Investigation of Finnish and German 9th grade students' personal meaning with relation to mathematics

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This study focuses on a comparison of personal meanings that students from Finland (FIN) and Germany (GER) assign to (learning) mathematics. Participants are 256 Finnish and 276 German ninth graders. The survey consists of 18 scales that are based on the theory of personal meaning. The original German version was translated into Finnish. Using item response theory (IRT) partial credit models, the psychometric properties of the scales were found to be good. As statistical procedure, Differential Item Functioning (DIF) analysis and mean comparisons were conducted to compare the two groups' (FIN and GER) responses. Indicators of educational system and curriculum could be found in students' responses to explain similarities and differences between the two samples. In both countries, social inclusion is meaningful for most of the students (*Support by teacher*, *Experience of relatedness*, and *Emotional-affective relation to teacher*). In addition, it is personally meaningful for Finnish students to do well in mathematics. This shows a link to identity-related questions such as confirming important aspects of the self. Hence, personal meanings related to mathematics are more common in Finland than in Germany (*Active practice of mathematics*, *Cognitive challenge,* and *Self-perfection*).

Keywords
comparative study Finland / Germany,
curriculum,
differential item functioning
educational system,
IRT partial credit models,
personal meaning

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1 Introduction

The claim for meaning in education has been raised for many years and meaningful learning is assumed to be a central impetus (Biller, 1991) as well as one of the major goals (Vinner, 2007) of education. Hence, one of the challenges of (mathematics) education is to find convincing answers to the quest for meaning as well as to develop learning environments that enable and foster meaningful learning for the students. Yet, even when only the field of mathematics education is considered, the notion of meaning is complex and multifaceted (Kilpatrick, Hoyles, & Skovsmose, 2005b). This article elaborates on a facet that considers the perspectives of the students and asks what is personally relevant for them when they are involved with mathematics in a school context. Vollstedt (2011b) terms this facet personal meaning (c.f. also Vollstedt, 2010, 2011a). Studying personal meaning is necessary to describe how students relate mathematics to their biography in order to better understand their learning processes from a research perspective (Meyer, 2008). Our research intention presents a small step towards an improved understanding

(Lester, 2005) of students' personal meaning when learning mathematics in order to take adequate account of them in lessons.

In a former qualitative study (Vollstedt, 2011b), 17 different personal meanings were reconstructed from interviews with secondary students in Germany and Hong Kong. Subsequently, a reliable instrument was constructed with the aim to assess those different personal meanings (Vollstedt & Duchhardt, 2019). This paper is a report of a study in which this survey was used with German and Finnish ninth graders to investigate which personal meanings they relate to (learning) mathematics and what similarities and differences can be found between the Finnish and the German sample. A comparison between two countries can help to get a better understanding of the theory of personal meanings and the instruments to measure it. Are the theory and instruments applicable only in the context in which they were developed, or do they persist also in a different cultural context? To test whether the construct personal meaning and the developed survey were specific to Germany, we conducted a comparative study in Germany, the country in which the theory and the survey were developed, and Finland. Finland was chosen as counterpart for this study as it is another European country in which the school system is quite different from the German one. Thus, although there might be similarities as both countries exemplify Western cultures, there are also structural differences that might contribute to different preferences and perceptions of mathematics. On these grounds, we first examined if it is possible to assess personal meaning: "Does the survey, which was originally developed in German, assess the different kinds of personal meaning with reliable scales in both countries?" Secondly, we conducted a Differential Item Functioning (DIF) analysis to examine if the latent variable models work equally across the two samples in Finland and Germany. In the last step, we compared the German and Finnish students' personal meanings using *t*-tests. Moreover, with the necessary diffidence, we provide tentative explanations for our results based on both countries' educational systems and curricula.

2 Theoretical framework

2.1 Personal meaning

There is a rich diversity of meanings of meaning (cf. Kilpatrick et al., 2005b, Reber, 2018). Thus, different interpretations of the term are often used synonymously although they are not synonymous at all. Kilpatrick, Hoyles, and Skovsmose (2005c) present different facets of meaning of a mathematical concept X which can be grouped as the meaning of X from a content perspective, the meaning of X within different spheres of practice, and the meaning of X from the perspective of different individuals involved in its construction. They conclude:

> "These views are actually different meanings of meaning insofar as different methodological tools are needed to explore them, different theoretical frameworks, etc. They insist on several different dimensions of meaning: psychological, social, anthropological, mathematical, epistemological or didactical. But all these dimensions must not be seen as isolated, one from the other. In fact, they constitute a system of meanings whose interactions shape what may be seen as *the* meaning of a mathematical concept." (2005c, pp. 14–15).

In addition, Birkmeyer, Combe, Gebhard, Knauth, and Vollstedt (2015) relate meaning to cognition and affect: For the individual learner's acts of consciousness, meaning represents a dimension that – apart from the areas of experience and action – focuses on a sphere of self-assuring clearance and clarification in the process of learning. The attainments of the consciousness with respect to giving meaning, as well as its affective embedment, create effects of meaningfulness in learning processes. These are to a greater or lesser extent distinct or can be experienced as such. Hence, it is also a matter of an inner psychic experience of meaning. This is neither sensation only nor thinking without emotion, and neither pure and isolated cognition nor knowledge that is independent from consciousness.

Following this description, the global concept of meaning has a dialectical relation to psychological as well as cognitive aspects. Both aspects are conducive to the development of one's own identity: when something is meaningful to an individual, the content somehow makes sense for him or her (in terms of sense-making and understanding) and she or he gains orientation from it (in terms of understanding oneself and the development of one's own identity) (Birkmeyer et al., 2015). Hence, meaning is something different than pure sense-making of the content as it additionally relates the content to the individual's identity and biography.

The distinction between cognitive and affective aspects of meaning also becomes clear when one regards that "even if students have constructed a certain meaning of a concept, that concept may still not yet be 'meaningful' for him or her in the sense of relevance to their life in general" (Kilpatrick et al., 2005c, p.14). The first kind of meaning from the quotation is of cognitive nature as the construction of a concept's meaning. It usually involves sense-making processes. The second kind of meaning, however, involves an affective interpretation as the relevance of the concept is connected to one's personal life. To conclude, two very distinct aspects of meaning can be differentiated here, namely "those relating to relevance and personal significance (e.g., 'What is the point of this for me?') and those referring to the objective sense intended (i.e., signification and referents). These two aspects are distinct and must be treated as such" (Howson, 2005, p.18). In line with Howson's distinction (see also Reber, 2018 for a distinction between subjective and objective meaning), Vollstedt (2010, 2011b) coined the term *personal meaning* to designate the first aspect of relevance and personal significance. Personal meaning describes the personal relevance of a mathematical procedure, content, or the people involved in the learning process for an individual, in our case mostly a student of mathematics. Key questions in this realm of research include: What is personally relevant for me when I am dealing with mathematical contents? Why should I get involved with this? What relations do the contents have to my own biography? Thus, personally experienced meaning occurs in the shape of a personal goal, a value, an intention, a purpose, a reference, or a use that an object or an action may have for the self (Vollstedt, 2011b).

In addition, Vollstedt and Duchhardt (2019) further differentiate the second facet of meaning as objective sense described by Howson above - they distinguish between collective and inner-mathematical meaning. They characterize collective meaning as follows:

> "(…) the relevance of a mathematical procedure or content for a certain group of people in contrast to an individual. This group of people can be characterised by a set of shared beliefs about the use of mathematics e.g. in terms of application in a certain profession, in life, in other scientific areas etc." (Vollstedt & Duchhardt, 2019).

The main question to be asked is whether the mathematical procedure or content has relevance in professional contexts at work or in other sciences. Adding to this, inner-mathematical meaning is characterized as "the relevance of a mathematical procedure or content without a relation that refers to something else than mathematical theory" (Vollstedt & Duchhardt, 2019). Here, central questions discuss the role of a certain mathematical theorem for other mathematical areas, the judgment of the importance of theorems for other areas (e.g. fundamental theorems), or criteria of relevance (cf. Vollstedt & Duchhardt, 2019).

As the focus of our study is on the individual and his/her relation to mathematics, we concentrate on personal meaning understood as personal relevance as described above. Personally experienced meaning is contingent on the individual and a certain context (see below). It has an endogenous character, i.e. it cannot be delivered by the teacher but, on the contrary, must be constructed out of the learner's individual biography (Meyer, 2008). With respect to mathematics, the need for meaning cannot be fulfilled altogether: personal meaning must be continually interpreted and subjectively constructed for each mathematical learning content anew (Fischer & Malle, 1985). Therefore, at the same time and in the same context, different students can assign different meanings to the same mathematical content

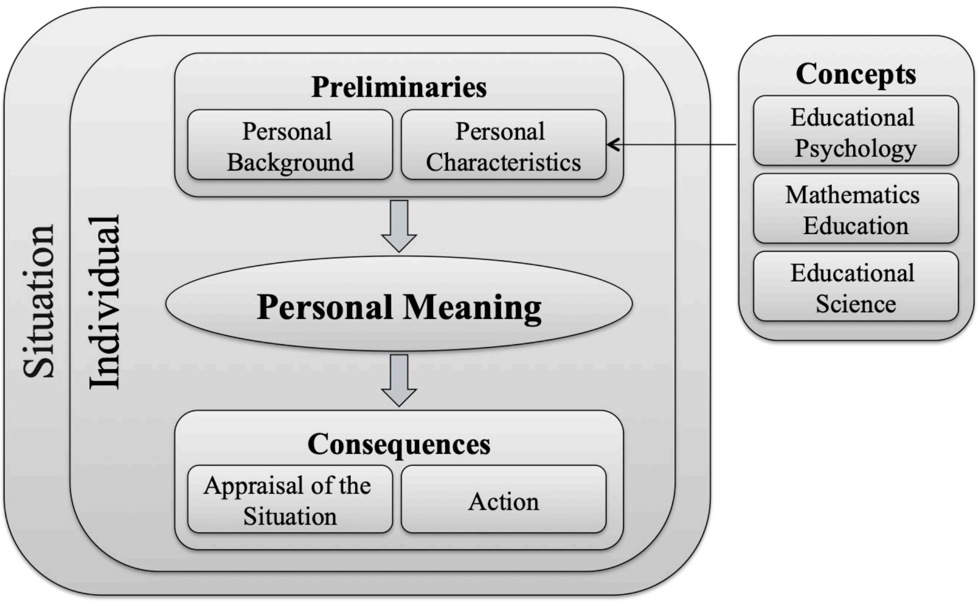

Figure 1. Relational framework of personal meaning (Vollstedt, 2011b).

Kilpatrick, Hoyles, & Skovsmose, 2005a; Vollstedt, 2011b). Vollstedt (2011b) proposed a model of personal meaning when learning mathematics and dealing with mathematical contents in a school context. In her theoretical framework she took the student's perspective. From this perspective, the following two main preliminaries influence the construction of personal meaning (see Figure 1): Firstly, the personal background of the student describes aspects which cannot be influenced by themselves like their socio-economic or migration background. Secondly, personal traits, i.e. aspects that concern the student's self, are relevant. They comprise concepts from various fields like educational psychology (self-concept, self-efficacy), mathematics education (beliefs), and educational science (developmental tasks). In addition to the individual preliminaries of a student, the situational context, i.e. context of the learning situation in terms of topic as well as classroom situation, is also a crucial factor for the construction of personal meaning.

The theory of personal meaning developed by Vollstedt (2011b) consists of 17 different kinds of personal meaning. They were constructed based on interview data with students from lower secondary level from Germany and Hong Kong. The aim of the study was on the one hand to develop a theory of personal meaning grounded in empirical data and, on the other hand, to investigate the role of (learning) culture for the construction of personal meaning (see Vollstedt, 2011a, 2011b for more information).

In total, 34 interviews were conducted with students from grade nine or ten (aged 15 or 16), 17 in each place. The interviews started with a sequence of stimulated recall (Gass & Mackey, 2000) in which the students watched a short video sequence of five to ten minutes from their last mathematics lesson. The sequence was chosen to show a situation in which the students dealt with something new for them as this might be a situation in which existing personal meanings might be reaffirmed or new ones might be constructed (e.g. in an “Aha” moment, cf. Liljedahl, 2005). The students were asked to reflect on the thoughts they had when they were attending the lesson as well as to name the thoughts they additionally had while watching the sequence. The subsequent interviews then addressed various topics inspired by the relational framework of personal meaning (see above, Fig. 1). They usually lasted for about 35 to 45 minutes with one exception in Hong Kong (90 minutes). Sample questions were for instance: How did you like this mathematics lesson? What was especially interesting? What feelings do you relate to mathematics lessons? Why do you learn mathematics? What can mathematics be used for? (cf.

Vollstedt, 2011c for the detailed interview guide). The data gained were coded following Grounded Theory (Strauss & Corbin, 1990; see Vollstedt, 2015 for a detailed description of the coding process and Vollstedt & Rezat, 2019 for the amendment of the coding paradigm). Theoretical saturation (Strauss & Corbin, 1990) was reached as the last two interviews did not provide any new categories and the relationships between the existing categories seemed well established and validated. In addition, the theory could be judged as dense for this age group from a theoretical point of view (Vollstedt, 2011b). This, however, does not mean that the theory may not require subsequent revision. Although the theory of personal meaning may be corroborated by future research, it may well be that it can also be elaborated further (Vollstedt, 2015).

The different kinds of personal meaning that were reconstructed from the data vary among the duty to deal with mathematics because it is a school subject, the cognitive challenge that is contained in mathematical tasks, and the experience of relatedness among the fellow students. The various kinds of personal meaning can be distinguished with regard to the intensity of the relatedness to mathematics and to the individual respectively, giving rise to seven superordinate types of personal meaning (cf. Figure 2).

Subsequent studies were carried out to develop a reliable survey on the basis of this theory (Büssing, 2016; Schröder, 2016; cf. Vollstedt & Duchhardt, 2019; Wieferich, 2016). At two stages, theoretical revisions were necessary. The first had to do with the fact that the personal meaning *Efficiency* from Vollstedt (2011b) combined two aspects: efficient classroom management and students' efficient ways of working, which could not be assessed with one scale. Instead, items addressing the latter aspect were merged with *Active practice of mathematics* and *Experience of autonomy*. The remaining scale was consequently renamed *Classroom management*. The second amendment followed from Büssing's (2016) results, which suggest splitting up *Relevance of application* into two facets, namely *Reference to reality* and *Application in life*. The resulting survey is used in the current study. The 18 kinds of personal meaning are presented in Figure 2.

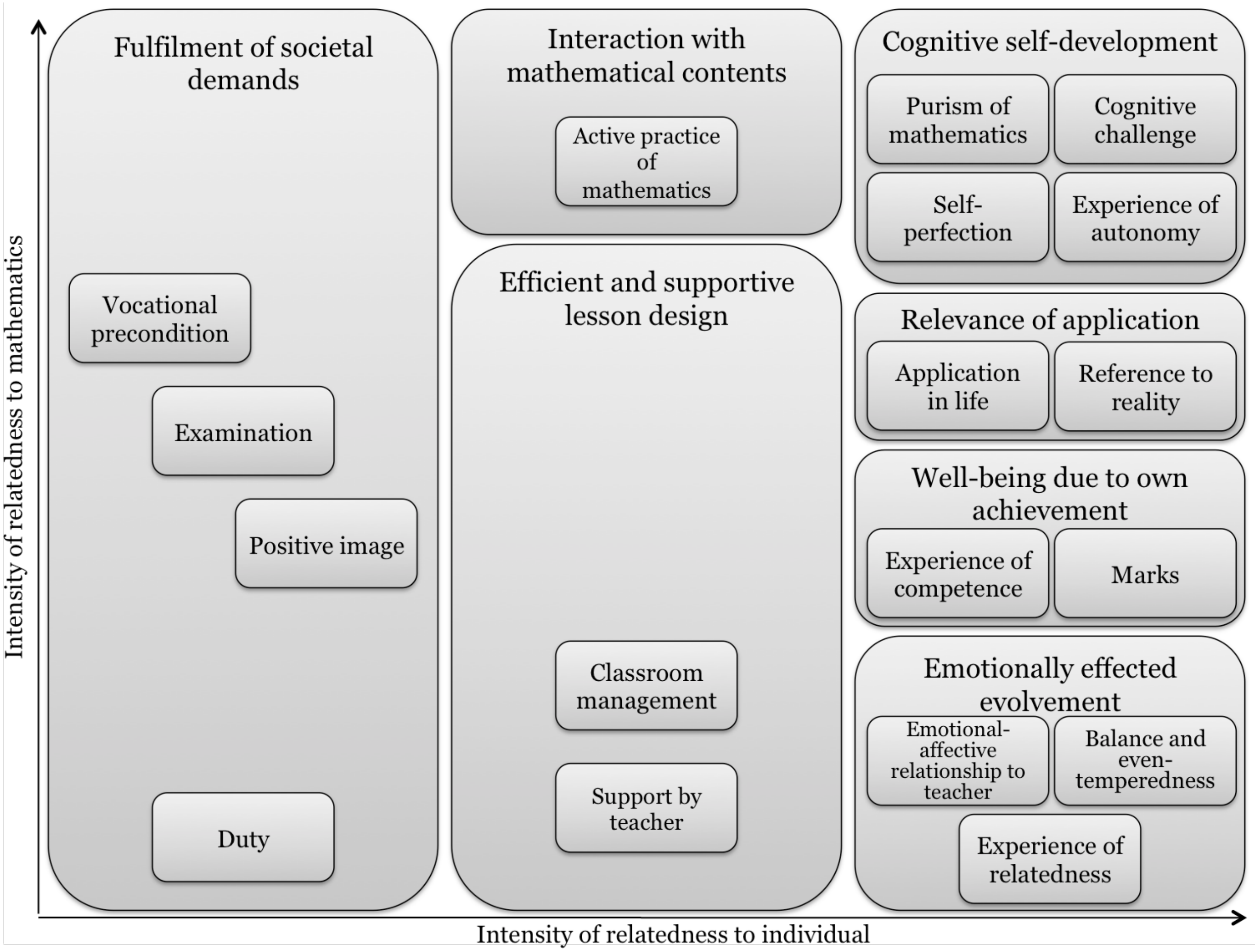

Figure 2. The typology of personal meaning with relation to the intensity of relatedness to mathematics and the individual consisting of 18 personal meanings. Note that amendments have been made with respect to the typology suggested by Vollstedt (2011b).

2.2 Educational systems in Finland and Germany

The previous section highlighted the construct of personal meaning and its relevance for learning mathematics in an educational context. In addition to students' background, foreground, etc., a countries' education reforms and policies may play a decisive role for learners' individual personal meanings in classroom. The educational context also affects and represents students' scholastic performance. Finland has been renowned for its high performing students in international comparative studies. However, in PISA 2015 Finnish students' mathematics performance, which shows a low correlation with their socio-economic status, had rapidly decreased compared to the former PISA studies. Now, Finland's PISA results are only a little better than the German results (OECD, 2018). The reasons for both countries' achievement level will not be discussed in the present study; the focus will rather be on their educational systems and mathematics curricula.

The mathematics curriculum of a country can be elaborated on different levels. Based on the results of the Second International Mathematics Study (SIMS; Travers, 1992) Valverde et al. (2002) describe the identified tripartite model of curriculum in detail: The intended curriculum comprises objectives in official documents for all students in a country. The implemented curriculum represents how these goals arise in mathematics lessons especially when teachers and students interact. The textbook is recognized as a mediator between intentions and implementation. The contents and processes that students deal with are focused in the attained curriculum. In general, the enacted mathematics curriculum comprises various stages within an educational system of a country, e.g. national objectives, educational goals, standards, syllabi, materials, teaching of a class (Thompson & Huntly, 2014). All stages are worthy of research as they would give an interesting insight into the development from intended to attained curriculum.

In our case, we intend to make a tentative analysis of the educational systems (attained curriculum) presented in the following sections. The analysis presented is not intended to completely meet criteria-guided empirical methods of comparing education systems. Nevertheless, it gives a first impression of interesting aspects of both countries' educational systems that might influence the construction of students' personal meanings.

A country's education is described by its educational system and core curriculum. These are essential to every education reform. Looking at the educational systems and curricula of both countries, disparities are noticeable.

According to its education philosophy "Every pupil is unique and has the right to high-quality education", Finland emphasizes students' individual growth, development and learning through equality, and high quality of learning. Finland has a comprehensive education for all (grades 1-9). Students visit one comprehensive school from primary level to lower secondary level independently of their academic performance. The low and high achievers sit in the same classroom and get individual support in accordance with their academic performance (Finnish National Agency for Education, 2017). Besides objectives of instruction and content areas related to the objectives, the national core curriculum for basic education defines seven transversal competence areas: Thinking and learning to learn (T1), Cultural competence/interaction and self-expression (T2), Taking care of oneself and managing daily life (T3), Multiliteracy (T4), ICT competence (T5), Working life competence and entrepreneurship (T6), Participation, involvement, and building a sustainable future (T7) (Finnish National Board of Education, 2016). Transversal competence areas are part of all subjects and play an important role in promoting students' individual development and their general learning. Another important fact is that during lessons students are engaged in reflecting about their own learning. Thus, during lessons students get support to understand their learning goals and receive help to recognize their own strengths and areas that need improvement. The Finnish teachers establish appropriate tasks that are necessary for learner's personal development. The teacher's role is to offer opportunities for the students to develop their skills for self-assessment and peer assessment in order to give and receive constructive feedback. Summarizing this, the focus of the Finnish curriculum is on cooperation rather than competition, and for teachers not to compare the students within a class. The continuous focus on these areas is considered to help students' life-long learning competencies.

In contrast, Germany focuses on the nascent need for skilled workers guided by their qualification initiative "Getting ahead through education" (*Aufstieg durch Bildung*). The federal government and the federal states had agreed on a common catalogue of objectives and measures whose aims are to raise the importance of education, to reduce the number of adolescents leaving school without vocational qualification, and to increase the number of students continuing education:

- Education is to have [*sic*] top priority in Germany
- Every child should have the best possible starting conditions
- Everyone should be able to gain school-leaving and vocational qualifications
- Everyone should have the opportunity to get ahead through education
- More young people should take a degree course
- More people should be filled with enthusiasm for scientific and technical vocations
- More people should take advantage of the opportunity for continuing education (KMK, 2017a, p.299)

In its federal states, Germany has many different school systems, which show variation e.g. with respect to the types of schools and the time span students visit them. One element that is similar in all systems is that there is an early selection into tracks according to students' academic performances (usually after four years, sometimes after six years of school attendance). The aim of this early separation is to provide optimal schooling with relation to the academic performance and needs of the students (KMK, 2017b). An analysis of the mathematical core curriculum shows that students' individual personal development is mentioned only superficially in the beginning of the educational standards (KMK 2005, p.6). The further description of the standards does not pick up this very fundamental topic at all. Hence, in the subject mathematics, the German education standards put a lot more emphasis on mathematical competences than on promoting students' individual development.

To conclude, the Finnish educational system focuses on every student's personal and academic development, as unique human beings and no separation is wanted. In contrast, the German educational system separates students early in order to respect their heterogeneous academic performances. In addition, the focus is on the development of mathematical competences rather than on personal development. These criteria are embedded in the core curriculum as a guidance for the mathematics lessons. Hence, the particular core curriculum of the country may also subconsciously influence teachers' actions in class and, thus, indirectly students' learning processes.

3 Research questions

In section 2.2, we provided a compact overview of the current Finnish and German education policy. The comparison illustrates remarkable differences in both countries' educational systems and curricula. Before it is possible to compare the results of two countries in a quantitative empirical study, we need to clarify some technical formalities. Therefore, we first examine technical questions focusing on the conduction of a comparative study on personal meaning in Finland and Germany. The following two major research questions are concerned with the compatibility of the results from Germany and Finland. The questions relate to the theory of personal meaning adapted for this study as described in section 2.1 above (Vollstedt, 2011b; Vollstedt & Duchhardt, 2019).

Validity of the instrument in Finland. The accessibility of personal meaning with a valid survey was confirmed in a former German pilot study with N= 195 ninth and tenth graders (Büssing, 2016; Schröder, 2016; Vollstedt & Duchhardt, 2019; Wieferich, 2016). The pilot study used data from the German federal states Bremen (two *Oberschule*, comprehensive school with school internal separation according to academic performance) and Lower Saxony (two *Gymnasium*, school for high achievers). This paper investigates ninth graders from Finland (comprehensive school) and Germany (different types of schools from various federal states). Hence, the first research question addressed in this paper is to test the validity of the Finnish survey of personal meaning (**research question 1**). In doing so, we investigate whether the Finnish translation of the instrument captures the same scales of personal meaning as the original German instrument.

Comparison between Finland and Germany. Building upon the results of the first research question, the second major target is a first approach towards a comparison of Finnish and German students' personal meanings (**research question 2**). The original survey was constructed and tested in Germany. Thus, students from Finland may understand and appraise the translated items in a different way than the original German formulation intended, or the German students rated the items. An interesting question in this comparison is what reasons can be detected for a different understanding or rating with respect to their educational system and curriculum. Therefore, it seems important to examine whether the latent variable models function equally across the samples in Finland and Germany. In the next step, meanings that are typically assigned to (learning) mathematics by Finnish and German students will be detected and significant differences will be discussed. This study considers crucial aspects of both countries' educational systems and curricula to make a tentative analysis of the formation of students' personal meanings.

4 Method

4.1 Sample

We collected survey data in Finland and Germany. In Finland, we collected data from 256 ninth graders (♀: 46%) in four comprehensive schools and 13 classes from the region Uusimaa. The 276 German participants (♀: 45%) from 17 classes were from different federal states (Bavaria, Baden-Württemberg, Bremen, and North Rhine-Westphalia) and attended different schools according to their academic performance (three Gymnasium (high achievers), one Realschule (middle achievers), three Oberschule (comprehensive school with school internal separation according to academic performance), and two Hauptschule (low achievers)). In our study, we are interested in all students' personal relevancies to deal with mathematics in an educational context. Therefore, we did not differentiate between high and low achievers to ensure having a heterogeneous group in Germany. In both countries, colleagues and private contacts of the researchers helped to find the schools.

4.2 Survey instrument

A research team at the University of Bremen (Büssing, 2016; Schröder, 2016; Vollstedt & Duchhardt, 2019; Wieferich, 2016) developed the German instrument to assess students' different personal meanings. The psychometric quality of the survey was good (Vollstedt & Duchhardt, 2019). For this study, the German version was translated into Finnish. We further validated the instrument in a cognitive lab (Zucker, Sassman, & Case, 2004). Based on the cognitive lab feedback we revised some items both in the Finnish and in the German version. Finally, the scale for the main study contained 131 items that were formulated as self-centered statements (like for instance "I deal with mathematics in order to…"). A 4-point Likert scale (0 = strongly disagree to 3 = strongly agree) was used to rate the survey.

4.3 Statistical procedure

Software. We conducted all statistical analyses in R (R Core Team, 2015). In particular, the R package TAM was used (Kiefer, Robitzsch, & Wu, 2015).

Scale analyses. Following an iterative approach, we tested the scales' psychometrical properties with item response theory (IRT) for both Finnish and German data. The IRT informed us about the validity of the survey in assessing students' personal meaning (see also Vollstedt & Duchhardt, 2019). For each scale of personal meaning, a partial credit model (PCM) with marginal maximum likelihood (MML) estimation was fitted to the data. We evaluated fit values of the PCM models ($0.8 < \text{Infit} < 1.2$; $-1.96 < t(\text{infit}) < 1.96$; $p(\text{infit}) > 0.05$) on item and scale level (Wu & Adams, 2007). Items with poor infit values were removed and the PCM model was refitted in an iterative procedure.

Differential Item Functioning (DIF). Differential Item Functioning analyses supported measurement equivalence of scales for people from two different groups. We compared the Finnish and German students' responses on items after adjusting for overall response tendency on the measured trait. This procedure was indispensable in this study in order to examine if the latent variable models functioned the same across the groups to ensure statistically fair comparison of any kind (Holland & Wainer, 1993; Monahan, 2007; Swaminathan & Rogers, 1990). An item had a DIF and was to be removed if two people from two different subgroups with the same overall agreement rate to this personal meaning had different agreement probabilities. We used the Educational Testing Service (ETS) classification system where an item has moderate to large magnitude of statistically significant DIF if the absolute DIF is >.638 and DIF significant >.426. Each item contributed to the estimation of the group means (Category C). The exclusion of a DIF item from a scale changed the estimate of the group difference. This allowed other items, which were previously inconspicuous, to show DIF. After removing the DIF items, the steps within the scale analyses were repeated.

Mean comparisons. We conducted Welch two sample *t*-tests (N = 532) to compare the Finnish and German students' personal meanings. Due to multiple comparisons, we controlled for false positives using Benjamini-Hochberg procedures (Benjamini & Hochberg, 1995) with a 1% (**) and 5% (*) false discovery rates. The computations were done using a published spreadsheet (McDonald, 2014).

5 Results and Discussion

Scale analyses. Psychometric properties of the Finnish and German surveys' scales were good. The estimated variances ranged from 0.49 to 5.73 (Finland) and from 0.58 to 5.30 (Germany) with most values around or above 1. Scale reliabilities ranged from an acceptable .65 to a very good .88 (Finland) and from .68 to .85 (Germany). Results from a former study with ninth and tenth graders from federal states Bremen and Lower Saxony show that it is possible to assess personal meaning in Germany with the valid German version of the instrument (Vollstedt & Duchhardt, 2019). Results relating to the assessment of Finnish personal meanings with a valid instrument (research question 1) show that the Finnish scales for the different personal meanings show all good psychometric properties. For most scales, two to four items were removed so that three to seven items remained. Exceptions were the two scales *Marks* (Finland reliability: .8, variance: 5.72; Germany reliability: .82, variance: 5.2) and *Duty* (Finland reliability: .83, variance: 5.73; Germany reliability: .83, variance: 4.73). They were assessed with only three items covering the core contents of the respective personal meanings with good values.

Looking at the scales with removed items, in both countries the scale *Balance and even-temperedness* (sample item: “It is important for me to sometimes play games in math lessons.”) had to be removed, as its psychometric properties were not acceptable. These results are rather surprising; this scale did not work at all in this study although it provided good values (variance = 1.07 and reliability = .68) in a former German study that was conducted in grades nine and ten (Vollstedt & Duchhardt, 2019). It was not yet possible to find a convincing explanation for why the current samples provided a different result.

The total reduction of 28 items provided a final instrument (in Finland as well as in Germany) with 103 items (17 scales) for further analyses.

Differential Item Functioning (DIF). Our second research question concerned the comparison between Finland and Germany. As a first step to this end, we conducted Differential Item Functioning (DIF) analysis. This analysis assessed whether the latent variable models function equally across the samples in Finland and Germany. The measurement equivalence of the survey is evaluated according to Educational Testing Service (ETS) classification (Monahan, 2007). Consequently, nine DIF items (Category C) were detected:

DIF items / Finland

- Active practice of mathematics (Act13): When I am actively challenged in lessons, I have the feeling to understand the math contents easily.
- Experience of autonomy (Aut5): It is important to me to organize the time for working on mathematical tasks on my own.
- Marks (Mar2): It is embarrassing when I have worse marks in mathematics than the others.
- Self-perfection (Sel3): It is important to me to perceive my learning progress.

DIF items / Germany

- Active practice of mathematics (Act2): I am happy when I can do mathematical tasks.
- Application in life (App3): I deal with mathematics so that I do not lack important knowledge later on.
- Experience of competence (Com2): I deal with mathematics because my learning success makes me feel good.

- Experience of competence (Com13): I am proud of myself, when I realize what I have learned in the last years in math lessons.
- Reference to reality (Rea6): I think that learning mathematics is important because it is of great importance for other sciences.

In total, nine items show DIF within the whole item pool, four from the Finnish version and five from the German version of the survey. To begin with Finland, Finnish students rated the items Aut5 (“It is important to me to organize the time for working on mathematical tasks on my own.”) and Mar2 (“It is embarrassing when I have worse marks in mathematics than the others.”) lower than German students. Item Aut5 from the scale Experience of Autonomy asks for students’ procedures when they deal with mathematics. However, the Finnish translation of this item (“Minulle on tärkeää saada järjestettyä aikaa matemaattisten tehtävien yksinään ratkaisemiseen.”) is more likely to be interpreted as referring to the time outside of school. So, the students may not be able to connect this statement with their classroom situation. Item Mar2 from the scale Marks deals with the topic of competition. As mentioned above (see section 2.2), both the Finnish educational system and curriculum do not support competition through comparison within the students in class. Thus, for Finnish students it is very strange to feel embarrassed. This may be a reason why they couldn’t identify with this item.

In contrast, German students rated the two items App3 (“I deal with mathematics so that I do not lack important knowledge later on.”) from the scale Application in Life and Rea6 (“I think that learning mathematics is important because it is of great importance for other sciences.”) from the scale Reference to Reality lower than the students from the Finnish sample. We assume that these students may not see the connection between the contents in their mathematics class and their need for knowledge later on or for other sciences. For the other five items (Finland: Act13, Sel3, Germany: Act2, Com2, Com13; see the list of DIF items for details), no sound reasons related to the education reforms and curricula could be found. At this point, it could be assumed that the students faced problems of misunderstanding in relation to wording.

All nine DIF items were excluded from further statistical procedures so that the remaining 94 items of the survey were considered for the comparative analyses between Finland and Germany. The psychometric properties of the new scales were again analyzed with good results.

Mean comparisons. We conducted *t*-tests to answer the second major research question with respect to commonality of personal meanings and significant mean differences between the Finnish and the German sample. The results presented in Table 1. give an interesting insight into Finnish and German ninth graders' preferred kinds of personal meaning. The following table presents an overview of the mean comparisons in an alphabetical order.

Table 1. Descriptive results per personal meaning of the Welch two sample t-test between Finland (FIN) and Germany (GER).

Personal meaning	**Mean of item means**		**Standard deviation**		***t*-Test**			
	FIN	GER	FIN	GER	*t*	*df*	*p*	Cohen's *d*
Active practice of mathematics	1.91	1.75	0.61	0.53	-3.16	508.19	0.001**	-0.80
Application in life	1.92	1.86	0.70	0.60	-1.04	497.13	0.297	-0.09
Classroom management	1.99	1.96	0.59	0.57	-0.61	523.73	0.537	-0.05
Cognitive challenge	1.54	1.38	0.68	0.60	-2.98	511.67	0.003*	-0.25
Duty	1.42	1.58	0.87	0.80	2.30	514.91	0.021	0.19
Emotional-affective relation to teacher	1.88	1.87	0.58	0.60	-0.17	529.04	0.858	-0.01
Examination	1.72	1.83	0.55	0.55	2.31	526.62	0.020	0.2
Experience of autonomy	1.70	1.68	0.60	0.57	-0.50	522.93	0.611	-0.03
Experience of competence	2.01	2.04	0.62	0.53	0.65	503.31	0.511	0.05
Experience of relatedness	1.89	1.96	0.53	0.48	1.71	514.77	0.087	0.13
Marks	2.14	1.87	0.71	0.78	-4.13	529.77	0.000**	-0.36
Positive image	1.45	1.48	0.60	0.59	0.56	525.29	0.574	0.05
Purism of mathematics	1.30	1.24	0.79	0.69	-1.02	509.37	0.304	-0.08
Reference to reality	1.62	1.69	0.59	0.53	1.42	506.59	0.155	0.12

Self-perfection	1.78	1.61	0.67	0.50	-3.25	474.64	0.001**	-0.28
Support by the teacher	2.08	2.20	0.66	0.53	2.37	488.42	0.017	0.2
Vocational precondition	2.05	1.72	0.69	0.75	-5.22	524.88	0.000**	-0.45

Note. All Likert scales were coded from 0 (*strongly disagree*) to 3 (*strongly agree*). Negatively worded items were recoded. Items removed during the scaling procedure were not included. *Statistically significant according to Benjamini-Hochberg procedure on 5% false discovery rate, **statistically significant according to Benjamini-Hochberg procedure on 1% false discovery rate, *N* = 532.

In general, both, students from Finland and Germany like less personal meanings that are related to mathematics like Purism of mathematics and Cognitive challenge and prefer personal meanings with a social inclusive character like Support by teacher, Experience of relatedness, and Emotional-affective relation to teacher. At first glance, the Finnish students' preference is easily explainable when taking into consideration the inclusive character of the Finnish educational system and curriculum: These meanings are in accordance with what is emphasized in the latest Finnish education reform (Finnish National Board of Education, 2016). The Finnish educational system and curriculum give top priority to collective learning environment and students' individual development. The continuous focus of these factors in math lessons clarifies why the Finnish students prefer these kinds of personal meaning related to social-inclusive factors. On the other hand, the German educational system and curriculum do not emphasize the social aspects as being as important as the competences related to the subject mathematics. Therefore, it seems that this kind of personal meaning is typical for both Finnish and German student, and that the Finnish curriculum is better aligned with student's preferences than the German curriculum.

Significant mean differences between Finland and Germany could be detected for the five personal meanings *Active practice of mathematics* (t = -3.16; df = 508.19; p < 0.01; Cohen's d = -0,80), *Cognitive challenge* (t =-2.98; df = 511.67; p < 0.05; Cohen's d = -0.25), *Marks* (t = -4.13; df = 529.77; p < 0.01; Cohen's d = -0,36), *Self-perfection* (t = -3.25; df = 474.64; p < 0.01; Cohen's d = -0,28), and *Vocational Precondition* (t = -5.22; df = 524.88; p < 0.01; Cohen's d = -0,45). The differences between the two educational systems and curricula may explain why Finnish students give top priority for *Marks* and *Vocational precondition* while in Germany these are far less emphasized. In Finland, grade nine is when students make the decision for the academic or the vocational track. As the acceptance to these institutes is based on grade nine marks, students need to achieve good grades to continue to popular tracks and schools. In contrast, the decision for vocational training or further education for most German students has only to be made after grade ten. Thus, the students' marks and their plans with respect to their future professional career are not yet equally decisive as they are for their Finnish counterparts.

The personal meanings that refer to mathematics and show significant differences (*Active practice of mathematics, Cognitive challenge,* and *Self-perfection*) were more common among Finnish students than among German students. Interestingly, these personal meanings had a quite high level of intensity of relatedness to individual (see Figure 2). Hence, Finnish students liked to deal with mathematics in order to improve their own skills and their self, respectively. This is also an important aspect that has top priority in the Finnish curriculum. The task of the subject mathematics includes, beside technical components, instruction that supports a positive attitude towards mathematics and a positive self-image as learners of the subject (Finnish National Board of Education, 2016).

6 Summary and further perspectives

In this study, we investigated the personal meanings of Finnish and German ninth grade students. The concept of personal meaning is multifaceted and highly relevant for learning mathematics in an educational context. We identified some relevant differences between the educational systems and curricula in these two countries. The Finnish educational system and curriculum focuses highly on the social nature (i.e. students' individual development) whereas the German education reform emphasizes more the subject related competences. In this paper, these aspects of the particular education reform are referred to for the tentative explanations of the quantitative results. We established the instrument of personal meaning in Finnish and German ninth grades to detect learners' personal meaning when learning mathematics. The scale analyses provided, in Finland as well as in Germany, scales with good psychometric properties. The personal meaning *Balance and even-temperedness* was removed as the reliability and the variance were found not to be good. After this procedure, the valid instruments were used for the Differential Item Functioning (DIF) analyses to evaluate the measurement equivalence. Nine DIF items could be detected and for the clarification of four of those DIF items, the particular educational system and curriculum of Finland and Germany was consulted. The exclusion of these nine DIF items allowed us to use the remaining items for the comparison between Finland and Germany. The mean comparisons came up with five significant mean differences, namely *Active practice of mathematics, Cognitive challenge, Marks, Self-perfection*, and *Vocational precondition*. The comparisons showed that Finnish and German learners gave more importance to social inclusive aspects and German learners less importance to the subject mathematics related aspect. In addition, meanings related to mathematics were typical among Finnish learners. This can be related to confirming important aspects of the self as one of the notions of the Finnish reform (Finnish National Board of Education, 2016). Our results showed differences between Finnish and German learners' personal meanings depending on the respective educational reforms. Future research will examine the different preferences of the personal meanings between Finnish and German students with regard to other affective constructs like learning motivation and self-concept, independently of curricula.

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