THE APPLIED KNOWLEDGE OF TRAINEES AS INDUSTRIAL CLERKS SOLVING PROBLEMS WITH VOCATIONAL AND NON-VOCATIONAL CONTEXT

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Following literacy frameworks, one aim of educational policy is to prepare students for their professional lives. Vocational training for industrial clerks, which relies on mathematical competence, is of high interest for mathematics education. One specific question is which role school-acquired mathematical competence plays in vocational training. It is suggested that mathematical competences connected to vocation-related mathematics may be a link between demands of general and vocational education. We designed problems that mirror these different demands and conducted an interview study with trainees as industrial clerks. The results show that the trainees' knowledge application differed for the different types of demands so that the approach enabled us to reveal qualitative differences between general and vocation-related mathematics.

THEORETICAL BACKGROUND

Following common literacy frameworks, one specific goal of general education is to prepare students for their professional lives. However, problems of transition from general to vocational education are known in many countries irrespective of the specific educational system (cf. OECD, 2000). In Germany, for example, there are growing difficulties of matching training place supply with training place demand across almost all vocational fields and there is a high dropout rate (25%) in vocational training with approximately one third of the dropouts during the first year (BIBB, 2017). Accordingly, it is important to gain more insight into the demands of vocational training and into the conditions for vocational preparation that are set within general school education.

Empirical investigations that address the transition from school to vocational training from a subject-specific perspective would help to understand the specific challenges trainees experience when transitioning to vocational education. However, educational frameworks for school education and vocational education are mostly not strictly commensurable. From the view of mathematics education, a starting point to investigate the transition problems is to focus on vocational training programs in which mathematical competences are of central importance. Vocational education standards show that particularly merchants and specifically industrial clerks face rich mathematical demands in professional training (e.g., KMK, 2002 for the German situation). These professions are, therefore, at the center of our attention.

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Due to the major structural differences of the systems of school and vocational education we focus the individual level of students and trainees. We ask in which way the differences of the two systems in terms of mathematical demands can be seen as a continuity or discontinuity from the perspective of the individual learner. In particular, we ask what kind of mathematical knowledge do trainees as industrial clerks apply when dealing with parallel mathematical problems in a vocational and a non-vocational context, so that possible discontinuities can be elicited.

Characterizing the educational context of this study

The German education system allows different ways to gain access to vocational training. After at least nine years of compulsory education in primary and secondary school, the students should possess the necessary competences to start a vocational training. However, for specific occupational fields, 10 or 12 years of schooling are required as access to vocational training. Vocational education in Germany is organized in the so-called dual system combining theory (vocational school) and practical work (individual training with a training supervisor at the workplace).

Approximately 60% of the training contracts each year fall within the commercial field. The dual vocational training for industrial clerks, which we focus in our study, is constantly over years among the most important training tracks in the commercial field (BIBB, 2017). The vocational training standards require a substantive part of the 3-year training time to be used for economics and mathematics contents (KMK, 2002). These contents fall into the economical categories of cost accounting, performance calculation, depreciation, and financing/investment. From an inner-mathematical point of view, they can be seen as applications of the rule of three and percentage calculation, which are contents belonging to lower secondary mathematics education. The difference between both implementations of the same mathematics is that in vocational education, the contexts are specific for industrial clerks, what is reflected amongst other in a specific terminology such as *break-even point*.

Although, the context where we investigate this transition from school to vocational training is coined by a specific national education system, this research is of wider interest from two perspectives: First, it specifically focuses on the (non-)compatibility of educational frameworks that built on ideas of literacy vs. frameworks that are oriented more narrowly on vocational demands, what is pertinent to many educational systems. Second, from a broader perspective, the approach can serve as a model how mathematics education can address questions with relevance for educational policy decisions related to incommensurable conceptions of (mathematics) education by refocusing from the system to the individual level.

To sum up, if general mathematics instruction should prepare for vocational training, the commercial field in general, and in particular industrial clerks, can be seen as especially important to provide a good starting point for research in transition conditions. Overlooking a successful transition to vocational training, it can lead to a

better understanding of goals of general education against the mathematical requirements that are given through the specific demands of vocational trainings.

From general mathematical competences to vocational competences

Educational contexts of general and vocational education differ in many aspects, resulting in fundamentally different task requirements in general education and vocational training. Nickolaus et al. (2013) tried to characterize the transition from general education into vocational training in Germany by contrasting and synthesizing the models of competence from a domain-specific point of view. On the one hand, future trainees leave school with "general mathematical competences" (in the sense of literacy-conceptions) according to the educational standards for mathematics as a subject. On the other hand, vocational training aims at "vocational competences" (in the sense of action competence) defined by specific demands that are necessary for the pursuit of a profession (e.g., Winther & Achtenhagen, 2009).

According to literacy-conceptions, however, future trainees should already acquire mathematical competences at secondary school that *prepare* for the successful participation in vocational training. The theory of cognitive flexibility supports the practice of integrating differing contexts into mathematical education in order to support the acquisition of rich, applicable, and flexible (mathematical) knowledge and competences (Spiro et al., 1988). Hence, students are expected to possess initial "vocation-related mathematical competences" so that it is an aim of general education that basic tasks related to vocational contexts can be solved (Nickolaus et al., 2013).

From a theoretical point of view, the "vocation-related mathematical" competences are seen as overlapping the other competence areas: They can be understood as being part of the general mathematical competences, subject to general education. Equally, they should serve as the base of the vocational competences that will be developed during vocational training. From a theoretical perspective, such "vocation-related mathematical competences" should facilitate transition processes as they function as link between competence acquisition in school and in vocational training. From an empirical perspective, it is unclear if this theoretical differentiation is relevant in the sense that "vocation-related mathematical competences" can actually be delineated as a being to a certain extent self-contained and not necessarily part of general mathematical competences.

RESEARCH QUESTIONS

Among others, literacy frameworks for mathematics secondary education aim for the preparation for professional life, especially vocational education. Thereby, the vocational field of industrial clerks offers a high proportion of mathematical contents and is predestined to investigate conditions of transition from secondary education into vocational training. Furthermore, vocation-related mathematical competences were seen as being a potential mediator between general mathematical competences acquired in school and vocational competences to be acquired in vocational training. A first

quantitative study from Siebert and Heinze (2014) points to an empirical separability of general mathematical and vocation-related mathematical competences for trainees. What remains unexplained so far is whether this separability can indeed be attributed to the application of different competences that were acquired in general and vocational educational contexts. Hence, we aim at addressing this possible explanation through the following research question:

- What knowledge do trainees as industrial clerks apply when dealing with mathematics-related problems in a vocational context?

METHOD

We implemented a three-stage research procedure aiming at the applied knowledge of trainees as industrial clerks in different (vocational and non-vocational) demands. At first, we developed three pairs of contextualized mathematical problems. Each pair comprises one problem with a vocational context of industrial clerks and one problem with an isomorphic mathematical structure and the same mathematical content in a non-vocational context. Both problems can be solved by applying general mathematical competence acquired in secondary school. Second, these problems were solved by $N = 42$ trainees as industrial clerks. The results of the testing informed the selection of a subgroup of trainees with high differences in test scores between the two types of problems and a control group with low differences. Third, these trainees participated in a subsequent guided stimulated recall interview study with the aim of investigating whether the differences in testing results can be explained by difference in the kind of knowledge applied.

Problems used in the assessment

As the starting point, we picked three complex problems of the collection for the final examination for trainees as industrial clerks from the German Chamber of Industry and Commerce. There was one problem consisting of three and two problems consisting of two subtasks. These problems contained mathematical and technical contents appearing during the first two years of vocational training for industrial clerks and, therefore, focused on vocation-related mathematical competences. We modified the tasks to receive parallel problems with different outer-mathematical contexts but kept the inner-mathematical content and structure.

For example, problems 3 and 6 deal with different tasks for the application of percentage calculation. Problem 3 looks at selling computer tables from the perspective of an industrial clerk. Price calculation, production costs and profit deviation are key terms for solving that problem. In contrast, problem 6 asks for the same calculations while regarding and comparing numbers of unemployment in two different districts from an external perspective. Thereby, the applied commercial terms are replaced by questions about, for example, the deviation of unemployment numbers so that other contexts of general interest, that are not located in the specific vocational field, were realized.

To check whether the designed problems are – as intended – parallel, the complexity and the demanded competences for the problems were classified using the framework of the German national educational standards. The classification of all six problems was realized with a multi-step classification process by experienced raters including the co-authors of this research report and led to an almost complete accordance between each of the three problems with vocational context and their parallel problems with non-vocational context. Thus, despite minimal deviation regarding the requirements of one pair of problems the parallelism of the problems in respect to mathematical demands can be assumed.

Test administration

The six problems were administered to a group of $N = 42$ trainees as industrial clerks from second (N_1=18) and third (N_2=24) year in a German vocational training track. Further, we applied a dichotomous 0-1-scoring to each subtask. Since we wanted to compare the three problem types, we standardized the score for each problem due to the different number of subtasks. Table 1 shows the descriptive results of the standardized test scores. The scores for the pairs of parallel problems (pairwise and in total) indicate that the vocational (problems 1-3) and non-vocational (problems 4-6) context has an influence on the solution rates and therefore offer a solid basis for the stimulated recall interview study.

M *(SD)*	Problems with vocational context	Problems with non-vocational context
Problems 1 & 4	.71 (*.24*)	.58 (*.30*)
Problems 2 & 5	.42 (*.25*)	.51 (*.37*)
Problems 3 & 6	.60 (*.35*)	.62 (*.36*)
Total (*N*=42)	.56 (*.17*)	.56 (*.25*)

Table 1: Mean (standard deviation) for the standardized scoring of trainees as industrial clerks (*N*=42).

In preparation for the interview study, we selected nine trainees from second and nine from third year of vocational training. These trainees either reached a significant better or a significant worse scoring on the three problems with vocational context (six trainees each). In addition, we selected a control group of six trainees showing only small differences. This theoretical sampling led to a heterogeneous group of test persons for the interviews.

Guided interviews and qualitative content analysis

For the implementation of stimulated recall interviews focusing on the applied knowledge of the trainees as industrial clerks, we developed a partially standardized questionnaire. In addition to questions about the solution process and noticed difficulties, we asked which knowledge they used to solve the problem and where they learned that knowledge (e.g., secondary school, vocational school, training supervisor). Due to time limitations, we restricted the questions related to the individual solution process to

the three problems with vocational context. Additionally, the interviews included questions about the perceived differences and similarities between the parallel problems in order to investigate if the differences (or parallelities) are relevant for the individual trainees.

According to the qualitative method of content text analysis (Schreier, 2012), we set up two main categories of classification for the evaluation of the interviews. The category *solution process* deals with the self-reported knowledge the trainees applied while solving the problems. This category aims at analyzing the applied knowledge indirectly. Concurrently, the category *knowledge acquisition* relates to the source of the applied knowledge directly. Both categories could occur either as a *vocation-related* or a *general education specification*. Furthermore, we set a third specification (*unknown*) for answers not falling into one of the two other specifications.

For nine interviews (50%), the coding was conducted by two trained raters independently. High values of interrater reliability (percentage agreement: $p_0 = .91$, Cohen's Kappa: $\kappa = .89$) indicate a high level of objectivity of the coding.

RESULTS

The qualitative content text analysis reveals insights into the applied knowledge of the trainees when working on the problems. Some of the answers showed a solution process with a vocation-related specification indicated by specific terms from the vocational field of industrial clerks:

> Interviewer: How did you proceed?
>
> P7: Well, then … I tried to … calculate the break-even-point, where the proceeds are equal to the costs.

Here, the vocation-related specification is directly marked by using the specific commercial terms (break-even-point, proceeds, costs) that are not part of secondary education. In a similar way, the vocation-related specification can appear while answering the questions referring to the question of knowledge acquisition:

> Interviewer: OK, what knowledge did you use to solve the problem?
>
> P10: Well, you need to know, from what, how you calculate the profit, that it is sales minus costs.

Here, the linking to vocational school as the place of knowledge acquisition happens indirectly just with background information about the structure of vocational training standards for industrial clerks. Elsewhere, test persons give the link to vocational school as knowledge acquisition as an answer to the same question directly through naming the relevant field of instruction (business processes and accounting):

> P4: Um, that what we had in instruction right now. … I don't know. Business processes and accounting.

Otherwise, P8 gives the link to secondary education (Gymnasium) as the place of knowledge acquisition:

P8: And, well, um, the remaining … that has been more math. … Standard math … Standard calculation. So rather from *Gymnasium*.

If the stated solution process of a test person for a problem or the stated knowledge acquisition falls into the category of vocation-related specification such as the examples P7, P10 and P4 above, we consider the applied knowledge for that person and problem as vocation-related. For the three problems (seven subtasks) with a vocational context, 67% of the solutions of the 18 trainees rely on vocation-related knowledge. Two of these seven subtasks were hardly solved so that noticeably lower proportions of vocation-related knowledge was identified (since no knowledge was available at all). By excluding these outliers, the value for vocation-related knowledge rises to 76%.

In addition, for each pair of parallel problems we asked for perceived differences and similarities. In 65% of the cases, the trainees detected the implemented similarities regarding the mathematical structure and differences regarding the contexts. Nevertheless, half of the trainees showed clear differences in the solution rates between the three problems with vocational contexts and the three problems with non-vocational contexts. The interview could hence substantiate that the differences did not result from a lack of insight into the structure of the problems. It indicates that these problems rather pose different demands for the trainees what leads to the different solution rates. Thus, a distinction between general mathematical competences and vocation-related mathematical competences is substantiated by the findings.

DISCUSSION

Our study addresses questions that stem from the immensurability of educational policy frameworks at the transition from general to vocational education. Vocation-related mathematical competence – as competences acquired in general education, but with connection to vocational demands – were suggested from a theoretical perspective as a potential link on the individual level. The study hence aimed at investigating whether they can be seen as a relevant construct also from an empirical point of view. Therefore it was investigated what kind of knowledge trainees as industrial clerks apply when they solve parallel problems with vocational and non-vocational contexts.

The vocational training standards include a high amount of mathematical contents, which can inner-mathematically be classified as content of lower secondary education. However, in vocational education, the contexts differentiate from general education contexts (while maintaining mathematics) and are specific for industrial clerks. Further, theory of situated cognition suggests the inseparability of knowing and action (Brown, Collins, & Duguid, 1989). As a consequence, it is not unlikely that such identified differences between the implementations of the same mathematics leads to the acquisition of separate areas of competences that ground in contextuallized knowledge.

The results based on a qualitative content text analysis indicate that the differentiation between general and vocation-related mathematical competences is relevant for trainees. In accordance with the theory of situated cognition, we could observe that they applied a specific body of knowledge when working on the mathematical problems in a vocational context that do not require, from an objective perspective, specific knowledge beyond what is subject to instruction in general education. It, thus, sets ground to further characterize transitions from general to vocational education with a focus on domain-specific competence development, which is considered a highly fragile and complex transition from the individual, but also institutional point of view.

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