

Albert, D., & Pilgerstorfer, M. (2007). Preliminary Considerations on Personalized Assessment of Logical and Moral Thinking Skills. In D. G. Camhy (Ed.), *Philosophical Foundations of Innovative Learning. Proceedings of the International Conference on Philosophy for Children. Conceptus-studien* (Vol. 18, pp. 55-61). Academia Verlag.

## **Preliminary Considerations on Personalised Assessment of Logical and Moral Thinking Skills**

### **Introduction**

Critical thinking transcends disciplinary as well as cultural boundaries. By integrating philosophical methods of developing thinking and basic psychological research, one can benefit from advantages of both approaches. Beside interdisciplinary aspects, intercultural differences will be taken into account. One aim of our research is to focus on the logical and moral thinking with respect to cultural (Austria and Japan) and gender aspects.

For starting directed interventions it is essential to get a detailed individual profile on which successful training has to be based. From a psychological point of view, for reaching a detailed profile usually a lot of items have to be presented to the students, what promptly leads to boredom on the one side or to excessive demands on the other side. In order to avoid this, new insights of cognitive psychology and methodology can be applied for personalised as well as for competence-based approaches.

Our aim is to develop a personalised, competence-based, computerised system, which includes not only psychological, but also philosophical and cross-cultural methodologies.

### **Personalised Assessment**

A central aspect of adaptive assessment is to uncover a learner's skill state in the frame of an efficient questioning by selecting the problems to be asked next taking into account the previous answers of a learner – like a private teacher. The main idea of an efficient, adaptive, and computerised assessment is to start with a problem of medium difficulty and then to move on to other problems depending on the answer. In case of a correct answer, the next problem will be more difficult than the first problem. If the learner fails to answer the first question correctly, easier problems will be selected. This querying ends whenever we have sufficient information concerning the learner's knowledge state.

A teacher's adaptive assessment of the learner's knowledge in an oral exam can be mimicked by using algorithms for the assessment of knowledge that are based on prerequisite relations, and dichotomous information on learners' mastery of these problems. A framework that allows for assessing skills and competencies with a reasonable

set of items and adapts to a child's answer behaviour is the competence-based extension of the Knowledge Space Theory (Korossy, 1997, 1999).

Prerequisite relationships are formalised within the Knowledge Space Theory (Doignon & Falmagne, 1985, 1999; Falmagne, Koppen, Villano, Doignon, Johannesen, 1990), which is based on performance. One way to represent such prerequisite relationships is the surmise relation. Two items  $x, y \in Q$  are in a surmise relation  $(x, y) \in S$  if, from a correct answer to item  $y$ , we can surmise a correct answer to item  $x$ .

Consider the following example of a knowledge domain  $Q$  in forming analogies, which will be used subsequently for illustrating the main concepts.

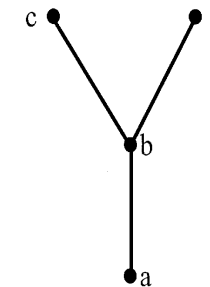
Example 1: Problems of the knowledge domain  $Q = \{a, b, c, d\}$ :

a.	Wing flipper	behaves to to	bird O fish O gill O foot O tail	like
b.	Rain snow	behaves to to	flood O ice O winter O spring O avalanche	like
c.	Bear salmon	behaves to to	mammal ?	like
d.	Sugar lemon	behaves to to	suit ?	like

The empirically observed solution behaviour on a given knowledge domain will exhibit some dependencies. In Example 1, from the mastery of problem  $b$  one could surmise the mastery of  $a$ , because whole-part relations are easier to solve than cause-effect relations. One could also surmise that task  $c$  and  $d$  are more difficult than task  $a$  and  $b$ , because there is no answer given. Thus, a student who is capable of solving task  $c$ , is also capable of solving  $a$  and  $b$ . (Note that these are only simplified assumptions for demonstration.)

Any surmise relation on a given knowledge domain can be illustrated by a so-called Hasse diagram, in which the mutual relationships among the problems are depicted in an economical way. Figure 1 presents a surmise relation defined on the knowledge domain  $Q$  of Example 1.

Figure 1: Hasse diagram the a Surmise relation for Example 1

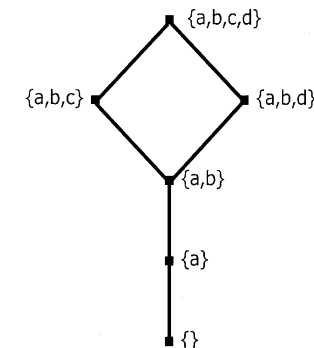


Note: Points represent the problems; lines between the tasks represent the functional dependencies. Superordinated points are more difficult than tasks under.

It can be read off the diagram that from a correct solution to problem  $b$  a correct answer to problem  $a$  can be surmised. The mastery of problem  $c$  implies correct answers to problems  $a$  and  $b$ , and also the mastery of problem  $d$  implies the mastery of problems  $a$  and  $b$ . From a correct solution to either problem  $c$  or problem  $d$  no inferences regarding the solution of the remaining problems can be made.

Doignon and Falmagne (1985, 1999) differentiate between *knowledge*, *knowledge state* and *knowledge structure*. Knowledge means the ability of a person to solve tasks of a certain knowledge domain. For a set of items  $Q$  the knowledge state of a student is described as the subset of items this student is able to master. The knowledge structure is the set of all possible knowledge states. Figure 2 shows the knowledge structure for the surmise relation in Figure 1.

Figure 2: Knowledge structure for Example 1



Note: Squares represent the knowledge states. Lines between the states represent the inclusion relationships for knowledge structures.

A knowledge structure and its corresponding prerequisite relation build the basis for comparing profiles, as well as for an adaptive assessment of individuals. Supposing

a person produces a correct answer to a certain problem  $x$ , we may then surmise the correct mastery of all problems, which are preceding problem  $x$  in the corresponding surmise relation (see Figure 1). Therefore, these problems do not have to be presented to the individual. In other words, the presentation of the next problem in an assessment procedure depends on the previous responses of the individual. Thus, the selection of the question to be presented next is more and more adapted to the learner's actual knowledge.

If in the above example (see Figure 2), a student's answer to problem  $b$  is correct, then his/her knowledge state is at least  $\{a,b\}$ . The next step is to explore the states  $\{a,b,c\}$  or  $\{a,b,d\}$  by asking problem  $c$  or  $d$ .

Another framework of knowledge assessment is skill- or competence-based (Fal-magne et al., 1990; Doignon, 1994; Düntsch and Gediga, 1995; Korossy, 1997, 1999).

A procedure, which requires to have available an underlying competence structure is based on the assignment of skills or competencies. The basic premise is to make a clear distinction between competence (skills, ability) and performance. Performance refers to the empirically observable behaviour on certain given problems. Competencies are conceptualised in terms of theoretically founded entities accounting for the observable solution behaviour.

A central task of the competence-performance conception is to create explicitly defined relations between the competence and the performance level.

The following example will be used to illustrate the competence-performance approach. First, to each problem of a knowledge domain the essential competencies are assigned.

Example 2: Problems of the Knowledge domain  $Q = \{a, b, c\}$  and the assigned competencies:

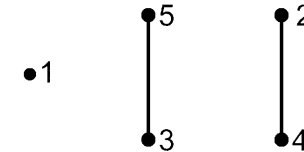
Tasks					Competencies	(No)
a.	Rain snow	behaves to to	flood O ice O winter O spring O avalanche	like	analogies cause-effect recognition	1 2 3
b.	Hammer table	behaves to to	tool O chair O joiner O furniture O house	like	analogies individual- class recognition	1 4 3
c.	Bear salmon	behaves to to	mammal ?	like	analogies individual- class reproduction	1 4 5

The next step is to create a surmise relation between the competencies. From research in memory psychology it is known, that reproduction (5) is more difficult than recogni-

tion (3). Thus, the pair  $\{5,3\}$  is in the surmise relation. Furthermore, we assume that individual-class relations (4) are easier to identify than cause-effect relations (2). (Note that these are only simplified assumptions for demonstration.)

The surmise relation between the competencies is shown in Figure 3.

Figure 3: Surmise relations between competencies for Example 2



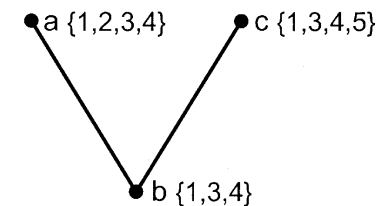
The set of all possible competence-states, resulting from Figure 3, are:  $\{\}, \{1\}, \{3\}, \{4\}, \{1,3\}, \{1,4\}, \{2,4\}, \{3,4\}, \{3,5\}, \{1,2,4\}, \{1,3,4\}, \{1,3,5\}, \{2,3,4\}, \{3,4,5\}, \{1,2,3,4\}, \{1,3,4,5\}, \{2,3,4,5\}, \{Q\}$ .

In order to form the surmise relation between the problems, in our simple case two procedures are possible.

1. *Interpretation function:* The interpretation function assigns to each problem a problem-specific set, which contains exactly those competence states, in which problem  $x$  can be solved.

Because of prerequisite relationships between the competencies (see Figure 3), the set of possible competence states is restricted. So for Example 2, considering that competence 4 is prerequisite for competence 2, the minimal set of competencies, which is necessary for solving tasks  $a$  is  $\{1,2,3,4\}$ , because  $\{1,2,3\}$  is not in the competence structure. In this state, and all its superordinated states, task  $a$  can be solved. For solving task  $b$  one needs the minimal set of competencies  $\{1,3,4\}$ , and for solving task  $c$ , the competence state  $\{1,3,4,5\}$  is needed. From this restrictions we can read off the surmise relation between the problems (see Figure 4).

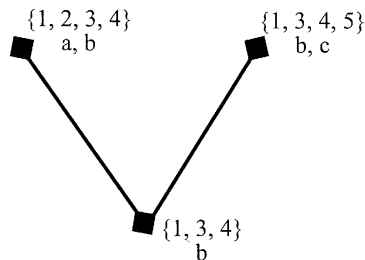
Figure 4: Surmise relations between problems for Example 2



2. *Representation function*: The representation function assigns to each competence state the set of all problems that are solvable in it.

Regarding Example 2 one can see that in the competence state  $\{1,3,4\}$  only task  $b$  is solvable, while a student who has available the competencies  $\{1,2,3,4\}$  is able to solve tasks  $a$  and  $b$ . A student in the competence state  $\{1,3,4,5\}$  should be able to solve task  $b$  and  $c$ . It is visible that problems  $a$  and  $c$  are more difficult to solve than problem  $b$ . From a correct solution to either problem  $a$  or problem  $c$  no inferences regarding the solution of the remaining problems can be made (see Figure 5).

Figure 5: Section of the competence structure for Example 2 and assigned problems



The assessment procedure follows the same schema as the problem-based assessment, unless that the competence structure substitutes the knowledge structure as being the basis for the assessment.

Obviously, an adaptive assessment procedure has the advantage that the assessment is shortened and more efficient, because it avoids confronting the learners with a large number of problems.

### Future Prospects

We will develop a computerised assessment system, which will support teachers for assessing and training logical and moral thinking skills, based on the integration of philosophical developing of thinking with basic psychological research.

For integrating a philosophical procedure it is necessary to provide interactive sequences of behaviour according to a Socratic dialog. (cp. Albert, Pivec, Spörk-Fasching, Maurer 2003). Thus, the diversity of answer formats can be extended and the dichotomisation replaced by a content analytical procedure.

The aim is a well-evaluated system, containing digitalised assessment and learning material and the assigned competencies. It will allow personalised diagnosis of student's competencies, and thus, support teachers and classroom teaching.

### References

- Albert, D., Pivec, M., Spörk-Fasching, T., & Maurer, H. (2003): Adaptive intercultural competence testing: A computerized approach based on knowledge space theory. Proceedings of the UNESCO Conference on Intercultural Education, Jyväskylä, Finland. June 15-18, 2003.
- Doignon, J. (1994): Knowledge spaces and skill assignments. In G. H. Fischer & D. Laming (Eds.): Contributions to Mathematical Psychology, Psychometrics and Methodology (pp. 111-121). New York: Springer-Verlag.
- Doignon, J.-P. & Falmagne, J.-C. (1985): Spaces for assessment of knowledge. Int. Journal of man-machine studies, 1985. 23, 175-196.
- Doignon, J.-P. & Falmagne, J.-C. (1999): Knowledge spaces. Berlin: Springer.
- Dütsch, I. & Gediga, G. (1995): Skills and Knowledge Structures. British Journal of Mathematical and Statistical Psychology, 48, 9-27.
- Falmagne, J.-C., Koppen, M., Villano, M., Doignon, J.-P. & Johannesen, L. (1990): Introduction to Knowledge Spaces: How to Build, Test, and Search Them. Psychological Review, 97, 201-224.
- Korossy, K. (1997): Extending the theory of knowledge spaces: a competence-performance approach. Zeitschrift für Psychologie, 205, 53-82.
- Korossy, K. (1999): Organizing and Controlling Learning Processes Within Competence-Performance Structures. In D. Albert & J. Lukas (Hg.), Knowledge Spaces--Theories, Empirical Research and Applications, pp. 157-178. Mahway, NJ: Erlbaum.