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Content Analysis of Chemistry Curricula in Germany
Case study: Chemical Reactions

Roxana S. Timofte

Abstract: Curriculum-assessment alignment is a well known foundation for good practice in educational assessment, for items' curricular validity purposes. Nowadays instruments are designed to measure pupils' competencies in one or more areas of competence. Sub-competence areas could be defined theoretically and statistical analysis of empirical data by using Rasch models could reveal if the sub-competence areas defined theoretically are belonging to the same empirical scale. As a result of unsatisfactory results of pupils to TIMSS in 2000, national educational standards were implemented in Germany and research in the area of competence assessment was started. Though, the compulsory, comprehensive content description of the material intended to be taught in class is depicted in curricula. As a result of federalism in Germany, each of the 16 federal states provides a curriculum. The aim of this exploratory study is the identification of the topics most frequent across the curricula of the 16 federal states. Consequently, curriculum analysis of the curricula for two type of schooling in Germany, for secondary level I, for each of the 16 federal states in proposed.

Key words: curriculum analysis, curriculum-assessment alignment, items' curricular validity, chemical reactions, competence measurement.

1. Introduction

Alignment of standards, curriculum[1] and assessment has been acknowledged to be the foundation for a sound approach to educational assessment (Webb, 1997). In 2003 and 2004 educational standards in Germany were defined, as a result of the disappointing results of German students at TIMSS in the 1990s and TIMSS 2000 (Köller *at al.*, 2012). To assess the implemented National Educational Standards (NES) in science (Sekretariat der Ständingen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland, 2005), the German Institute for Educational Progress assembled the interdisciplinary project "Evaluation of the National Educational Standards for Natural Sciences at the Lower Secondary Level" (ESNaS) in 2007 (Kremer *et al.*, 2012). The aim of this project was the creation of an item bank, in order to measure the performance of pupils in Science areas upon the implementation of NES. A competence model was developed, by considering the concept of competence as described by Klieme *et al.* (2006) and by Weinert (2001). This model has three axes: area of competence, cognitive processes and complexity level (Figure 1).

In this model are considered four areas of competence: use of content knowledge, acquirement of knowledge, communication, evaluation and judgment. The complexity term refers to the number of single scientific items and their interconnectivity necessary to solve a task. This dimension includes five levels: 1 fact (I), 2 facts (II), 1 relation (III), 2 relations (IV), and generic concept (V). Facts are seen as the smallest possible units of knowledge in a particular area, relations indicate quantitative and

[1] The intended curriculum is referred to in this paper as curriculum. For a definition of intended curricula see UNESCO International Bureau of Education, 2013.

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qualitative functional connections between facts, and concepts are defined as general scientific constructs. The cognitive processes depicted in the model are the cognitive activities necessary to solve a specific test item. There are four levels of cognitive activities: reproduction, selection, organization and integration. These processes were adapted from theories of information processing.

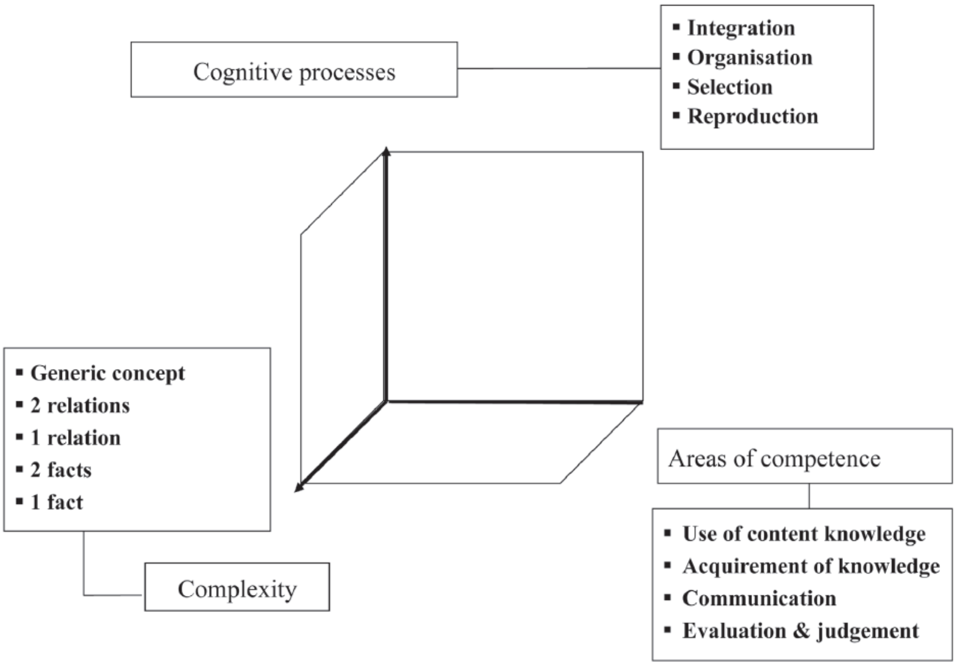

Figure 1. Three-dimensional ESNaS competency model

Item Response Theory (IRT) models such as Rasch models are used for analysis of empirical data in the area of competence assessment (Hartig, 2008). The advantage of Rasch analysis of data is that the data are converted into ratio scaled data and that item parameters and person parameters are produced (Bond *et al.*, 2001). Parameters such item fit statistics, local independency of items, Wright map characteristics, item difficulty, person ability, person separation reliability and item separation reliability, different item functioning, dimensionality of the instrument could be acquired by using such analyses (Boone *et al.*, 2006). Instruments are designed to measure different traits or aspects of a single trait regarding the knowledge or performance of pupils. The aspects of a single trait are usually referred to as instrument dimensions. A Rasch analysis of a set of data may be used to measure each one of these dimensions. Nevertheless, a multi-dimensional Rasch analysis allows the analysis of dimensionality of a set of items. Hence, Rasch analysis could be used to establish empirically if an instrument measures one single trait or more traits (Burnham *et al.*, 2004; Hartig, 2008).

Through NES basic concepts for the area of competence 'use of content knowledge' were defined, in order to structure the content knowledge of the subjects (Kremer *et al.*, 2012). By the introduction of basic concepts it was intended to foster cumulative learning and to enable students to better organize their knowledge. A structuring of content was proposed (Köller *et al.*, 2008), with the categorisation tree having three levels of generality: basic concepts, aspects and indicators. The basic concepts in Chemistry are: matter-particle relations, structure-property relations, chemical reactions and energy. However, the mandatory, comprehensive description of content expected to be covered in class is provided by curriculum. Due to federalism in Germany, a curriculum was defined for each federal state. Furthermore, a curriculum was defined for each type of schooling. The outcome for such educational policy was that, for example, in 2008 were 53 different curricula for Chemistry (Walpuski *et al.*, 2011). In a previous study regarding the identification of common topics across curricula in Germany for Chemistry for Chemical Reactions, the topics belonging to three aspects of the basic concept Chemical Reactions were subjected to identification in curricula (Ropohl *et al.*, 2014). These aspects were: general characteristics of chemical reactions, redox reactions, acid-base reactions. Their findings revealed that in curricula from 3 federal states were present only 9% of topics from the total amount of topics identified in analysed curricula. A total of only twelve indicators were identified in every curricula analysed. Furthermore, only one curriculum covered two thirds from the total amount of topics identified in the analyzed curricula. A more ample analysis of curricula appeared to be necessary, including the identification of indicators of aspects regarding organic reactions and reactions used in qualitative and quantitative analysis. Herein it is proposed a comprehensive analysis of curricular content of curricula in Germany. A further step of this project is the development of an instrument for measurements in the area of competence 'use of content knowledge', including items belonging to the five aspects of the basic concept 'Chemical Reactions'. It is envisaged that the topics of the developed items would be the indicators indentified most frequently across the analyzed curricula. After Rasch analysis of data and determination of dimensionality, it could be established if the sub-competence areas defined theoretically are belonging to the same empirical scale. Therefore, the results of this study are relevant for items curricular validity purposes as well as for competence measurement.

2. Research Question

Which are the indicators identified most frequently in the curricula from the 16 federal states in Germany, for the basic concept 'Chemical Reactions', for secondary level I,[2] for Gy[3] and Ge[4] type of schooling?

3. Methods and Design of Study

Curricula for Gymansium and Gesamtschule type of schooling from the 16 federal states were analyzed. Given that not every Ministry of Education from the 16 federal states in Germany provided a curriculum for Gy and a curriculum for Ge, a total of 20 curricula for Gy and Ge type of schooling, at secondary school I level were analyzed. A deductive content analysis approach (Mayring, 2000; Elo *et al.*, 2008) was applied for curriculum analysis. The coding was performed at indicators level. Both manifest and latent content were coded. Herein is presented an example of coding latent content: the content 'Die Schülerinnen und Schüler haben das Konzept der Stoffumwandlung zum Konzept der chemischen Reaktion so weit entwickelt, dass sie …chemische Reaktionen von Aggregatzustandsänderungen abgrenze' [The students had the concept of chemical transformation so well understood, that they can delimitate chemical reactions from change in aggregation state] (Ministerium für Schule und Weiterbildung des Landes Nordrhein-Westfalen, 2008, pp. 26) was coded as 'definition of reactions.'

4. Results and Discussion

The categorization tree has three levels and is depicted in Table 1. Five aspects were defined theoretically: fundamentals of chemical reactions, acid-base reactions, redox reactions, organic chemistry reactions, reactions used in qualitative and quantitative analysis. A total number of 79 indicators were identified in the course of curriculum analysis: 34 indicators for the aspect redox reactions, 12 indicators for the aspect acid-base reactions, 6 indicators for the aspect organic reactions, 7 indicators for the aspect reactions used in qualitative and quantitative analysis, 20 indicators for fundamentals of chemical reactions.

[2] Class 5-10 for Gymansium and class 5-11 for Gesamtschule.
[3] Gymansium (Gy) is a high school type preparing students for entering university.
[4] Gesamtschule (Ge) is a high school type enrolling pupils with various levels of ability.

Table 1: Categorization tree for the basic concept 'Chemical Reactions' and identified Indicators

Main category	**Generic category**	**Sub-category**
Basic Concept	**Aspects**	**Indicators (number)**
Chemical Reactions	Redox Reactions	34
	Acid-Base Reactions	12
	Organic Reactions	6
	Reactions used in Qualitative and Quantitative Analysis	7
	Fundamentals of Chemical Reactions	20

An example of the identified list of indicators is depicted in Table 2, for the aspect acid-base reaction.

Table 2: Indicators for the aspect 'Acid-Base Reactions'

Basic Concept	**Aspect**	**Indicators**
Chemical Reactions	Acid-Base Reaction	Acid - Base Reactions / Neutralisation
		Ampholit
		Buffer
		Indicator
		pH
		Titration
		Dissociation
		Acid-Base Equilibrium
		Arrhenius Concept of Acids and Bases
		Bronsted-Lowry Concept of Acids and Bases
		Lewis Concept of Acids and Bases
		Protolysis

A second coder coded 10 % of the material from the 20 curricula and the inter-rater reliability value was Cohen's Kappa=0.68 (substantial agreement). The maximum number of indicators identified in a curriculum is 47 and the minimum number of indicators identified in a curriculum is 6. The mean value is 29, with a SD value equal with 11. Information regarding the identified indicators in the Gy or Ge curricula from each federal state is depicted in Figure 1. In the curricula for the federal states Thüringen (Gy curriculum), Mecklenburg-Vorpommern (Gy curriculum) and Sachsen (Gy curriculum) were indentified the largest numbers of indicators: 47 indicators (representing 60% from the total of 79 indicators), 44 indicators (representing 44% from the total of 79), 40 indicators (representing 40% from the total of 79 indicators), respectively (Figure 2).

In 2012 a national study was pursued in Germany (IQB-Ländervergleich 2012. Mathematische und naturwissenschaftliche Kompetenzen am Ende der Sekundarstufe I. [Institute for Educational Progress - Comparison of Federal States-2012. Competence Measurement for Mathematics and Science at the end of secondary level I], 2013) to measure the competency level of pupils from 9th class, across the 16 federal states. The purpose of this study was to measure the degree of alignment of pupils' competencies with the standards implemented in 2004. The results of this study reveled that pupils from Thüringen, Mecklenburg-Vorpommern and Sachsen have high levels of chemistry content knowledge, while pupils from Bremen, Hamburg and North Rhine-Westphalia had the lowest performance comparing with the pupils from the other federal states who participated in the Ländervergleich study. In the intended curricula for federal states Thüringen, Mecklenburg-Vorpommern, Sachsen were identified the highest number of indicators in curriculum analysis. Furthermore, in the intended curricula for federal states Bremen, Hamburg and NRW were identified the lowest number of indicators in curriculum analysis. These results appear to provide evidence for the direct relationship between the intended curricula and students' results at national assessments.

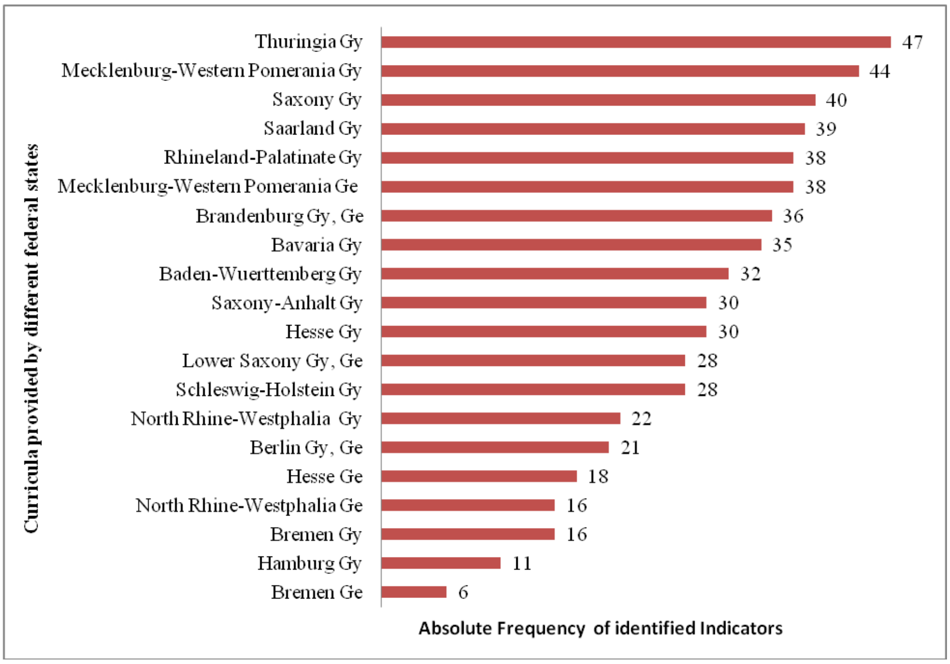

Figure 2: Frequency of indicators across the curricula analyzed for the 16 federal states

The most frequent indicators identified in the analyzed curricula (Table 3) could be the most suitable topics for the development of items to be used for competence assessment of pupils from schools across Germany.

Table 3: Most frequent indicators identified for each aspect

Aspect	Most frequent Indicators (frequency value)
Redox Reactions	Redox Reactions (20) Oxidation (17)
Acid-Base Reactions	Acid-Base reaction / Neutralization (18) pH (15)
Organic Reactions	Substitution (11) Addition (10)
Reactions used in Qualitative and Quantitative Analysis	Reactions used in Quantitative Analysis (general) (12) Detection of Organic Compounds (12) Reactions used in Qualitative Analysis (general) (12)
Fundamentals of Chemical Reactions	Definition of Reaction (19) Law of conservation of Mass (17) Word Equation (16) Formula Equation (16)

Further studies would involve assessment of pupils' competence in the area of competence 'use of content knowledge' for the basic concept 'Chemical Reactions'. Statistical analysis of empirical results would provide information regarding the dimensionality of an instrument measuring pupils competence in the area of the basic concept ‘Chemical Reactions’ (*ie*, it could be determined if the sub-competence areas defined theoretically are belonging to the same empirical scale).

5. Conclusion

The vast variety of content present in curricula from the 16 federal states in Germany as well as the dissimilar results of pupils from the 16 federal states in Germany at competence assessment tests could signal the need for an increase in unity of curricula in Germany.

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Author

Roxana S. Timofte, University of Duisburg-Essen, Faculty of Chemistry, Chemical Education Department, Essen, Germany, e-mail: roxanasidonia_timofte@yahoo.com

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