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# Secondary school students' chemistry self-concepts: gender and culture, and the impact of chemistry self-concept on learning behaviour

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While science self-concepts of secondary school students have received considerable attention, several important aspects of chemistry self-concepts have not yet been understood: gender relations, the impact of students' cultural backgrounds, and the impact of chemistry self-concept on learning processes. In the present study, (i) we could confirm our hypothesis that chemistry self-concept is strongly related to learning goal orientations. This part of the study built upon knowledge from educational psychology. Our results open the field for practical interventions designed to influence chemistry self-concepts. (ii) We investigated the gender relations in chemistry self-concept with a special focus on students' cultural backgrounds. The results show that chemistry self-concept differs from science self-concept: the gender gap traditionally described in the literature could not be found. Instead, the study suggests that an interaction of gender and cultural background might influence chemistry self-concepts. (iii) We were interested in the influence of the context of chemistry classroom and language on self-concept. In line with the literature, we found that a good relationship with the chemistry teacher seems to have a positive impact on chemistry self-concept. Also, the perception of chemistry language and chemistry self-concepts were strongly correlated. Suggestions are made for practical interventions based on these findings.

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## Introduction

Chemistry education should enable students to develop positive attitudes towards chemistry. For science in general, this is established in the concept of Scientific Literacy of which positive science self-concepts form an important part (OECD, 2006). Scientific Literacy is composed of cognitive and affective aspects (Bybee, 1997), and self-concept is part of the affective side of Scientific Literacy. This comprises "attitudes and values that individuals may have towards science" (OECD, 2006). Following the same rationale, positive chemistry self-concepts can be defined as a feature of Scientific Literacy in chemistry. In addition, self-concepts are strongly associated with achievement. They are thus important as such – in terms of Scientific Literacy in chemistry – and as facilitators of chemistry learning.

However, many aspects of secondary school students' chemistry self-concepts are insufficiently understood. While general science and physics self-concepts of secondary school students have been studied extensively, studies in chemistry education tend to concentrate on chemistry self-concepts of college students (*e.g.*, Bauer, 2005; Nielsen and Yezierski, 2015, 2016). Regarding secondary school students, several questions remain unresolved.

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The study presented in this article covers three aspects: (i) the relation of self-concept to learning processes in chemistry. In educational psychology, it is assumed that students with positive self-concepts tend to show learning goal orientations (Dishon-Berkovits, 2014). Based on these findings, we assume that a similar relation can be found for chemistry, *i.e.*, a positive relation between chemistry self-concept and chemistry learning goal orientations. Establishing this relation is important because it helps to think about the practical implications of self-concept research. In many studies, self-concept research remains at the theoretical level because self-concept is difficult to act upon. Learning goal orientations are more concrete and, therefore, interesting for the design of interventions. Suggestions for practical implications of the study's results are given in the discussion.

(ii) The impact of gender on secondary school students' chemistry self-concepts is not entirely clear. Here, we assume we will find differences to the other science fields because research suggests that chemistry might be less closely associated with masculinity than physics but more so than biology: girls tend to have stronger self-concepts in biology than boys and select biology courses more frequently (Nagy *et al.*, 2006). Boys have higher self-concepts in physics and are more likely to choose a physics-related career than girls (Sikora and Pokropek, 2012). In contrast, girls and boys seem to be equally interested in

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chemistry (Broman and Simon, 2015). Is chemistry, therefore, gender-neutral? This aspect needs further investigation. We will look at this from a perspective that takes into account students' cultural backgrounds. This is necessary because students' science self-concepts depend on their cultural backgrounds (*e.g.*, Leslie *et al.*, 1998; Riegle-Crumb *et al.*, 2011; Lau, 2014), and gender is a cultural construct. In the present study, we thus aim at gaining a deeper understanding of the impact of gender in its interplay with culture on students' chemistry self-concepts.

(iii) We investigate how the social context and the use of chemistry language affect self-concept. Here, we are unaware of a study investigating the relation between language and self-concept in science. However, it is known that chemistry language poses difficulties to many students, as is the case for physics, too. Because of this lack of investigations, we focus on the relation between self-concept and language in chemistry in an exemplary manner. In educational psychology, it is assumed that self-concept is closely related to the social context in class (Lin *et al.*, 2009; Jacques *et al.*, 2012). Since linguistic issues play an important role in chemistry learning (*e.g.*, Markic and Childs, 2016), we assume that the perception of chemistry language is closely related to chemistry self-concept.

# Theoretical background

### Self-concept and its relation to achievement

Chemistry self-concept research has its origins in educational psychology. In this context, self-concept has been defined as "a person's perception of himself" (Shavelson *et al.*, 1976, p. 411), which means a person's thoughts and feelings about himself or herself. Today, research concentrates mainly on ability self-concepts, *i.e.*, peoples' thoughts and feelings about their abilities in a certain domain. The academic dimension has received particular attention: self-concepts in various school or university subjects have been investigated, such as mathematics self-concept, English self-concept, and many more (Marsh *et al.*, 2012). For the purpose of this study, we define chemistry self-concept as part of the motivational side of Scientific Literacy, being a student's perception of his or her abilities in chemistry.

The main reason for the interest in academic self-concept is its strong relation to outcome variables such as achievement (an overview: Marsh and Craven, 2006; for chemistry: Lewis *et al.*, 2009; Jansen *et al.*, 2014) and career choices (Nagengast and Marsh, 2012; Taskinen *et al.*, 2013). Students with positive self-concepts in a subject are more likely than other students to achieve well in the subject and to opt for related careers. Today, it is assumed that self-concept influences achievement and *vice versa* (the 'reciprocal effects model', Marsh and Craven, 2006). But how can beliefs about one's abilities translate into achievement?

### The role of learning goal orientations as mediator variables between self-concept and achievement

It is often suggested that learning goal orientations play a mediating role in the relation between self-concept and achievement (Lin *et al.*, 2009; Dishon-Berkovits, 2014). Learning goal orientations are positively related to both self-concept (Ferla *et al.*, 2010) and achievement (Lin *et al.*, 2009). These goal orientations are interpretative lenses. Learning goal oriented students tend to interpret situations as opportunities to improve their skills (Dweck, 1986; Dweck and Leggett, 1988). It is hypothesized that the recognition of these opportunities then contributes to effective learning behaviour and thus to higher achievement.

There are several indicators of learning goal orientations. One such indicator is the incremental theory of intelligence. It means that students with a learning goal orientation tend to perceive their abilities as changeable (Dweck and Leggett, 1988, p. 262). They believe that they can develop their competencies if they make enough effort. Further, students with a learning goal orientation tend to be more persistent when they are confronted with a difficult task (Dweck, 1986). They do not give up quickly because they believe in their ability to learn and to understand. Persistence is thus another indicator of learning goal orientations. The third aspect of learning goal orientations is the need for cognition (Cacioppo and Petty, 1982). Students with a learning goal orientation tend to "engage in and enjoy thinking" (Dickhäuser and Reinhard, 2006, p. 491). This enjoyment of thinking is closely related to learning goal orientations (Day *et al.*, 2007).

We can conclude from these two sections that self-concepts have a close relationship with achievement that seems to be mediated by learning goal orientations. We, therefore, hypothesize that a similar structure can be found for chemistry self-concepts. We assume that chemistry self-concepts influence chemistry learning goal orientations. If this is true, it could have important implications for chemistry research and teaching practice. It could, for instance, be interesting to develop and test teaching strategies that focus on task choice behaviour. Teaching strategies that help students to reflect their goal orientations in chemistry class could help them to overcome persisting cognitive and behavioural patterns. Discussions with other students could provide insights into alternative perspectives on task choices in chemistry. This could increase the practical outreach of chemistry self-concept research.

### The role of the social context

The socio-cultural context has been found to be crucial in the formation of students' self-concepts. Self-concepts depend on the social relationships in school as well as on the wider cultural context. The student–teacher relationship seems to be pivotal for academic self-concepts (Wentzel *et al.*, 2010; Jacques *et al.*, 2012; Raufelder *et al.*, 2015; Dudovitz *et al.*, 2017). Also, teachers' beliefs about gender differences in science self-concepts seem to be associated with students' self-concepts (Thomas, 2017), as well as the teachers' use of cooperative learning methods (Hänze and Berger, 2007). If peer relationships have an impact on academic self-concept is less clear. Some studies have found a positive relationship (Wentzel *et al.*, 2010; Jenkins and Demaray, 2015; Wentzel *et al.*, 2017), while others have found no relationship (Raufelder *et al.*, 2015). These findings about the role of the social context remain mainly subject-unspecific. We, therefore, do not know what impact the social context in

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chemistry class has on chemistry self-concept. We assume we will find a similar positive relationship between chemistry self-concept and social support as described in the literature from educational psychology.

However, we do know that language plays a pivotal role in chemistry learning (for an overview see Markic and Childs, 2016). The same is true for the social context. Social support is crucial in chemistry identity formation (Grunert and Bodner, 2011). Supportive and collaborative work among peers can reduce anxiety and support student achievement in chemistry (*e.g.*, Eren-Sisman *et al.*, 2018). In addition, a supportive relationship with the teacher seems to be of high importance for achievement in chemistry. This is particularly true for students from marginalized ethnic groups (Wood *et al.*, 2013).

If chemistry self-concept is related to the social context, this would open the field for further practical implications of chemistry self-concept research. Just as described in the section above, it could be interesting for both teachers and students to engage in discussions about task choice behaviour and chemistry self-concepts. Interventions could focus on creating supportive and encouraging relationships between peers and with the teacher.

### Findings from science and chemistry education

Regarding science and technology self-concepts, some important findings have been made. Gender relations have been investigated intensely. Many studies have shown that boys tend to have stronger science self-concepts than girls (*e.g.*, Simpson *et al.*, 2016; Wan and Lee, 2017). However, when differentiating between science domains, these gender relations are more complex (Hardy, 2014). In physics, boys tend to have higher self-concepts than girls (Koul *et al.*, 2016). Similar relations have been found for chemistry although gender differences seem to be less pronounced (Ziegler and Heller, 2000; Chan and Bauer, 2015). In contrast, in biology, girls tend to have stronger self-concepts (Nagy *et al.*, 2006). This is reflected in students' career aspirations in science. Girls tend to prefer occupations in biology and health, while boys prefer occupations in computing, engineering, and maths (Sikora and Pokropek, 2012).

Cultural differences have received some attention in science self-concept research as well. East Asian students achieve well in science but their self-concepts tend to be lower than those of students in many Western countries (Lau, 2014). Furthermore, the self-concepts of minority students have been investigated. Minority students tend to have lower self-concepts than students who belong to a country's dominant ethnic group (Leslie *et al.*, 1998; Riegle-Crumb *et al.*, 2011; Woods-McConney *et al.*, 2013; Simpkins *et al.*, 2015). An exception is Asian students living in a Western country. These students show stronger science self-concepts than the dominant group (DeWitt *et al.*, 2011). These findings indicate that science self-concepts might be influenced by the students' cultural backgrounds. For chemistry education, there seem to be no studies investigating the impact of students' cultural backgrounds on self-concept. We, therefore, do not know if the students' cultural backgrounds influence chemistry self-concepts, or if they are independent of culture.

Thoroughly tested and validated instruments for measuring chemistry self-concept exist for higher education. Here, the Chemistry Self-Concept Inventory (CSCI) (Bauer, 2005) is available. Also, the Attitude toward the Subject of Chemistry Inventory (ASCI) (Bauer, 2008; revised version: Xu and Lewis, 2011) provides a scale for measuring chemistry self-concept. Both scales can measure chemistry self-concepts of college students because they are based on Marsh's Self-Description Questionnaire III (SDQ) (Marsh, 1992), which is designed for young adults. For secondary school students, we are not aware of an instrument that would constitute a standard in measuring chemistry self-concept. However, for science, several established and well-tested instruments exist (*e.g.*, SDQ II, Marsh, 1992; and the PISA 2006 science self-concept scale, OECD, 2009b).

In order to advance chemistry self-concept research, it would first be necessary to develop and validate an instrument for assessing secondary school students' chemistry self-concepts. Furthermore, if gender and cultural background have an impact on chemistry self-concept, these factors would need to be considered in future research on chemistry self-concept. In addition, the relations of gender and cultural background with chemistry self-concept would need further attention in qualitative studies investigating identity constructions in chemistry as has been done for many science disciplines (*e.g.*, Archer *et al.*, 2010).

### The present study

The literature review shows that secondary school students' chemistry self-concepts have received little attention. The present study seeks to investigate the following aspects. (i) The relation between chemistry self-concept and learning goal orientations – here, we assume we will find a positive relation between chemistry self-concept and learning goal orientations, as has been shown in educational psychology. (ii) The gender relations regarding chemistry self-concepts of secondary school students – here, we assume that chemistry self-concepts differ from those in science in general because chemistry seems to be less closely associated with masculinity than physics. Also, regarding the relation of chemistry self-concept with students' cultural backgrounds, we lack knowledge. (iii) The influence of the social context in chemistry class and chemistry language on chemistry self-concept – here, we assume we will find a positive relation, just as it has been found in educational psychology.

### Pilot study

We addressed these questions in a preliminary study (Rüschenpöhler and Markic, 2019) in which we investigated the chemistry self-concepts of secondary school students in Germany ($N = 116$). Using a questionnaire, we obtained quantitative data that were analysed using ANOVA. In this analysis, we wanted to investigate the effects of culture and gender on chemistry self-concept. To do so, we compared boys and girls without migration background to boys and girls with a Turkish migration background. We limited the analysis to these culture groups because here sample sizes were sufficient. In fact, the largest group of students in Germany with a migration background is made up of students with a Turkish migration

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background (Statistisches Bundesamt, 2017). The same was true in our data set. The analysis of the data revealed that the main effects of gender and culture were not significant. This indicated that gender and cultural background alone might not have an impact on chemistry self-concept. Interestingly, however, we found that the interaction effect of gender and culture was significant. The Turkish girls seemed to have slightly stronger chemistry self-concepts than the boys, while in the German sample the boys showed stronger self-concepts than the girls. This surprised us since this had not been documented in the literature. This suggests that maybe chemistry is gendered differently in the groups of students with a Turkish background and without migration background.

In addition to the quantitative part of the study, we conducted interviews with some of these students ($N$ = 43) (Rüschenpöhler and Markic, 2019). In these interviews, we sought to find out how chemistry self-concepts might be associated with learning behaviour and the social context. The data suggested that learning and performance goal orientations, as well as social orientations, might not be the same in the different culture and gender groups. For example, the Turkish girls showed strong social orientations, whereas this seemed to be of little relevance for the German boys although the chemistry self-concepts were quite strong in both groups. The language of chemistry seemed to be perceived as difficult especially by those students with weak chemistry self-concepts (Rüschenpöhler and Markic, 2019).

### Research questions

In this article, we now present the results of the subsequent study in which we test hypotheses based on the findings in the preliminary study. The research questions are grounded in the findings of both the preliminary study and several gaps in the literature we pointed out.

(i) What chemistry self-concepts do secondary school students of different genders and cultural backgrounds have?

(ii) How are secondary school students' chemistry self-concepts related to learning goal orientations?

(iii) How are secondary school students' chemistry self-concepts related to the social context in the classroom and the perception of chemistry language?

## Methods

### Instrument

We designed a questionnaire (see the Appendix) based on measures that had previously been employed in large-scale studies, that are established in their respective fields, and that are available in both English and German.† Only in the case of the students' feelings of their understanding of the scientific language of chemistry (language scale), we could not find an appropriate scale and, therefore, developed a new one with six items. In all other cases, we adapted existing scales to the context of chemistry education and, in some cases, deleted items in order to limit the students' time on task to a reasonable amount. We expected the excluded items' linguistic level and, therefore, task difficulty, to be high for a considerable proportion of students. By carefully selecting the items and reducing their numbers, we intended to help the students to fulfil the task.

Self-concept was measured using an adapted version of the PISA 2006 science self-concept scale (Q37) (OECD, 2009b) with six items in which we replaced the word "science" with "chemistry". To assess the students' feelings of social belonging, we chose to employ three separate scales. We measured the perception of the social context using three indicators: (i) the feeling of belonging to the group was measured with the five-item PISA 2003 sense of belonging scale (Q27) (OECD, 2005) that we adapted slightly to fit the context of chemistry class; (ii) the perceptions of peer relationships were measured with the student support scale from the HBSC 2013/2014 study (MQ61) (Inchley *et al.*, 2016) with three items, in which we replaced "my class" with "my chemistry class"; and (iii) the perceptions of the relationship to the chemistry teacher were measured with the teacher support scale from the same study (MQ62) (Inchley *et al.*, 2016) with three items, in which we replaced "teacher" with "chemistry teacher".

We measured the students' learning goal orientations with three indicators. The first indicator was (i) the students' need for cognition in chemistry. We based the scale upon the measure developed by Cacioppo and Petty (1982) and added "in chemistry" to the sentences. However, with its 45 items, it would have been too long for our purpose, so we retained only items 1, 4, 18, 23, 40, and 41. This choice was partly based on the limited number of items for which a German translation was available (Bless *et al.*, 1994). Out of the 33 items that were available in English and German, we chose six that we expected to be both comprehensible for the students and pertinent in the specific context of chemistry education. Besides the need for cognition, we measured (ii) the students' perceptions of their task persistence in chemistry with the five-item scale of the PISA 2012 questionnaire (Q36) (OECD, 2014a) in which we inserted "in chemistry" in each sentence. As the third indicator of learning goal orientations, we chose (iii) the students' theory of intelligence in chemistry, namely their entity and incrementalist beliefs about their abilities in chemistry. To construct this scale, we selected four out of six items from Dweck's (2000) entity and incrementalist beliefs scales, added "in chemistry" to the sentences and used Spinath's (1998) translation.

### Data collection

The questionnaire was pre-tested in a cohort of three classes ($n$ = 68) at a Realschule and discussed with their chemistry teacher. The only major issue that occurred was that not all of the students had covered chemical equations in their classes yet. Therefore, the students could not give meaningful answers to items 5 and 6 of the language scale. In the following, we

† The reason for choosing only measures that are available in the English language as well was twofold: first, we intended to provide the possibility for later comparative studies at least in English-speaking countries, and second, we wanted to allow for a critical scrutiny of our study not only by German-speaking researchers but also in the international community.

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asked the teachers if chemical equations had been covered. If not, we told the students to leave these items blank. Because of the low response rate, these items were discarded from the analysis.

The majority of the questionnaires (70.1%) was collected by one of the authors, following a predefined procedure with which we aimed at enhancing the linguistic comprehensibility of the items: all text was read aloud. The general introduction was read by students who volunteered to read, whereas the items of the scales were read by the administrator. Our concern was that reading competencies vary greatly between students as a considerable number of students are below the baseline reading level defined in the PISA studies (OECD, 2014b). Limiting the number of items, reading them aloud, and encouraging student questions concerning the meaning of the phrases and words aimed at obtaining data of higher quality than could be expected from a design in which students were to read all questions silently by themselves, especially for non-native students and second language learners. In order to ensure a high level of objectivity in the test situation, the questionnaires that we could not collect in person (29.9%) were accompanied by instructions for the teachers who administered them.

### Sample

585 students from 30 classes in 10 German schools participated in our study. The students were aged 12–18 ($M$ = 15) and enrolled in grades 8–10 in German secondary schools. This group was chosen since they had already experienced chemistry classes for at least one year. Almost 90% fell in the age range of 13–16 years which is typical for these grades. 0.5% were younger. They are probably students who had skipped a grade. The students who were older are probably either those who had to repeat a school year because they did not achieve well, or immigrants who first attended a separate German class before entering the regular school system.

We included all types of secondary schools except for special needs education schools.‡ Most of them (7) were situated in the metropolitan area of Stuttgart, in the south of Germany, two schools in an urban setting in Bremen, in the north of the country, and one school in a rural area close to Stuttgart. Our sample, therefore, represents a rather urban population. 266 (45.5%) of the students were female, 314 (53.7%) male, and 5 (0.8%) did not report their gender.

‡ The German school system is traditionally composed of three school types, *i.e.*, *Gymnasium*, which prepares for university, *Realschule*, and *Hauptschule*. Traditionally, the students are assigned by the teachers to the school type, based on their achievement and their learning behaviour in primary school. In many parts of the country, the situation is changing: other school types have been created and sometimes the parents rather than their teachers decide about their children's school. However, the division is still present in most parts of the country. This study was conducted mainly in Baden-Württemberg and Bremen. Baden-Württemberg adheres to the tripartition with *Gymnasium*, *Realschule*, and *Werkrealschule*, and has recently introduced a fourth type for inclusive learning, the *Gemeinschaftsschule*. However, since this type was developed only recently, we were unable to find schools with grades 8–10 that we needed for our sample. All other school types were covered. In Bremen, the tripartition has been reduced to a division into two school types, *Gymnasium* and *Oberschule*, which were both covered in this study.

In order to group the students according to their cultural backgrounds, we employed the definition of migration background that had been used for the official 2013 census (Statistisches Bundesamt, 2013) in Germany. According to this definition, every student who was born in a country other than Germany or whose parent(s) was(were) born in a country other than Germany has a migration background. Since the concept of migration background is quite abstract and especially so for underage students, we included an explanation for the criteria for having a migration background in the questionnaire in order to attain more valid results. Following this definition, 72 (12.3%) had a Turkish or Kurdish migration background, 19 (3.2%) an Italian, 17 (2.9%) each a Greek, Kosovan, or Polish, 11 (1.7%) a Croatian, 10 (1.7%) a Russian, and 9 (1.7%) each a Bosnian or Romanian migration background. 85 (14.5%) had other migration backgrounds, 50 (8.5%) reported a multiple migration background, while 18 (3.0%) did not specify the type of their migration background. 248 (42.4%) stated not to have a migration background. For research question (i), we analysed only the data of the students without migration background and those with a Turkish background. For research questions (ii) and (iii), we used the complete data set.

Participation in the study was based on informed consent. Prior to conducting the study, we obtained permission of the local ministry of education, youth, and sports (*Ministerium für Kultus*, *Jugend und Sport Baden-Württemberg*) and the schools. Since most of the students were underage, we also obtained the teachers', the students', and their parents' permissions. This was done in a letter to the parents, teachers, and students in which we described the purpose of the study and the students' role in it, and in which we informed them about the voluntary nature of the participation. We explained that school principals, teachers, students, and parents could withdraw their permission at any moment in which case the student data would be deleted. Only those students who volunteered and whose parents and teachers had consented to their participation in written form participated in the study. A code was generated for each questionnaire that allowed tracing it back to its class. However, it was not possible to trace the data back to individual students.

### Analysis

First, we analysed the reliability of the scales using Cronbach's $\alpha$. In order to assess unidimensionality, we ran a confirmatory factor analysis for each scale. In order to answer research question (i), we conducted a $2 \times 2$ ANOVA with type III sums of squares, analysing the strength of self-concept. For this analysis, we used a subsample: we compared the four groups of German boys ($N$ = 129) and girls ($N$ = 115), and Turkish boys ($N$ = 40) and girls ($N$ = 32). Only these groups were sufficiently large for this type of analysis. We conducted the analysis using group mean centred values because we were interested in self-concept at the individual level. Using group mean centred values allows investigating the self-concepts of the individuals while cleansing the scores from group effects (Enders and Tofighi, 2007).

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Second, we tested a linear regression model on the data. For this analysis, we used the whole sample ($N = 585$). We constructed a model with self-concept as the dependent variable and sense of belonging, perceived student and teacher support, incremental theory, perceived task persistence, need for cognition, and feeling of understanding chemistry language as independent variables in order to answer research questions (ii) and (iii). Here again, we used group mean centred values. In all analyses, negatively worded items were reverse coded (see the Appendix) so that, *e.g.*, high scores on the self-concept scale indicate positive self-concepts.

We analysed the data using R (R Core Team, 2017) with the packages car (Fox and Weisberg, 2011), psych (Revelle, 2017), QuantPsyc (Fletcher, 2012) and WRS2 (Mair *et al.*, 2017) as well as multiple helper functions (Wickham, 2007, 2009, 2011; Dahl, 2016; Henry and Wickham, 2017; Wickham *et al.*, 2017; Lüdecke, 2018; Wickham and Henry, 2018).

# Results

### Quality of the measurement

The reliabilities of most scales were in the desired range of 0.7 to 0.8 (Kline, 2000; Table 1). The α of the self-concept scale was slightly too high. In the literature, reliabilities between 0.88 and 0.94 had been reported for this scale (OECD, 2009b). The reliability of 0.91 measured in this sample is very close to the reliability measured for the German sample in the PISA 2006 study (OECD, 2009b) and was, therefore, judged to be acceptable.

Problematic was the incremental theory scale. Its reliability was quite low (0.65). In addition, unidimensionality could be confirmed *via* CFAs for all the scales except for the incremental theory scale (SRMR = 0.122; CFI 0.716, see Table 1). Observations in class pointed to the underlying problems. A number of items were difficult to understand for some of the students due to the items' sophisticated language. We knew about these difficulties because we had encouraged the students to ask us if there was something they did not understand. In several classes, discussions with the students emerged about the items of the incremental theory scale. Other scales, such as the language and self-concept scales, raised almost no questions. In addition, some teachers had expressed their concerns about the comprehensibility of the scale in informal conversations before or after conducting the study.

Table 1 Mean values, standard deviations, and values for Cronbach's α for all the scales. SRMR and CFI values from the confirmatory factor analyses for all the scales. The incremental theory scale was excluded from further analyses

| | Item | *M* | SD | α | SRMR | CFI |
|---|---|---|---|---|---|---|
| Student support | 3 | 4.55 | 1.14 | 0.72 | 0.036 | 0.978 |
| Belonging | 5 | 4.85 | 1.14 | 0.78 | 0.041 | 0.939 |
| Teacher support | 3 | 4.38 | 1.32 | 0.72 | 0.059 | 0.948 |
| Self-concept | 6 | 3.91 | 1.23 | 0.91 | 0.026 | 0.971 |
| Incremental theory | 4 | 4.24 | 1.22 | 0.65 | 0.122 | 0.761 |
| Persistence | 5 | 3.81 | 1.22 | 0.77 | 0.057 | 0.890 |
| Need for cognition | 6 | 3.63 | 1.43 | 0.76 | 0.039 | 0.951 |
| Language | 4 | 4.30 | 1.31 | 0.80 | 0.018 | 0.987 |

Based on these findings, we decided to exclude the incremental theory scale from further analyses since the scores were not sufficiently reliable, its unidimensionality was not shown and some students seemed to have had difficulties understanding the items.

### Relationships of gender and cultural background with self-concept

The analysis of the relationship of gender and cultural background with chemistry self-concept (research question (i)) was conducted with the Turkish and German subsamples (German: $N = 248$, Turkish: $N = 72$) because the sample sizes in all the other groups were too small. The interaction graph (Fig. 1) indicated there might be an interaction effect of gender and cultural background on chemistry self-concept but no significant main effect of the two variables.

Levene's test was significant for both gender ($p < 0.01$) and the interaction variable ($p < 0.05$). We, therefore, conducted a robust analysis using a bootstrap with 599 repetitions using the modified one-step estimator of location and Mahalanobis distances provided in the t2way function of WRS2 (Mair *et al.*, 2017). The main effects of gender, $F(1, 312) = 0.04$, $p = 0.843$, and cultural background, $F(1, 312) = 2.98$, $p = 0.089$ on chemistry self-concept were not significant. The test revealed a significant interaction effect of gender and cultural background on chemistry self-concept, $F(1, 312) = 6.51$, $p < 0.05$. This indicates that gender differences might not be the same between the German and Turkish students, just as the preliminary study had indicated.

### Relationships between self-concept and the other psychological variables

For the multiple linear regression (research questions (ii) and (iii)), we used the entire sample of 585 students. The exploration of the data indicated strong positive relationships of task persistence, need for cognition, and the understanding of scientific language with self-concept (Fig. 2).

After the exploration, we ran the linear model with deviation contrasts for the categorical variables (Table 2). The values of the psychological variables were group mean centred and standardised. Persistence, need for cognition and understanding of scientific language in chemistry seemed to be good predictors of

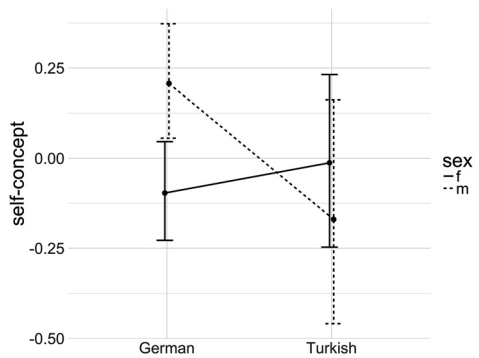


Fig. 1 Interaction plots of the effects of gender and Turkish migration background on chemistry self-concept with error bars.

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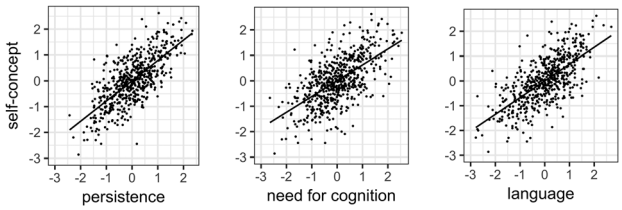


Fig. 2 Scatterplots with linear regression for the relationships of persistence, need for cognition, and language with self-concept.

Table 2 Results of the linear regression model; $R^2$ = 0.629. *** = <0.001, ** = <0.01, * = <0.05

| | $\beta$ | SE $\beta$ | $p$ |
|---|---|---|---|
| Student support | 0.044 | 0.034 | 0.191 |
| Belonging | 0.052 | 0.038 | 0.172 |
| Teacher support | 0.075 | 0.028 | 0.008** |
| Persistence | 0.365 | 0.044 | <0.001*** |
| Need for cognition | 0.197 | 0.035 | <0.001*** |
| Language | 0.327 | 0.035 | <0.001*** |
| Gender | 0.040 | 0.024 | 0.097 |
| Turkish background | −0.091 | 0.035 | 0.009** |
| No migration background | 0.062 | 0.048 | 0.193 |

chemistry self-concept with high $\beta$ values. Teacher support and Turkish migration background contributed significantly to the model but with lower $\beta$ values. All the other variables had much smaller $\beta$ values, indicating that their predictive power was lower, and they did not make a significant contribution to the model. These findings suggest that chemistry self-concepts are closely related to learning goal orientations and the perception of chemistry language. The social context in chemistry class seemed to explain only little variance in chemistry self-concept. The only exception was the students' relation to their chemistry teacher which seemed to have an impact on chemistry self-concept.

# Discussion and conclusion

To discern the structure of chemistry self-concept, questionnaire data from 585 secondary school students were analysed. We investigated the distribution of chemistry self-concepts in culture and gender groups, as well as the relationship of self-concept with learning goal orientations, the classroom context, and the language of chemistry in a multivariate model.

### The impact of self-concept on chemistry learning

In line with the literature in educational psychology (Ferla *et al.*, 2010), we found chemistry self-concept to be strongly related to learning goal orientations. Students with positive self-concepts in chemistry apparently tend to be more persistent in their chemistry learning and to enjoy thinking about chemistry. This underlines the importance of chemistry self-concept for chemistry learning.

For researchers and chemistry teachers, this opens an interesting field for application-focused research. We believe that a reflection on task choice behaviour in small groups of students could be an interesting approach for supporting students' development of a positive chemistry self-concept. For instance, in a teaching sequence, students could be asked several times to choose a task individually. These choices would need to be supported and reflected. This could be done by first asking the students to explicit their goals using several guiding questions or items. In the next steps the students could discuss their rationales in small groups of peers in order to discover alternative ways of thinking and of choosing tasks. This exchange could broaden the students' set of alternative ways of thinking and also increase mutual understanding of the difficulties the individual students face. We believe that this type of intervention could unfold the potential of chemistry self-concept research for concrete impact on teaching practice.

### The influence of the classroom context on chemistry self-concept

Regarding the classroom context, only the relationship to the chemistry teacher had a significant impact on chemistry self-concept. This had been shown in educational psychology in general (*e.g.*, Wentzel *et al.*, 2010) and was confirmed for chemistry self-concepts in the present study. Peer relationships in chemistry did not have a significant impact on chemistry self-concept. This could be due to the fact that German students usually participate in chemistry lessons in a class with which they share most of their school life. The feeling of belonging and student support are, therefore, rather subject-unspecific.

The perception of language seems to be closely related to chemistry self-concept. This finding could possibly be explained by underlying identification processes. If a student can think of himself or herself as a chemistry person, he or she will be more likely to perceive the language in chemistry class as natural. In contrast, if a student feels like he or she is unable to understand the language in chemistry class, this can be a sign of a lack of identification with chemistry.

Here, too, application-focused research could be interesting because language is something that can be worked on in interventions. While language-sensitive chemistry teaching is quite established, its link to self-concept and chemistry identity formation seems not to have been explored yet. Here, too, chemistry self-concept research could have practical implications. Language-sensitive chemistry teaching tends to focus on helping students to address practical challenges in chemistry teaching. The emotional and social aspects of the perception of chemistry language tend not to be discussed in class. It would, for instance, be interesting to discuss in class in how far students know chemistry language from home – which terms they already knew before entering chemistry classes and who in their surrounding understands certain chemical terms. If carried out in a sensitive way, this could help students and teachers to acknowledge that chemistry language is familiar to some, while it feels alien to others. This type of discussion could be followed by a language-sensitive science teaching sequence. We believe that this could deepen the students' and teachers' sensitivity for the different relations the students have with chemistry language. This perspective on language-sensitive chemistry teaching inspired by self-concept and identity

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research could open the field for a practical impact of chemistry self-concept research.

### Gender relations in chemistry self-concept

Regarding the gender relations in chemistry self-concept, the findings from this study are only partly in line with existing research. In the literature, a gender gap in chemistry self-concept had been documented, with boys showing stronger chemistry self-concepts than girls (Ziegler and Heller, 2000; Chan and Bauer, 2015). In our study, this seemed to show only in the sample of students without migration background. Here, the boys tended to be more confident about their abilities in chemistry than the girls. In the Turkish subsample, the girls showed slightly stronger chemistry self-concepts than the boys. These findings are in line with those from our pilot study. However, the gender effects in the subgroups were too small to allow for a definite claim. Only the interaction effect of gender and cultural background was at a significant level.

The data suggest that gender relations in chemistry self-concept might not be the same in these two groups based on their cultural backgrounds. What could explain these differences? Although a thorough analysis of the literature is beyond the scope of this study, we identified one factor that could contribute to the more balanced gender relation in chemistry self-concept among students with Turkish migration background. It seems like in Turkey science is less strongly associated with masculinity. Slightly more young women than men hold science degrees in Turkey (OECD, 2009a). Also, girls achieve substantially better in science than boys and are more ambitious in their work in the subject (Batyra, 2017a, 2017b). This contrasts the situation in Germany and most other developed countries where more men than women hold science degrees (OECD, 2009a). One hypothesis could be that the students with a Turkish migration background see chemistry as a domain that is open to both genders. However, this hypothesis would need further investigation.

It becomes clear that students' cultural backgrounds need to be considered in research using chemistry self-concept as a variable and, in particular, when investigating gender relations and the construction of chemistry identities. If students with a Turkish background think about chemistry differently, it could be interesting to explore their thoughts and feelings about the masculinity of the subject in class. In particular, it would be interesting to discuss potential chemistry role models that might be relevant for the students. It could be fruitful to try to introduce chemistry role models in class – be it in person, *via* traditional or social media, or using fictional stories. Also, further implementing language-sensitive teaching in chemistry class could contribute to positive chemistry self-concepts because the perception of chemistry language seems to be closely related to chemistry self-concept. Here, the practical interest of science self-concept research becomes visible.

## Conflicts of interest

There are no conflicts to declare.

## Appendix

The English version of the survey instrument. Please refer to the authors for the German version that has been used in this study.

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Perceived student support
*HBSC 2013/2014 (MQ61) (*Inchley *et al.*, 2016*), "my class" replaced with "my chemistry class"*
1. The students in my chemistry class enjoy being together.
2. Most of the students in my chemistry class are kind and helpful.
3. In chemistry class, other students accept me as I am.

---

Sense of belonging
*PISA 2003 (Q27) (*OECD, 2005*), "My school is a place where" replaced with "In my chemistry class"*
1. In my chemistry class, I feel like an outsider (or left out of things). (reverse coded)
2. In my chemistry class, I make friends easily.
3. In my chemistry class, I feel like I belong.
4. In my chemistry class, I feel awkward and out of place. (reverse coded)
5. In my chemistry class, other students seem to like me.

---

Perceived teacher support
*HBSC 2013/2014 (MQ62) (*Inchley *et al.*, 2016*), "teacher" replaced with "chemistry teacher"*
1. I feel that my chemistry teacher accepts me as I am.
2. I feel that my chemistry teacher cares about me as a person.
3. I feel a lot of trust in my chemistry teacher.

---

Self-concept
*PISA 2006 (Q37) (*OECD, 2009b*), "science" replaced with "chemistry"*
1. Learning advanced chemistry topics would be easy for me.
2. I can usually give good answers to test questions on chemistry topics.
3. I learn chemistry topics quickly.
4. Chemistry topics are easy for me.
5. When I am being taught chemistry, I can understand the concepts very well.
6. I can easily understand new ideas in chemistry.

---

Incremental theory of intelligence, excluded from analyses
Dweck's (2000), *entity and incrementalist beliefs subscales, "for chemistry" added to the sentences*
1. You have a certain amount of intelligence in chemistry, and you can't really do much to change it. (reverse coded)
2. You can learn new things in chemistry, but you can't really change your intelligence in chemistry. (reverse coded)
3. No matter who you are, you can significantly change your chemistry intelligence level.
4. No matter how much intelligence for chemistry you have, you can always change it quite a bit.

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Perceived task persistence
*PISA 2012 (Q36) (*OECD, 2014a*), "in chemistry" or "chemistry" added to the sentences*
1. When confronted with a problem in chemistry, I give up easily. (reverse coded)

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2. In chemistry, I put off difficult problems. (reverse coded)
3. In chemistry, I remain interested in the tasks that I start.
4. In chemistry, I continue working on tasks until everything is perfect.
5. When confronted with a chemistry problem, I do more than what is expected of me.

Need for cognition
Cacioppo and Petty (1982), *items 1, 4, 18, 23, 40, and 41, "in chemistry" added to the sentences*
1. I really enjoy a task in chemistry that involves coming up with new solutions to problems.
2. I would prefer a task in chemistry that is intellectual, difficult, and important to one that is somewhat important but does not require much thought.
3. In chemistry, I find it especially satisfying to complete an important task that requires a lot of thinking and mental effort.
4. In chemistry, I would rather do something that requires little thought than something that is sure to challenge my thinking abilities. (reverse coded)
5. In chemistry, I would prefer complex to simple problems.
6. In chemistry, simply knowing the answer rather than understanding the reasons for the answer to a problem is fine with me. (reverse coded)

Feeling of understanding chemistry language
*Constructed by the authors*
1. I understand the texts we read in chemistry.
2. After having read a text in chemistry I sometimes don't really know what it was about. (reverse coded)
3. When my chemistry teacher is talking in class, I can follow easily.
4. In chemistry class, it sometimes seems to me as if they all spoke a language I don't understand. (reverse coded)
5. Chemical equations confuse me. (reverse coded)
6. I find it exciting to work on chemical equations.

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