEPTUAL FRAMEWORK

The measurement of occupational competence presupposes a theoretical and standards-based competence model that can be developed into a measurement model based on psychometric criteria (see Martens and Rost, 2009, pp. 95 et seq.). Competence models have the following functions:

- to operationalise the fundamental criteria that have to be met in the context of problem-solving in the workplace as well as the associated principles and objectives of vocational education and training, and

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This exclusion is not transferable to vocational training, since occupational commitment based on the development of a sense of occupational identity is actually a key aim of vocational training alongside the development of vocational skills. For practical reasons these aspects are dealt with separately in the KOMET project (see Heinemann and Rauner, 2009)
• to provide sufficiently concrete guidelines for the formulation of test assignments.

Table 1  Aspects of ability and learning that cannot be measured by large-scale competence diagnosis

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tacit knowledge</td>
<td>In the practice of occupational activities, tacit knowledge is observable, particularly through skills that depend on such knowledge, and its quality can be assessed, but it does not lend itself to explicit description and explanation in specialised terminology. It thus remains a mystery why, for example, a toolmaker is able to file down a smoother surface than any grinding and milling machine.</td>
</tr>
<tr>
<td>Occupational aptitude</td>
<td>This is established through the various forms of testing. These chiefly comprise the checking of all the skill requirements laid down for the assessment of occupational aptitude in respect of each of the defined occupational profiles. It is a matter of testing the skill requirements defined in the occupational profiles in real workplace situations.</td>
</tr>
<tr>
<td>Social skills</td>
<td>Very high priority attaches to social skills in the workplace and hence in vocational training too. It is questionable whether social skills can be measured as key areas of interdisciplinary competence. For primarily practical reasons, social skills have not yet been measured by large-scale competence diagnosis.</td>
</tr>
<tr>
<td>Abilities that come into play in interactive work processes</td>
<td>These abilities relate to the creative type of activity, as opposed to goal-driven activity. There are limits to the scope for theoretical planning of outcomes in this type of activity. Particularly where options have to be sought, ideas conceived and solutions found in a given situation, the measurement of occupational competence becomes well nigh impossible.</td>
</tr>
<tr>
<td>Manual dexterity</td>
<td>In numerous occupations, manual dexterity is a major criterion of occupational aptitude. It is likewise beyond the scope of large-scale competence diagnosis.</td>
</tr>
</tbody>
</table>

For the identification of the basic criteria for work-related problem-solving in the KOMET project, a level of abstraction was chosen that makes it possible to define these criteria on an interdisciplinary basis. An analysis of occupational profiles and training curricula and of marking guides in cases where test assignments were used to assess the development of occupational competence in the GAB pilot project (see Bremer and Haasler, 2004) resulted in the identification of eight criteria which occupational problem-solving must satisfy (see Table 2). It is therefore logical to incorporate these criteria into a competence model for vocational training so that the reality of the workplace and the associated principles and objectives of vocational training can be reflected in the formulation of test assignments and in the assessment of their outcomes.
THE TWO-DIMENSIONAL KOMET COMPETENCE MODEL

The two-dimensional KOMET competence model distinguishes between the *expectations dimension* (competence levels) and the *content dimension*.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Criteria for measuring occupational competence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functionality</strong></td>
<td>This criterion relates to instrumental specialised competence and hence to non-contextual specialised knowledge. The ability to perform a task functionally is basic to all other requirements in the realm of occupational problem-solving.</td>
</tr>
<tr>
<td><strong>Clarity/Presentation</strong></td>
<td>The outcome of occupational tasks is anticipated in the planning and preparation process and is documented and presented in such a way that the task-setters (superiors or customers) can communicate and assess the proposed solutions. That is why this is a basic form of occupational activity and vocational learning.</td>
</tr>
<tr>
<td><strong>Sustainability/Focus on utility value</strong></td>
<td>Occupational work processes and assignments always relate to customers, who are interested in high utility value and sustainable solutions. In work processes with extensive division of labour, the aspects of utility value and sustainability often fade from the minds of employees as they go about their tasks. By emphasising sustainable solutions, vocational training helps to counteract this phenomenon.</td>
</tr>
<tr>
<td><strong>Cost-effectiveness/Efficiency</strong></td>
<td>Occupational tasks must, in principle, be performed economically. The competence of skilled workers is reflected in their consideration of cost-effectiveness in the context of their occupational duties.</td>
</tr>
<tr>
<td><strong>Business and process orientation</strong></td>
<td>This criterion covers aspects of task performance that take account of the higher and lower tiers of the company hierarchy (the hierarchical aspect of the business process) and of the upstream and downstream links in the process chain (the horizontal aspect of the business process).</td>
</tr>
<tr>
<td><strong>Social acceptability</strong></td>
<td>This criterion primarily relates to the ergonomics of the work process and workplace organisation, to health and safety and, where appropriate, to the social aspects of working life that transcend life on the shop floor.</td>
</tr>
<tr>
<td><strong>Environmental compatibility</strong></td>
<td>This is a criterion which is relevant to almost all work processes. It is not a question of general environmental awareness but of the environmental requirements specific to particular occupations and specialisations in so far as they affect work processes and their outcome.</td>
</tr>
<tr>
<td><strong>Creativity</strong></td>
<td>This is an indicator that plays a leading role in the performance of occupational tasks. One reason for this is the extreme variations in the scope for creativity in the performance of occupational tasks in different situations.</td>
</tr>
</tbody>
</table>

The eight competence criteria listed in Table 2 are assigned to the skill levels, which are of fundamental importance in assessing the proper performance of occupational tasks (see Figure 1). For the modelling of the expectations dimension (skill levels), the KOMET competence model is based on the four-stage scientific and technical literacy model proposed by Bybee (1997), which was also used in the PISA project:

- **Nominal scientific and technological literacy**: at this first level of competence, apprentices possess superficial conceptual knowledge which is not yet applicable in practice in terms of occupational ability. Their understanding of occupational terminology scarcely goes beyond the colloquial use of specialised terms. Since the level of occupational competence is not reached at this stage, it is not included in the grid.

- **Functional literacy**: at this stage, instrumental abilities in a discipline are based on the requisite elementary subject knowledge and skills, although their connections and their occupational applications have not yet been fully assimilated. ‘Specialisation’ amounts to non-contextual specialised knowledge and corresponding skills.

- **Procedural literacy**: occupational tasks are interpreted and addressed in terms of their relationship
to work processes and workplace situations. Aspects such as economic viability and customer and process focus are now taken into account.

- Multidimensional literacy: at this level of competence, occupational tasks are considered in their full complexity with due regard to the diverse operational and social conditions in which they are performed and to divergent requirements in terms of the work process and its outcome.

The selection of typical substantive elements of an occupation can serve to decode the content dimension of occupational competence in terms of structures based on the development continuum ‘from novice to expert’ in a given discipline. Thereafter, a distinction is made between four stages of learning, in accordance with which the occupational activity and learning areas are structured on the basis of a development continuum into areas for beginners, advanced beginners, advanced trainees and experts. On this basis, content can be developed for the formulation of test assignments by reference to the subject’s stage of training (see Becker, 2009, pp. 241-242, and Rauner et al., 2009(a), chapter 2.1). The test assignments developed and set in the framework of the KOMET project related to the developmental stage of readiness for employment.

TEST ASSIGNMENTS

The format of test assignments is based systematically on occupational practice and on the principle of a training system geared to procedural and creative competence. This gives rise to the following three fundamental requirements for the design of test assignments:

1. The degree of complexity must be set at such a level that contextual understanding – and not just a collection of distinct skills – can be measured.
2. Open-ended test assignments are necessary, since specialists must choose between alternative solutions when performing occupational tasks.
3. The content of test assignments must be characteristic and representative of the occupation in question. It is not necessary to cover the whole occupational profile in all of its disciplinary breadth in test assignments.

The assessment of open-ended test assignments with the aid of checklist items that have been used to operationalise the eight skill criteria requires the description of a feasible area within which the various candidate solutions can be situated. In the performance of these test assignments, the level of occupational competence is revealed in the way in which the whole feasible area covering the potential solutions is exhausted in terms of its eight competence dimensions.
A typical test assignment comprises a realistic description of a scenario. The specifications for professional problem-solving can be derived from this.

**Example of a test assignment**

One test assignment, for example, describes the basic conditions for the conversion of an existing storage area into a drying area for painted machine parts, using a sketch to illustrate the scenario.

**Task:** Draw up a concrete proposal for the conversion and the electrical wiring of the area. Present your design with the aid of practice-related documentation. Provide a comprehensive and detailed explanation of your proposed solution. Should you have any questions, for example to the contractor, the user or another subcontractor, please write these down in preparation for consultations.

**Resources:** All the usual resources, such as books of tables, specialised reference books, your own notes and your own pocket calculator, may be used to assist you in the performance of this task.

The grading of test results is ability-based. If a test subject does not go beyond the presentation and explanation of a feasible solution, his or her level of competence differs from that of another test subject who is able to develop a solution that also takes account of criteria with which the second and third levels of competence are defined. With the aid of 40 checklist items – five for each skill criterion – the assessors rate the solutions on the basis of the grading scale.

**Figure 1:** Structure of the expectations dimension: criteria and levels of occupational competence

<table>
<thead>
<tr>
<th>Competence levels</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multidimensional literacy</td>
<td>Environmental compatibility</td>
</tr>
<tr>
<td>Procedural literacy</td>
<td>Cost-effectiveness</td>
</tr>
<tr>
<td>Functional literacy</td>
<td>Functionality</td>
</tr>
</tbody>
</table>

Source: Rauner et al., 2009(a), p. 91.

**Psychometric validation of the competence and measurement model**

The basic prerequisite for a model designed to measure open-ended test assignments is a high degree of consistency in the assessors’ rating of solutions. In the KOMET project, this goal has been achieved in all of the subprojects conducted to date. To validate the psychometric quality of the competence and measurement model, an exploratory factoring analysis was conducted in the first instance in which, on the basis of the correlations between the 40 checklist items, those items were gathered into implicit structures, known as factors. On the whole, the outcome of the factoring analysis was highly consistent.
with the initial theoretical assumptions (for details, see Erdwien and Martens, 2009).

The assumptions underlying the theoretical competence model, namely that better performance in terms of procedural literacy cannot be achieved until functional literacy is firmly enough established and that a substantial degree of creative competence will not emerge until functional and procedural literacy are sufficiently well established, were also empirically conformed (op. cit.)

Experience with large-scale competence diagnosis and future prospects

The experience gathered in three years of piloting the preparation, implementation and evaluation of cross-sectional and longitudinal studies involving 700 test subjects in 2008 and 1,500 in 2009 may be summed up as follows:

• Complex open-ended test assignments have proved their worth. The individual assignments, which test subjects are given a maximum of 120 minutes to complete, serve to measure occupational competence and, in the case of longitudinal studies, the development of occupational competence in realistic conditions, with reference to the principles and objectives of vocational education and in a manner that permits international comparison.

• The KOMET competence and measurement model lends itself to comparative studies in which groups of test subjects are drawn from various training systems (the test subjects have hitherto come from the dual system of vocational education and training, technical colleges and specialised vocational colleges).

• Educationalists from the relevant specialised disciplines estimate that it would be necessary to amend some 15 to 20% of the checklist items in order to adapt the measurement model for occupations in the realm of personal service provision.

• The collection of data on identification with an occupation, commitment and the design of in-company and college training makes it possible to develop recommendations on vocational-training practice.

Problems and unresolved issues

• The influence of the motivating power of tests on test results was underestimated. The findings of a study on test-driven motivation suggest that the timing of tests should be altered.

• A case study supports the hypothesis that the test venue (company premises or college) affects the problem-solving horizons of test subjects and therefore influences test results.

• The measurement of workers’ identification with their occupation and their commitment to it and the collection of contextual data require an adjustment of national survey instruments for the purpose of international comparative studies.

The KOMET project planning provides for the involvement of additional occupations and occupational fields in 2010.

One of the priorities of the project lies in the introduction of project-type forms of learning and self-appraisal methods for apprentices, instructors and trainers which are based on the KOMET competence and measurement model (see Katzenmeyer et al., 2009). The results of the project suggest the need for gradual extension of VET research in the realm of large-scale competence diagnosis.
Bibliography

M. BECKER, ‘Kompetenzmodell zur Erfassung beruflicher Kompetenz im Berufsfeld Fahrzeugtechnik’, in C. Fenzl et al. (eds), Berufsarbeiten von morgen in gewerblich-technischen Domänen. Bielefeld, 2009, pp. 239-245


R.W. BYBEE, Achieving scientific literacy: from purposes to practices. Portsmouth, NH, 1997


