CULTURE-SENSITIVE CHEMISTRY SELF-CONCEPT RESEARCH

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THE RELATIONSHIP OF CHEMISTRY SELF-CONCEPT WITH CULTURE, GENDER, AND CHEMISTRY CAPITAL

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TO MY MOTHER

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ABSTRACT

In Germany, secondary school students differ greatly in their science achievement, a dispersion that is far above the OECD average (Schiepe-Tiska, Rönnebeck, & Neumann, 2019). Immigrant students tend to be at the lower end of the scale in Germany – on average, they achieve substantially less well in science than non-immigrant students (OECD, 2016d), which is partially due to the German school system (Zoido, 2013). These differences in achievement translate into underrepresentation of immigrants in science-related jobs in Germany (OECD, 2008). Achievement and career choices are closely intertwined with academic self-concept (for an overview see Marsh & Craven, 2006). Regarding science self-concept, the pattern that immigrant students tend to score lower is present in many countries (e.g. Riegle-Crumb, Moore, & Ramos-Wada, 2011).

The goal of the present research project was to investigate these inequalities between immigrant and non-immigrant secondary school students. This was done focusing on secondary school students' chemistry self-concepts. Chemistry self-concepts were focused on because achievement in chemistry is an important factor for careers in natural sciences (Cohen & Kelly, 2019). Research on chemistry self-concept has concentrated on young adults (e.g. Bauer, 2005; Xu & Lewis, 2011) and so little is known about secondary school students. Besides the impact of students' migration background, the research project analyses the role that gender plays because gender has important effects on science self-concepts (e.g. Jurik, Gröschner, & Seidel, 2013; Riegle-Crumb et al., 2011; Wan & Lee, 2017).

A big challenge in this context was that the prevailing methods in academic self-concept research are prone to yield biased data (Byrne, 2002; Byrne et al., 2009). Although this was pointed out more than 15 years ago, the problem persists in science self-concept research. The present research project addresses this issue and presents a new mixed methods approach to culture-sensitive academic self-concept research. The term 'culture' is used in the sense of migration background, a concept that categorizes people's migration histories in Germany. A combination of qualitative interview data and quantitative data permit an investigation of certain types of bias defined by Byrne and colleagues (2009). The pilot study operated with a chemistry self-concept questionnaire (N=116) and qualitative interviews (N=43). The main study was based on an extended questionnaire comprising several other scales (N=585) and deeper qualitative interviews (N=48).

The hypotheses based on the literature were that in Germany, (h1) immigrant students would show more negative chemistry self-concepts than non-immigrant students. (h2) Female students would show more negative chemistry self-concepts than male students. The third hypothesis (h3) was that the home environment has an important impact on students' chemistry self-concepts. The first two hypotheses (h1 and h2) were not confirmed. Gender and migration background did not show a significant effect on students' chemistry self-concepts. Instead, gender relations differ depending on the students' migration background. Among students without a migration background, boys tend to have stronger chemistry self-concepts than girls. In contrast, among students with a Turkish migration background, girls tend to have stronger chemistry self-concepts. Existing science self-concept literature did not explain this.

Literature on gender relations in science in Turkey suggests that this interaction effect could be due to a more gender-neutral conception of science in Turkey. Slightly more

women than men work in science in Turkey (OECD, 2009a) and girls achieve substantially better (Batyra, 2017a, 2017b). According to the third hypothesis (h3), the gender conceptions in Turkey could potentially be transmitted to students with a Turkish migration background in the home environment, through their parents or other people.

Science education literature did not provide a satisfying model for conceptualizing the influence of the home environment on students in the field of chemistry that would allow investigating the third hypothesis (h3). Therefore, the concept of chemistry capital was introduced based on the analysis of the interviews in the main study. Chemistry capital was developed based on the concept of science capital by Archer and colleagues (2015). Chemistry capital conceptualizes the resources a person possesses that have value in the field of chemistry. This encompasses social networks (e.g. knowing a chemist) as well as emotional and cognitive resources (e.g. attitudes towards chemistry and chemistry knowledge), and the engagement in chemistry-related activities. In particular, the concept allows analyzing the transmission processes of chemistry from the home environment to the individual student.

The qualitative analyses in the main study showed that the chemistry capital home environment influences the students in the field of chemistry in multiple ways. This supports hypothesis 3 (h3). Further, the data suggest that structural inequalities in the German school system might foster differences in chemistry. Students who already possess little chemistry capital in their home environments are in addition found more often at the type of school (*Hauptschule*) in which the proportion of chemistry teachers who do not hold a university degree in chemistry is the highest, depriving these students of another possible source of chemistry capital. Vice versa, students who already possess a lot of chemistry capital in their home environments more often attend school types (*Gymnasium, Realschule*) where also more formally qualified chemistry teachers are available, thus potentially widening the gap.

The mixed methods analysis in the main study suggested that a simple linear relationship between student chemistry self-concept and chemistry capital in the home environment does not exist. A study based on quantitative (or mixed methods) analyses of data of a larger sample on chemistry capital in the home environment and students' chemistry self-concepts could provide further insights. It is not yet clear if the third hypothesis (h3) is true.

To sum up, the present research project thus advances the field of chemistry education in three regards: (i) it provides an approach to culture-sensitive academic self-concept. This approach proved to increase both the validity and the explanatory power of chemistry self-concept research. It is not chemistry-specific and can, thus, be used in other areas of research as well. (ii) The research discovered an interaction effect of gender and migration background on chemistry self-concept that was unknown in science education literature. (iii) It introduces and defines the concept of chemistry capital which permits to analyze chemistry education from a sociocultural perspective. Employing the concept of chemistry capital helps to shift the focus from the individual student to the resources a student possesses in the sociocultural context that help him or her succeed in the field of chemistry. This allows uncovering social inequalities in the field that need to be addressed in educational policy. Moreover, it can inspire intervention studies and application-focused research (e.g. approaches to culture-sensitive chemistry teaching).

ZUSAMMENFASSUNG

Schülerinnen und Schüler in Deutschland unterscheiden sich immens in ihren Leistungen in den Naturwissenschaften, eine deutlich breitere Streuung als im OECD-Mittel (Schiepe-Tiska et al., 2019). Schülerinnen und Schüler mit Migrationshintergrund befinden sich in Deutschland tendenziell am unteren Ende der Leistungsskala – im Durchschnitt zeigen sie erheblich schlechtere Leistungen in den Naturwissenschaften als Schülerinnen und Schüler ohne Migrationshintergrund (OECD, 2016d). Dies scheint zu einem Teil dem deutschen Schulsystem geschuldet (Zoido, 2013). Diese Leistungsunterschiede in den Naturwissenschaften schlagen sich auf dem Arbeitsmarkt nieder: In Deutschland sind Personen mit Migrationshintergrund in naturwissenschaftsnahen Berufen unterrepräsentiert (OECD, 2008). Leistungen und Berufswahl sind eng mit akademischen Selbstkonzepten verwoben (for an overview see Marsh & Craven, 2006). Und auch hier zeigt sich, dass Schülerinnen und Schüler mit Migrationshintergrund in vielen Ländern schwächere naturwissenschaftliche Selbstkonzepte haben (e.g. Riegle-Crumb et al., 2011).

Ziel des vorliegenden Forschungsprojekts war es, diese Ungleichheiten zwischen Schülerinnen und Schülern der Sekundarstufe zu untersuchen. Hierzu wurden ihre Selbstkonzepte analysiert, mit besonderem Fokus auf den Aspekt des Migrationshintergrunds. Genauer gesagt wurden Chemie-Selbstkonzepte untersucht, da Leistungen in diesem Fach eine Gatekeeper-Funktion für naturwissenschaftliche Karrieren besitzen (Cohen & Kelly, 2019). Die Forschung über Chemie-Selbstkonzepte hat sich in der Vergangenheit auf junge Erwachsene beschränkt (e.g. Bauer, 2005; Xu & Lewis, 2011), weshalb wenig über die Chemie-Selbstkonzepte von Schülerinnen und Schülern der Sekundarstufe bekannt ist. Neben dem Migrationshintergrund wird auch Gender als Variable betrachtet, da Gender bedeutenden Einfluss auf naturwissenschaftliche Selbstkonzepte ausübt (e.g. Jurik et al., 2013; Riegle-Crumb et al., 2011; Wan & Lee, 2017).

In diesem Kontext stellte sich die große Herausforderung, dass die vorherrschenden Methoden in der Forschung zu akademischen Selbstkonzepte möglicherweise verzerrte Daten liefern (Byrne, 2002; Byrne et al., 2009). Obwohl diese Problematik schon vor über 15 Jahren thematisiert wurde, besteht es in der naturwissenschaftlichen Selbstkonzeptforschung bis heute fort. Das vorliegende Forschungsprojekt befasst sich mit diesem Problem und legt einen neuen Forschungsansatz für kultursensible akademische Selbstkonzeptforschung im Mixed-Methods-Design vor. Der Begriff der ‚Kultur' wird hier im Sinne des Migrationshintergrunds genutzt, ein Konzept, mit dem sich die Migrationsgeschichten der Menschen in Deutschland kategorisieren lassen. Die Kombination aus qualitativen Interviewdaten und quantitativen Daten ermöglicht es, einige der Arten von Verzerrungen zu detektieren, die von Byrne und Kollegen (2009) definiert wurden. In der Pilotstudie wurden Daten mittels eines Fragebogens zum Chemie-Selbstkonzept (N=116) sowie qualitativer Interviews erhoben (N=43). Die Hauptstudie basiert auf Fragebogen (N=585), der einige weitere Skalen umfasst, sowie qualitativen Interviews (N=48).

Aus der Literatur wurden folgende Hypothesen abgeleitet: (h1) Schülerinnen und Schüler mit Migrationshintergrund zeigen vermutlich schwächere Chemie-Selbstkonzepte als solche ohne Migrationshintergrund. (h2) Weibliche Schülerinnen zeigen vermutlich schwächere Chemie-Selbstkonzepte als männliche Schüler. (h3) Das

häusliche Umfeld übt vermutlich einen bedeutenden Einfluss auf die Chemie-Selbstkonzepte der Schülerinnen und Schüler aus. Die ersten beiden Hypothesen (h1 und h2) bestätigten sich nicht. Gender und Migrationshintergrund zeigten keine signifikanten Effekte auf die Chemie-Selbstkonzepte der Schülerinnen und Schüler. Stattdessen zeigte sich, dass die Geschlechterverhältnisse von den Migrationshintergründen der Schülerinnen und Schüler abhängen. Bei den Schülerinnen und Schülern ohne Migrationshintergrund haben Jungen tendenziell stärkere Chemie-Selbstkonzepte als Mädchen. Im Gegensatz hierzu zeigen bei den Schülerinnen und Schülern mit türkischem Migrationshintergrund die Mädchen tendenziell stärkere Chemie-Selbstkonzepte als die Jungen. Die bestehende Forschung zu naturwissenschaftlichen Selbstkonzepten vermochte diese Befunde nicht zu erklären.

Literatur über die Geschlechterverhältnisse in den Naturwissenschaften in der Türkei legt die Vermutung nahe, dass dieser Interaktionseffekt auf einem stärker genderneutralen Konzept der Naturwissenschaften in der Türkei beruhen könnte. In der Türkei arbeiten etwas mehr Frauen als Männer in naturwissenschaftlichen Berufen (OECD, 2009a) und Mädchen zeigen deutlich bessere Leistungen in Naturwissenschaften (Batyra, 2017a, 2017b). Nach der dritten Hypothese (h3) könnten diese Gender-Konzepte möglicherweise durch das häusliche Umfeld, also durch Eltern oder andere wichtige Bezugspersonen an die Schülerinnen und Schüler mit türkischem Migrationshintergrund weitergetragen werden.

Die naturwissenschaftsdidaktische Literatur hielt kein zufriedenstellendes Modell bereit zur Konzeptualisierung des Einflusses des häuslichen Umfelds auf die Schülerinnen und Schüler im Feld der Chemie und somit zur Untersuchung der dritten Hypothese (h3). Aus diesem Grund wurde im vorliegenden Forschungsprojekt das Konzept des *chemistry capital* entwickelt und in die Forschungsliteratur eingeführt. *Chemistry capital* basiert auf der Forschung zu *science capital* nach Archer und Kollegen (2015). *Chemistry capital* konzeptualisiert die Ressourcen einer Person, die im Feld der Chemie Wert haben. Dies umfasst soziale Netzwerke (z. B. Kontakt zu einer Chemikerin/einem Chemiker), emotionale und kognitive Ressourcen (z. B. Chemie-Wissen und Einstellung gegenüber Chemie) sowie chemiebezogene Aktivitäten.

Die qualitativen Analysen zeigten, dass das *chemistry capital* im häuslichen Umfeld die Schülerinnen und Schüler im Feld der Chemie auf vielfältige Weise beeinflusst. Dies unterstützt Hypothese 3 (h3). Weiterhin legen die Daten die Vermutung nahe, dass strukturelle Ungleichheiten im deutschen Schulsystem die Unterschiede in Chemie verstärken. Schülerinnen und Schüler mit wenig *chemistry capital* in ihrem häuslichen Umfeld besuchen tendenziell Schulen, in denen der Anteil an fachfremden Chemielehrkräften besonders hoch ist. Hierdurch wird diesen Schülerinnen und Schülern eine wichtige Quelle von *chemistry capital* vorenthalten. Im Gegensatz hierzu scheinen die Schülerinnen und Schüler, die bereits in ihrem häuslichen Umfeld über *chemistry capital* verfügen, tendenziell Schulen zu besuchen, in denen Chemie fast ausschließlich durch Fachlehrkräfte unterrichtet wird.

Die Mixed-Methods-Analyse in der Hauptstudie legte die Vermutung nahe, dass zwischen Chemie-Selbstkonzept der Schülerinnen und Schüler und *chemistry capital* im häuslichen Umfeld kein linearer Zusammenhang besteht. Eine Studie mit größerem Stichprobenumfang basierend auf quantitativen (oder Mixed-Methods-) Analysen von chemistry capital im häuslichen Umfeld und Chemie-Selbstkonzept könnte tiefere Einblicke bieten. Es ist derzeit noch unklar, ob die dritte Hypothese (h3) wahr ist.

Das vorliegende Forschungsprojekt treibt die chemie- und naturwissenschafts-didaktische Forschung also in dreifacher Hinsicht voran: (i) Es legt einen Ansatz für kultursensible Erforschung akademischer Selbstkonzepte vor. Dieser Ansatz verbesserte sowohl die Validität als auch die Erklärungskraft der Chemie-Selbstkonzeptforschung. Er ist nicht chemiespezifisch und kann daher in anderen Bereichen der Selbstkonzeptforschung genutzt werden. (ii) Ein Interaktionseffekt von Gender und Migrationshintergrund wurde entdeckt, der in der Literatur zuvor noch nicht beschrieben wurde. (iii) Das Konzept des *chemistry capital* wurde definiert und in die Literatur eingeführt. Es ermöglicht Analysen des Chemielernens aus einer soziokulturellen Perspektive. Der Fokus verschiebt sich von den individuellen Schülerinnen und Schülern hin zu den Ressourcen, über die eine Schülerin oder ein Schüler in seinem oder ihrem sozikulturellen Kontext verfügt und die sie oder ihn im Feld der Chemie unterstützen. Dies erlaubt es, soziale Ungleichheiten in dem Feld aufzudecken, mit denen sich die Bildungspolitik befassen muss. Weiterhin birgt *chemistry capital* das Potential, Interventionsstudien und anwendungsorientierte Forschung (z. B. Ansätze zu kultursensiblem Chemieunterricht) zu inspirieren.

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1 | INTRODUCTION

In Germany, immigrant students achieve substantially less well in science than non-immigrant students in secondary school (OECD, 2016d)[1]. In PISA 2015, this difference between immigrant and non-immigrant students was 72 points corresponding to about two school years, which is a far larger gap than the OECD average (OECD, 2016d). Gaps in achievement seem to depend on the national school system which has been shown in other areas of academic performance, for instance in reading performance:

> Immigrant students from Turkey living in the Netherlands score 45 points below the OECD average, those in Belgium, Denmark, Germany and Switzerland score between 70 and 80 points below average, and Turkish students in Austria score 115 points below the OECD average. (Zoido, 2013, p. 2)

In addition to the achievement gap in science, immigrant students are by far less likely to expect a career in science (OECD, 2016b), they tend to show lower science aspirations (DeWitt & Archer, 2015), and some groups are in fact underrepresented on the job market in science (OECD, 2008). These inequalities are devastating and could reflect structural deficits in the German school system.

These social phenomena are closely intertwined with the mental construct of academic self-concept which is a person's perception of his or her abilities in an academic domain (Shavelson, Hubner, & Stanton, 1976). Science self-concepts are strongly associated with achievement in science (e.g. Chiu, 2008; Yeung et al., 2010), they shape students' choices for or against science-related careers (e.g. Eccles & Wang, 2016; Taskinen, Schütte, & Prenzel, 2013), and are thus key factors in science education. Students with positive beliefs about their abilities in science tend to achieve better and to aspire science-related careers more strongly than students with negative beliefs about their abilities. This means that science self-concepts have a huge impact on important decisions in young peoples' lives. Further, self-concept seems to reflect social disparities in science. It differs between students of different ethnicities and cultural backgrounds, with students belonging to a country's dominant ethnicity tending to show stronger science self-concepts than students belonging to non-dominant ethnic groups (e.g. Riegle-Crumb et al., 2011). Also, it has been shown that science self-concepts are strongly gendered with girls tending to show weaker science self-concepts than boys (e.g. Jansen, Schroeders, & Lüdtke, 2014). Since gender is a cultural construct, this suggests that the students' cultural background plays a crucial role in the formation of science self-concepts. Science self-concept research could, therefore, be interesting for understanding the mechanisms through which social inequalities are (re-)produced in the field of science. Moreover, science self-concept research could guide the development of ideas on how to change this.

Combined efforts in research and teaching practice are needed to adapt science education in secondary schools to the situation of young immigrants. In both research and teaching practice, foundational work is still missing. Some teaching approaches for culture-sensitive science teaching have been developed (e.g. for First Nations in

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[1] The references for this first part of the dissertation, in which the research project is briefly summarized, can be found on pages 69-83. After this, the articles that constitute the basis of this dissertation can be found. The references for the articles are included following each article.

North America, Aikenhead, 1997; for the UK, Essex, 2016; for Germany, Rüschenpöhler & Baginski, accepted; Tajmel, 2017; for Tanzania, Wandela, 2014). However, not much concrete teaching material for culture-sensitive science teaching is available. This would be needed to develop approaches for teaching science in Germany in ways that would provide adequate learning opportunities allowing all students to achieve well, irrespective of their cultural background and migration history. Further, research methods in many fields are not adapted to investigations in cultural diversity and are prone to bias (Byrne, 2002; Byrne et al., 2009; van de Vijver & Poortinga, 2005). Since the term of 'culture' is very complex and can refer to a multitude of entities (for an overview see Sewell, 1999), in the present work, the focus is narrowed down to 'migration backgrounds' which is used in the German context to conceptualize a person's migration history, taking into account the person's nationality, the parents' places of birth and other factors (Statistisches Bundesamt, 2013).

The present work provides a research perspective on the situation of immigrant students in science education. The focus is laid on chemistry self-concept, which has been described as being a gate-keeper for careers in science because it predicts drop-out rates in science degrees at the post-secondary level (Cohen & Kelly, 2019). Despite its central role, self-concept in chemistry tends to be less well understood than the self-concepts in other science subjects (article 3, see appendix; Rüschenpöhler & Markic, 2020a). In particular, it is currently unclear how students' cultural backgrounds shape their chemistry self-concepts. This knowledge would give insights into whether social inequalities impact chemistry learning in Germany and if so, in what ways.

The investigation is composed of (i) a literature review which investigates the blind spots in science self-concept research, (ii) conceptual parts (the development of a research approach and of an analytical perspective for culture-sensitive academic self-concept research), and (iii) an empirical investigation of the chemistry self-concepts of secondary school students with different cultural backgrounds living in Germany. Due to the novelty of the research approach, this work is partly explorative and aims to lay foundations for more research in chemistry education that can be culture-sensitive. Five articles constitute the basis of this work (for an overview, see fig. 1; the articles can be found in the appendix).

Article 1 (see appendix; Rüschenpöhler & Markic, 2019a). The first article provides a systematic literature review of self-concept research in science and technology education 1997-2017. Due to the close relations in research in science and technology education (through constructs such as STEM and STEAM), both fields are considered. Three aspects are focused on in the analysis: the theoretical foundations of science and technology self-concept research, its main findings and the methods used. One central finding in this study is that methodological difficulties in science and technology self-concept research are not adequately addressed: almost exclusively quantitative methods are used. These are known to be prone to produce biased results in self-concept research (Byrne, 2002; Byrne et al., 2009; van de Vijver & Poortinga, 2005).

Article 2 (see appendix; Rüschenpöhler & Markic, 2019b; see also, 2017, 2018a, 2018b). Based on this knowledge, a mixed methods approach to culture-sensitive academic self-concept research is proposed in the second article to address the methodological issues. This approach explores the potential of Hattie's (2008) model of the self in combination with research using the established self-concept models by Shavelson and Marsh (Marsh, 1986; Marsh & Shavelson, 1985; Shavelson et al., 1976). Besides this conceptual work, a pilot study was conducted to test the potential of this approach and to gain first insights into the chemistry self-concepts of secondary school students in Germany. The pilot study shows that the mixed methods approach allows reflecting on measurement bias and that it fosters investigations that try to understand the cultural embeddedness of self-concept. Further, the data suggest that in Germany, an interaction effect of gender and cultural background seems to shape the chemistry self-concepts of secondary school students, a finding that had not been documented previously and that has the potential to change the way the gender gap in science is looked at. Among students without a migration background, boys tend to have more positive self-concepts in chemistry than girls. In the group of students with a Turkish migration background, in contrast, the girls tend to have more positive chemistry self-concepts. This difference in gender relations could possibly be explained with a different association of chemistry with masculinity. The literature suggests that in different countries, the associations of chemistry with masculinity in the Turkish society differ and that these concepts of chemistry might be passed on from parents to their children. These concepts of the relation chemistry–masculinity present in the families could cause the difference in gender relations between students of different cultural backgrounds. The analyses in this first pilot study are based on a small sample and the results, therefore, require stronger empirical evidence.

Article 3 (see appendix; Rüschenpöhler & Markic, 2020a; see also Rüschenpöhler & Markic, 2019c). In order to provide a stronger empirical basis for the findings from the pilot study, the main study was designed which is presented in three separate articles (3-5). Its purpose was to test the hypotheses stemming from the pilot study. In the first step, a quantitative analysis of the effects of cultural background and gender on chemistry self-concept was conducted using a larger sample than in the pilot study

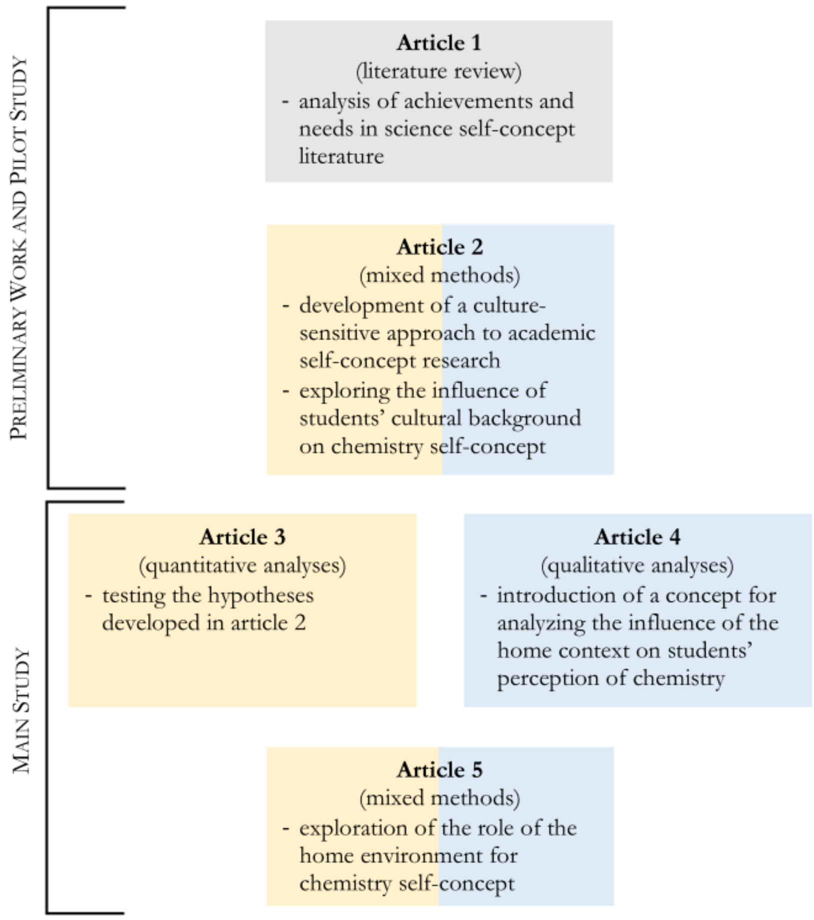

Figure 1. Overview of the articles this dissertation is based on. Quantitative analyses are symbolized with yellow color, qualitative analyses with blue color.

(article 3). The results of this analysis confirm the finding from the pilot study that an interaction effect of gender and culture impacts the chemistry self-concept of secondary school students in Germany.

Article 4 (see appendix; Rüschenpöhler & Markic, 2020b). In article 4, the results of a qualitative analysis of interviews from the main study are presented. The interviews were conducted with some of the students who participated in the quantitative part of the main study. Based on the assumption that families might play a role in the formation of students' chemistry self-concepts, the interviews focus on the role chemistry plays in the students' lives at home, at school, and in their private lives. In this study, the concept of chemistry capital is developed based on science capital literature. The study shows mechanisms through which the home environment[2] influences on the students' individual connections with chemistry. The concept of chemistry capital serves as an analytic lens for analyzing concrete processes through which social inequalities are (re-)produced in chemistry education.

Article 5 (see appendix; Rüschenpöhler & Markic, 2020c). The last article examines the hypothesis that the chemistry capital in the students' home environments influences their chemistry self-concepts. While in article 4, the concept of chemistry capital was established as such, the last article investigates the relation between the new concept of chemistry capital and self-concept. This is done in a mixed methods analysis, based on the quantitative data that were analyzed in article 3 and the qualitative data that were analyzed in article 4. This last article is based on the finding from the pilot study and the first parts of the main study that gender relations in chemistry self-concept depend on students' cultural backgrounds. However, this study did not reveal a clear relation in quantitative terms between chemistry self-concept and chemistry capital. This could be due to methodological limitations this study faces. The present research project presents the first investigation of chemistry capital and is, therefore, limited in sample size. Several alternative explanations are discussed in article 5 as well.

[2] Throughout this work, the term 'home environment' is used to describe the private space in which the students live, be it with their parents, other principal caregivers, friends, relatives or in other surroundings. This term is employed to account for the fact that not all students live with their parents.

2 | THEORETICAL BACKGROUND

Although the chemistry self-concepts of young adults have been investigated in some studies (Bauer, 2005, 2008; Xu & Lewis, 2011), secondary school students' chemistry self-concepts have received little attention in research. Therefore, the present theoretical background is not limited to chemistry self-concept but presents the current state of research on secondary school students' science self-concepts. To this purpose, a systematic literature review was conducted (article 1, see appendix; Rüschenpöhler & Markic, 2019a) with the goal to analyze (i) the theoretical concepts referred to in science self-concept research and to provide an overview of (ii) the employed research methods and of (iii) key findings. Due to the overlap between science and technology self-concept research such as in the research on STEM, both fields were considered in the review. A selection of 74 peer-reviewed journal articles published between 1998 and June 2017 indexed in the ERIC database was considered. The method for the selection of the literature and the analysis procedure are described in more detail in article 1 (see appendix; Rüschenpöhler & Markic, 2019a). In addition to the literature reviewed in the first article, this section considers science self-concept literature from the years 2017-2019 in order to map the latest advances and trends in this field.

This section starts with a description of a methodological problem in academic self-concept research that seems to have received no attention in science self-concept research and that currently remains unresolved (chapter 2.1). Against the backdrop of this issue, the theoretical foundations of science self-concept research are critically scrutinized (chapter 2.2). The last section of this chapter summarizes central findings about science self-concept (chapter 2.3).

2.1 The lack of culture-sensitivity in current academic self-concept research

Academic self-concept research in its present form is insufficiently adapted to the cultural diversity in which research takes place (Byrne, 2002). The data type used in academic self-concept research is prone to bias: quantitative data from self-report items of the Likert type are being used almost exclusively which creates severe measurement difficulties because the measures might not be equivalent across cultures (Byrne, 2002). This has been argued by leading academic self-concept researchers in educational psychology more than ten years ago (Byrne, 2002; Byrne et al., 2009; van de Vijver & Poortinga, 2005). However, not much seems to have changed in science self-concept research where investigations are still mostly based on exactly this data type. Around 90 % of the studies about science self-concept are based exclusively on quantitative data from self-report instruments with Likert items. The remaining 10 % mostly use a mixed methods design (article 1, see appendix; Rüschenpöhler & Markic, 2019a).

Bias is quite likely to occur in science self-concept research because many studies operate with data from different countries and some even compare the data from regions spread around the globe. And even if the data is collected within a single country, the data could still potentially be biased due to the cultural diversity that exists within many countries caused e.g. by migratory processes or by the diversity that is essential to a nation-state. In the studies using exclusively quantitative data, this type of bias is not being controlled for.

The bias Byrne and colleagues (2009) refer to falls into three categories:

(i) structural non-equivalence
(ii) measurement non-equivalence and
(iii) bias in the interpretation of the results.

A lack of (i) structural equivalence means that the theoretical construct that is being investigated differs between cultural contexts. This can be a difference in the definition of a construct, as it is the case e.g. for the concept of intelligence which is defined in Western cultures mainly referring to abstract thinking. However, in other cultural contexts, the concept of intelligence can contain a component of social intelligence (van de Vijver & Poortinga, 2005). This construct is relevant in academic self-concept research because many scales contain items that ask students if they think they are intelligent in a certain subject.

The second domain in which bias can occur is the measurement process. A lack of (ii) measurement equivalence can occur regarding multiple aspects, for example, if the participants differ in response style (Byrne et al., 2009). People from individualist cultures tend to give more extreme responses while the responses of people from collectivist cultures tend to be more moderate (Shulruf, Hattie, & Dixon, 2011). Also, the measurement instrument can produce bias if its format is well-known in a certain cultural context while it is known very little to people from another context. This is the case for example for very culture-specific formats such as specific games and depiction styles but also regarding multiple choice tests and Likert items which are commonly used in some school systems while they are less well-known in other contexts (van de Vijver & Poortinga, 2005). Other measurement bias can occur in the measurement process. This can be the case when the social groups from two contexts are not comparable, for instance, if the level of education or the societies' compositions differ. Moreover, the interpretation of items is not necessarily the same and misunderstandings in the communication with the investigators can occur in the test situation (van de Vijver & Poortinga, 2005). In many cases, translations of test instruments also lack precision (Byrne et al., 2009).

The third measurement difficulty is (iii) bias in the interpretation of the gathered data. If differences show in the data, there are no clear guidelines when to explain these with culture and when to attribute them to other influences. It has been shown that in the social domain, differences tend to be attributed to culture while in the cognitive domain, this type of explanation tends to be rejected (Byrne et al., 2009). The underlying assumptions about human nature are seldom discussed.

For dealing with these types of bias, it has been suggested by several scholars to use mixed methods designs combining quantitative self-report data of academic self-concept with qualitative data from interviews (Byrne, 2002; Byrne et al., 2009; van de Vijver & Poortinga, 2005). Quantitative data needs to be used in a reflective manner which can be facilitated by additional qualitative analyses of other data types. Qualitative data can help to control for bias, e.g. by comparing oral statements with data from multiple choice items. Further, qualitative data can enhance the explanatory power of research. It puts self-concept data into the concrete contexts of the respondents' lives, connecting it with their experiences, thoughts, and narratives.

2.2 Re-examining the theoretical basis of academic self-concept research

Against the backdrop of these measurement difficulties, it is important to critically review the theoretical basis of science self-concept research. This analysis serves two purposes: first, it helps to identify its strengths and weaknesses in science self-concept research, and second, it can inspire new pathways, especially for the qualitative part of mixed methods designs in science self-concept research.

Critical scrutiny regarding the culture-sensitivity of the methodological approaches employed in self-concept research seems to be rare in science education literature. The definition of self-concept in science education literature appears to be so common that many researchers do not even refer to any particular source in their articles. In the systematic literature review (article 1, see appendix; Rüschenpöhler & Markic, 2019a), 73 % of all articles covering science and technology self-concept did not refer to any particular model of self-concept but seem to assume the definition of self-concept to be clear. In many cases, this lack of a definition is probably due to the fact that science self-concept is used as one variable among a multitude of other variables for explaining an outcome such as achievement in science (e.g. Koutsoulis & Campbell, 2001; Lay & Chandrasegaran, 2016) and science course choices (e.g. Bøe & Henriksen, 2013; Riegle-Crumb et al., 2011). In other cases, the concept of science self-concept is used to evaluate interventions and the context in which science learning takes place (e.g. Brown & Ronau, 2012; Glowinski & Bayrhuber, 2011; Hänze & Berger, 2007), or it is conceptualized as part of broader categories such as science engagement (e.g. Chandrasena, Craven, Tracey, & Dillon, 2014; Grabau & Ma, 2017), attitudes towards chemistry (e.g. George, 2006; Zain, Samsudin, Rohandi, & Jusoh, 2010) or science identity (e.g. Capobianco, Yu, & French, 2015; Gilmartin, Denson, Li, Bryant, & Aschbacher, 2007) and, therefore, not the main focus. Another issue in science self-concept research is the lack of clarity when a conceptualization of science self-concept is provided. In some articles, self-concept is confused with a general feeling of self-worth (Cheong, Pajares, & Oberman, 2004) or, in many cases, the definition remains unclear (e.g. Ehmke, Drechsel, & Carstensen, 2010; Jack, She, & Lin, 2016; Kind, Jones, & Barmby, 2007; Mohammadpour, 2012; Mubeen & Reid, 2014; Mujtaba & Reiss, 2014; J. Wang, Oliver, & Staver, 2008; Wender, 2004).

To bring some clarity to this situation, in this chapter, three perspectives on academic self-concept are discussed. First, the prevailing models of Marsh, Shavelson, and colleagues are reviewed (chapter 2.2.1) (Marsh, 1986; Marsh & Shavelson, 1985; Shavelson et al., 1976). Following this, two additional perspectives are introduced, namely Hattie's (2008) process-oriented model of the self (chapter 2.2.2) and a sociological perspective on science self-concept (chapters 2.2.3 and 2.2.4), using the concept of science capital (Archer, Dawson, et al., 2015). In the last part (2.2.5), a summary is provided.

2.2.1 The structure of self-concept: the Marsh and Shavelson models

The most well-known models of self-concept are those of Shavelson, Hubner, and Stanton (1976), Marsh (1986), and Marsh and Shavelson (1985). These models provide insights into the structure of self-concept and bring some clarity into its different sections and the relationships between those. Shavelson, Hubner, and Stanton (1976) defined self-concept as "a person's perception of himself" (p. 411) and proposed a model of self-concept that is organized hierarchically. The authors assume that a person has different perceptions of him or herself, depending on the different domains in life. They divide the self-concepts into three broad categories: the material, spiritual and social self-concepts. People have perceptions about their bodies, their intellectual abilities, and their social selves. It was assumed that a person's general self-concept would be the sum of the self-concepts in these three domains. Of course, these are very broadly defined fields which can be further differentiated, as, for instance, it has been done for the various academic self-concepts. Academic self-concepts describe a person's perceptions of his or her abilities in a certain academic domain. Following this definition, chemistry self-concept is part of a person's academic self-concept and can be defined as a person's perception of his or her abilities in chemistry.

Within the multiple facets of academic self-concept, Marsh (1986) found an internal structure: people compare their abilities in a certain domain with those of other people in their surroundings (external frame of reference) and also with their abilities in other domains (internal frame of reference). For example, a student in secondary school might think that he or she is quite good at chemistry compared to his or her schoolmates. Referring to this external frame of reference, this student develops a positive chemistry self-concept. However, the student might think that he or she is much better in foreign languages, especially in Spanish. Compared to the perceived abilities in Spanish, his or her abilities in chemistry appear quite low to the student. The student rates his or her abilities in chemistry as rather low when referring to this internal frame of reference. These comparisons are usually assumed to exist between the domain of languages (verbal self-concept) and mathematics (mathematical self-concept). Marsh conceptualized the origin of this structure with two frames of reference which serve as a basis for comparison processes. This led to the definition of the internal and external frame of reference model (I/E model, Marsh, 1986). The external frame of reference that research usually assumes to be relevant is the level of the school. These contrast effects due to intrapersonal comparisons have been documented in numerous empirical studies from various regions all over the world (e.g. Chiu, 2008; Marsh & Hau, 2004; Möller, Pohlmann, Köller, & Marsh, 2009; Möller, Retelsdorf, Köller, & Marsh, 2011; Skaalvik & Rankin, 1990). The description of the two frames of reference has provided an explanation for the phenomenon that students' self-concepts do not always correspond to their abilities. Students who achieve high in two separate domains tend to contrast their abilities in these domains leading to self-concepts differing in strength.

The clarity of the definition of self-concept provided by Shavelson, Hubner, and Stanton (1976) combined with the simple hierarchical structure has inspired very clear investigations of the self-concepts in the various academic domains. Exactly this was the purpose of the authors who worked in a field that they described as quite diverse and chaotic (Shavelson et al., 1976). The prevailing models have led to very systematic research implying that findings from different studies can be compared and discussed in a coordinated approach. Instruments for assessing academic self-concepts have been developed which are theoretically well-grounded, standardized, and that have been validated (e.g. the fundamental works of Marsh 1990b, 1992b, 1992a). All of these instruments rely on self-report data and are composed of Likert items. The most popular of these (for secondary school students' science self-concepts: Marsh, 1992b; Martin, Mullis, & Foy, 2008; OECD, 2009b) are sufficiently short to allow for the collection of data of large samples. This can be important, for example, for evaluating whole educational systems or for detecting social inequalities in a population. Research based on the prevailing models is very clear, with highly standardized research instruments, and precise definitions of self-concepts in the various academic fields.

In light of the measurement difficulties discussed in chapter 2.1, this clarity has the downside that it gives only limited room for gaining an understanding of the role self-concept plays in different cultural contexts. It has been recommended to use interviews alongside the established Likert scales (Byrne, 2002; Byrne et al., 2009; van de Vijver & Poortinga, 2005). This could be very insightful but, using the prevailing models of academic self-concept, difficult to achieve: the students could be asked to talk about their abilities in a certain subject, such as chemistry. In this situation, the students would probably display exactly the phenomena that research about academic self-concept has revealed: they would probably compare their abilities in chemistry with related subjects such as physics, mathematics, and biology, and some would certainly also contrast them with their abilities in languages. Additionally, differences between boys and girls could become apparent, just as research has already shown. This would provide further evidence for the accuracy of the prevailing models. What this type of interview does not allow, however, is grasping the role chemistry self-concepts plays in the students' lives. For this, the prevailing models of academic self-concept appear too narrow. Different perspectives on academic self-concept are needed.

2.2.2 A focus on processes: Hattie's theory of the self

To enhance the culture-sensitivity of academic self-concept research, it could be enriching to examine academic self-concept from new perspectives. This can provide the opportunity for developing an understanding of the role self-concept plays in the students' lives in a broader sense, and thereby help to limit bias.

Hattie (2008) proposes a model of the self that shifts the focus on processes but which researchers currently do not employ in science self-concept research (article 1, see appendix; Rüschenpöhler & Markic, 2019a). This perspective on the self could allow investigating individual dynamics associated with particular self-concepts and to evaluate self-concepts and their individual dynamics in a more holistic manner. The question is not 'How strong is a person's self-concept?', leading to quantitative analyses, but rather 'What self-processes lead this person to the adoption of this particular self-concept?', leading to an analysis of the individual inner dynamics that explain the strength of the self-concept. The definition of chemistry self-concept provided by Shavelson and colleagues (1976, see chapter 2.2.1) remains the same. What changes is the framing of this self-concept: it is not examined as such but it is tried to understand the broader picture – the context in which people develop a particular self-concept.

For understanding Hattie's (2008) model of the self, Hattie proposes a metaphor inspired by the German philosopher Wittgenstein. Wittgenstein compared learning processes to the construction of a rope. The strength of a rope depends mainly on the quality of the intertwining of a multitude of fibers, not on the qualities of a single fiber (Wittgenstein, 1958). This is, according to Wittgenstein, similar to learning processes. To develop an abstract concept, people need to establish a multitude of links to other conceptions, terms, and objects. Therefore, the strength of the new concept depends on the degree of embeddedness and connectedness. The better people intertwine the new concept with knowledge and experiences, the stronger it becomes, just as the rope does. Hattie uses Wittgenstein's metaphor because the self is an abstract concept that every person develops. In Hattie's analogy, the self grows stronger as a person learns how his or her self works in different contexts. Every person develops a sense of context specificity, meaning that the specific strategies a person employs are beneficial only in specific situations. For example, each person needs to develop a sense of situations in which it is beneficial to activate learning goal orientations (e.g. in a socially 'safe' environment) and when it is better to rely on performance goal orientations (e.g. under time constraints). Knowing when to use which strategy is extremely complex and the rationales behind these patterns are highly individual. The better this knowledge, the stronger the self. The different parts of the rope – the strands, yearns, and fibers – represent the different levels of strategies a person can use, whereas the length of the rope symbolizes a temporal dimension, i.e. that the self is not static but constantly being produced (Hattie, 2008).

Self-concept research inspired by the perspective of Hattie's model could lead to a focus on the individuality and the temporality of self-concepts. Self-concepts can be high or low, but they are always essentially different and dynamic in nature. This could help to understand self-concept as embedded in individual contexts. Employing this perspective in addition to the perspective of the established models has the potential to enhance the culture-sensitivity of academic self-concept research. However, the fact that Hattie's perspective seems not to have been employed in science self-concept research (article 2, see appendix; Rüschenpöhler & Markic, 2019b) means that the design of an appropriate research approach is not clear-cut. New approaches need to be tried out in an exploratory fashion. The lack of such research designs complicates covering large, representative samples, as it is possible in academic self-concept research based on the Marsh and Shavelson models.

2.2.3 Adopting a sociological perspective

The two types of perspectives discussed above allow investigating the psychological structure and the dynamics of academic self-concepts. They constitute intrapersonal perspectives on academic self-concept. Only in certain cases, this can stretch to analyses of sociocultural patterns, as, for instance, regarding evaluations of gender relations in science self-concept (see chapter 2.3.3). In general, however, self-concept research employing these perspectives tends to remain focused on the intrapersonal domain.

To further enhance the culture-sensitivity of academic self-concept research, adopting a sociological perspective could be interesting. This would allow accounting for the sociocultural structures in which an academic self-concept might be embedded. This would further open the perspective on academic self-concept because it would be possible to investigate the sociocultural contexts in which certain academic self-concepts appear. In particular, it could be interesting to examine the significance of students' home and school environments regarding the development of academic self-concepts and chemistry self-concepts. The home environment can be conceptualized as the private space in which students live and in which they are in contact with significant others such as their parents, other principal caregivers, relatives, and friends. For instance, the families' cultural backgrounds, socioeconomic status, educational backgrounds, and other factors influence students' science aspirations (Archer et al., 2012b). The hypothesis is that the families' ways of dealing with chemistry at home could influence students' chemistry self-concepts.

The interplay of the home environment with chemistry learning has been conceptualized by Aikenhead in his theory of cultural border crossings (1996, 2001). Aikenhead investigated the situation of First Nations (Native American) students in science education (Aikenhead, 1997). He developed a model of teaching science that is designed for this specific context: in his view, some First Nations students are at home confronted with ways of doing and thinking about science that differ from the ways science is practiced at school. He described cultural conflicts that some students experience when "crossing cultural borders" between school science and their homes (Aikenhead, 1996, p. 2). Teachers, in this view, should act as a "culture broker" (Aikenhead, 1997, p. 232) whose role is to help students with these border crossings so that the students can engage in science learning at school without risking their social relationships at home (Aikenhead, 1996; Aikenhead & Jegede, 1999).

Aikenhead's theory provides a sociocultural perspective on science learning but it is embedded in a context that differs from the situation that can be found in Germany. For historical reasons, there are no First Nations in the country. In Germany, several other migratory processes have taken place over decades which have resulted in differences in educational outcomes in science. Immigrant students achieve less well in science (OECD, 2016d). The average difference is 72 points[3] which correspond to a difference of almost two school years (OECD, 2016d). More than 40 % of the first-generation immigrant students and 30 % of the second-generation immigrant students in Germany are low performers, while the proportion among the non-immigrant students is only slightly above 10 % (OECD, 2016a). These data reflect inequalities between immigrant and non-immigrant students which the school system either creates or is unable to compensate. However, since the context in Germany differs greatly from that for which Aikenhead's concept was developed, it seems not to be directly adaptable to the context of science learning in Germany. The group of immigrants in Germany is very diverse and their situation does not correspond to that of First Nation students in North America. Aikenhead's conceptualization of cultural border crossings between different ways of doing science at home and in school can, therefore, not be applied without critical scrutiny and, probably, some fundamental modifications.

2.2.4 Self-concept seen through the lens of science capital

For the German context, the concept of science capital appears more promising. It offers a sociological perspective on science learning that Archer and colleagues (2015; 2012b) developed in Europe, more precisely in Great Britain. It could potentially be better applicable to the local context of Germany because it is not limited to a situation in which students experience two very distinct ways of doing science at home and in school. Rather, science capital research provides a resource-oriented perspective on science learning. The concept of science capital encompasses all resources that have value in the field of science, e.g. science knowledge, personal connections to someone who works in science, interest in science, etc.

The term 'science capital' refers to the Bourdieusian notion of capital. His conception of capital goes far beyond the economic capital that is used in everyday language. Bourdieu defines capital as:

> a social relation, which is to say a social energy that exists and has its effects only in the field in which it is produced and reproduced (…). [T]he logic of every field determines those [types of capital] that are accepted as *valid* on the market, which are pertinent and *effective* in the game at hand, which, *in relation with the field*, function as specific capital (Bourdieu, 1979, p. 127, translated from French by L.R.)

This conceptualization of the notion of capital emphasizes the relation between an entity and a specific field. If an entity is 'valid' in the field, i.e. recognized as a valid 'currency', and if it is 'effective' in the field, i.e. if it can be used as a resource, then it is capital with 'exchange value' in this specific field. That means that it can be

[3] There is no minimum or maximum score in the PISA study. The scores are scaled in a way to achieve a normal distribution with a mean of 500 points and a standard deviation of 100 points. A difference of 72 points thus corresponds to an effect size of 72 % (OECD, 2016c).

exchanged, inherited and traded against other goods. What can these other types of capital be? Three types of capital can be broadly distinguished[4]:

(i) *Cultural capital*. This category encompasses all cultural goods that can function as capital in a certain field. These can be objectified cultural goods (e.g. books) as well as embodied (e.g. knowledge, a certain taste, a certain type of humor, a certain way of presenting oneself in society) and institutionalized cultural goods[5] (e.g. educational qualifications) (Bourdieu, 1986). In the field of science, cultural capital can, for instance, be science knowledge, the enactment of a nerdy science identity with its specific types of humor, science-related activities or positive emotions towards science (embodied science capital), it can consist in the possession of science books and equipment for conducting experiments at home (objectified science capital), or it can be a diploma in astrophysics (institutionalized science capital). Cultural capital, in particular, can make very subtle distinctions, consisting of differences in taste, etc., which is difficult to learn or to teach explicitly (Bourdieu, 1979). This is one of the main reasons why distinctions between social classes tend to persist over generations (Bourdieu, 1979). Cultural capital tends to be transmitted from parents to children almost unconsciously, which is particularly true for the embodied forms of cultural capital. This makes cultural capital quite exclusive.

(ii) *Social capital*. This refers to the social networks a person is part of and these networks' relations with the specific field. More precisely, it refers to the fact that people become a member of particular groups (e.g. the family, groups of friends, class, a certain school club) meaning that they are recognized as a member of these groups. This process of recognition is crucial regarding any type of capital because it is specific to the particular field at hand what counts as valuable and is, therefore, a certain type of capital. Belonging to certain social groups and having social connections can constitute a certain capital in a specific field. In the field of science, for instance, knowing someone who works in science can be a certain capital because this person is a potential resource of knowledge and can transmit an enthusiasm for science (embodied cultural capital) or this person can provide objectified cultural goods such as books. Further, knowing people with whom talking about science is possible or parents who hold science degrees is social capital in the field of science (Archer, Dawson, et al., 2015). The importance of a supportive home environment for science learning has been shown (J. A. Thomas & Strunk, 2017). Acquiring social capital in the field of science is a challenging task. The person needs to be accepted as a member of a group, an act that Bourdieu (1986) emphasized as a key to social capital. Being accepted as a new member of an existing group can be difficult because groups have support structures and accepting a new member means that the other group members show commitment to the new member which can be difficult to obtain. Being accepted as a member by birth or through being introduced by one of the older members, can be much easier.

(iii) *Economic capital*. This type of capital has only auxiliary functions. Up to a certain degree, economic capital such as money can acquire certain types of science

[4] The distinctions in this section follows the order defined by Bourdieu (1986) which differ slightly from those proposed by Archer and colleagues (2015) though not in content.

[5] Bourdieu is not entirely clear about the status of institutionalized cultural goods. It is part of cultural capital but at the same time something apart because obtaining e.g. a science degree presupposes that a person possesses embodied cultural capital (Bourdieu, 1986).

> capital "but only at the cost of a more or less great effort of transformation" (Bourdieu, 1986, p. 287). It is possible to buy books and science kits but it is not possible to buy an interest in science, scientific knowledge, and the particular tastes of humor shared in the different scientific communities. However, economic capital can increase science capital indirectly, for instance by increasing the range of opportunities for its acquisition.

Since the development of the concept of capital by Bourdieu in France in the 1970s, many things have changed in society. The ways social distinctions work might not be exactly the same as they were in the 1970s. In addition, the theory stemming from the French context might not fit the contexts in other countries. In France, Bourdieu argued, social distinctions take place mostly in relation to the field of 'highbrow culture', i.e. the field of classic literature, fine arts, etc. (Bourdieu, 1979). This has changed as Prieur and Savage (2013) argue: 'highbrow' culture is not as influential as it was in the 1970s. Instead, the field of science has gained rapidly in importance for social distinctions. This shift requires attention to the field of science even though Bourdieu's theory as such remains powerful for explaining mechanisms of social distinction. This argument is taken up by Archer and colleagues in their conceptualization of science capital (Archer, Dawson, et al., 2015; Archer, DeWitt, & Willis, 2014). The assumption is that the field of science and technology is an arena in which major social distinctions are made and social inequalities are enacted (see Prieur & Savage, 2013). And, as Archer and colleagues (2014) clarify, "'science capital' is not a separate 'type' of capital" (p. 5) that could be juxtaposed to cultural, social, and economic capital. Rather, it allows investigating in the particular field of science the ways how cultural, social, and economic capital work, how social distinctions are made (see e.g. Carlone, Webb, Archer, & Taylor, 2015), and through which mechanisms social reproduction works (for analyses of social reproduction see Archer, Dewitt, & Osborne, 2015; Archer et al., 2012a, 2013).

Science capital can offer a sociological perspective on psychological phenomena. DeWitt and Archer (2015) showed that many students enjoy science but do not develop science aspirations. Instead of reducing this to individual preferences in a psychological view as science identity research tends to do (Shanahan, 2009), science capital allows investigating certain social structures in which this psychological phenomenon appears. This kind of research allows drawing connections between individual states of mind and the social environments in which these states of mind have a sense for the individual. It could help to think of self-concept not only as an individual psychological phenomenon but as a reflection of certain social structures and power relations.

The field of chemistry has not been investigated yet in science capital research. In one study (Mujtaba, Sheldrake, Reiss, & Simon, 2018), the relation between science capital and the students' aspirations to study post-compulsory chemistry was investigated. However, no distinction was made between the field of science and its sub-field chemistry. For the field of chemistry, there are currently no conceptualizations of the power relations, the mechanisms of social reproduction, and the ways social distinctions are made.

2.2.5 Summary

This section showed the potentials of different theoretical perspectives on science self-concept for culture-sensitive academic self-concept research. The established models by Shavelson and Marsh (Marsh, 1986; Marsh & Shavelson, 1985; Shavelson et al., 1976) provide a very precise definition of academic self-concept that has yielded very productive and insightful research in educational psychology. However, this perspective on academic self-concept might be too narrow to allow for culture-sensitive analyses. For this reason, two additional perspectives were discussed regarding their potential to open academic self-concept research again for mixed methods analyses as suggested by Byrne and others (Byrne, 2002; Byrne et al., 2009; van de Vijver & Poortinga, 2005).

The perspective of Hattie's (2008) rope model of the self could allow investigating different psychological patterns in which self-concept is embedded. This model could enrich academic self-concept research by shifting the focus on psychological processes. It could also allow for more culture-sensitive analyses of academic self-concept because research using this model can reveal different meanings and functions that academic self-concept can have in individual contexts. This could allow formulating hypotheses about underlying cultural concepts.

The third type of model that could be interesting provides a sociological – or rather sociocultural – perspective on academic self-concept. The notion of science capital developed by Archer and colleagues (2015) analyzes the field of science using the notion of capital by Bourdieu (1986). This perspective is interesting in academic self-concept research because it would allow conceptualizing the relations between self-concept – a phenomenon that happens in the minds of individual human beings – and the specific context in which they are produced, i.e. the sociocultural context.

2.3 Central findings about science and chemistry self-concept

2.3.1 The relation with achievement

Academic self-concepts predict achievement (for an overview, see Marsh & Craven, 2006; foundational work: Wylie, 1979), which is particularly true if subject-specific academic self-concepts are considered (Marsh & Yeung, 1997b, 1997a). This is probably one of the main reasons for the attention that academic self-concepts receive in research. Self-concept research shows how mindsets, i.e. psychological states, can influence important behaviors in people's lives such as their performance in school. In the literature, the logic lying behind the relation between the two variables is explained with the reciprocal effects model (Marsh, 1990a). It is assumed that achievement has a positive influence on one's self-concept (self-enhancement) and self-concept positively influences one's achievement (skill development). Today, this explanation is widely relied upon in educational psychology and constitutes probably the best available explanation for the close relation between self-concept and achievement. Important aspects that are assumed to mediate this relationship is the relation of self-concept with learning strategies (McInerney, Cheng, Mok, & Lam, 2012), motivation (Guay, Ratelle, Roy, & Litalien, 2010), and task selection (Marsh & Yeung, 1997b). However, the relation between science self-concept and learning behavior has not been sufficiently understood (Möller & Trautwein, 2015).

The findings about science and technology self-concept literature were only partly in line with those from educational psychology. This was found out in article 1 (see appendix; Rüschenpöhler & Markic, 2019a) which presents a systematic review of current trends in science and technology self-concept literature. Central findings from this literature review will be presented in this chapter with additional insights from more recent publications about the science and technology self-concepts of secondary school students. The review shows that science and technology self-concepts are positively related to achievement (e.g. Acar, 2019; Grabau & Ma, 2017; Lavonen &

Laaksonen, 2009; Mason, Boscolo, Tornatora, & Ronconi, 2013; C.-L. Wang & Liou, 2018). However, there is some evidence that this relation might depend on the cultural context. In some studies conducted in East Asian countries, the association between science self-concept and achievement appeared to be weaker or even negative (Lay & Chandrasegaran, 2016; Wilkins, 2004). These findings seem to be neglected in certain cases where the positive relation between self-concept and achievement is presented as universal. While the relation between science and technology self-concept and concrete learning behavior in class remains unclear (Cheong et al., 2004), the relation between science and technology self-concept and the motivational side of chemistry learning is more clear: students with positive science and technology self-concepts tend to show more positive attitudes towards chemistry (Sheldrake, 2016; Taskinen et al., 2013) and more thinking patterns that support learning (Lu, Chen, Hong, & Yore, 2016; Ziegler, Finsterwald, & Grassinger, 2005).

2.3.2 The relation with career and course choices

Another important outcome variable that is closely related to self-concept is choice behavior, touching both course choices and career choices. Positive self-concepts in a certain domain predict career choices in the respective field (Eccles, 2011). This can be understood in terms of the expectancy-value theory (Eccles, 1983) which states that if a person expects to succeed in a certain domain, he or she is more likely to choose a career in the respective field.

For science, it has been shown that self-concept is closely related to science career aspirations (Archer & DeWitt, 2017; DeWitt et al., 2011; Riegle-Crumb et al., 2011) and career choices (Eccles & Wang, 2016; Leslie, McClure, & Oaxaca, 1998; Taskinen et al., 2013) (article 1, see appendix; Rüschenpöhler & Markic, 2019a). Also, the positive relation between self-concept and post-compulsory science course choices has been shown (Mujtaba & Reiss, 2014). Science self-concepts predict the engagement in science-related activities in free time (Jack et al., 2016), and interest in science (Cheung, 2018).

However, the relation with choice behavior is not as universal in science as it might seem – just as the relation between science self-concept and achievement. Gender could have an impact: science self-concept might be more important for boys than for girls because girls with strong science aspirations tend to have lower science self-concepts than boys (Mujtaba & Reiss, 2016). This hypothesis would, of course, require further investigations, but there is further evidence that gender and cultural background play a role in the relationship between science self-concept and science aspirations (Koul, Lerdpornkulrat, & Poondej, 2017; Riegle-Crumb et al., 2011). A sample from the U.S. showed that science self-concept is less important for the science aspirations of White and Black girls and more important for White boys and Hispanic girls. Here again, gender and culture and their interaction seem to play a role. In addition, there seems to be a group composed of students who have no intention to follow science-related careers despite positive self-concepts (the "confident indifferent" student described by Potvin & Hasni, 2018).

2.3.3 Gender differences

The two sections above suggest that gender plays an important role regarding science and technology self-concepts. Indeed, much research has shown this. In many contexts, a gender gap exists regarding science self-concepts: boys tend to show stronger science self-concepts than girls (in Germany: Jurik et al., 2013; in Tanzania: Makwinya & Hofman, 2015; in the U.K.: Mujtaba & Reiss, 2016; in the U.S.: Riegle-

Crumb et al., 2011; in Hong Kong: Wan & Lee, 2017). However, this gender gap seems to depend on the cultural context. Some studies showed that the gender gap is not present in certain cultures (in some East Asian regions: Lau, 2014; in Malaysia and Singapore: Ng, Lay, Areepattamannil, Treagust, & Chandrasegaran, 2012; in Canada and Australia: Woods-McConney, Oliver, McConney, Schibeci, & Maor, 2014). These findings, especially from East Asia tend to be overlooked in the literature discussing the gender gap in science self-concept although exactly this cultural embeddedness of the gap could help to gain a deeper understanding of the mechanisms producing the gender gap. It would be interesting to further understand the roles that the conceptions of gender play in the formation of science self-concepts because they could be based on stereotypes and stereotypes shape academic self-concepts (Baron, Schmader, Cvencek, & Meltzoff, 2014).

The rationale behind the influence of gender stereotypes on science self-concept can be understood using the framework of Balanced Identity Theory by Greenwald and colleagues (Greenwald et al., 2002). It argues that people who identify with a certain concept (e.g. they identify with masculinity) tend to ascribe the corresponding stereotypes to themselves. In a society, in which a stereotype exists that men are good at science, a person who identifies with masculinity tends to adopt this stereotype and to think about himself that he is good at science (Baron et al., 2014). This rationale has been shown regarding mathematics and physics gender stereotypes and the students' self-concepts (Cvencek, Meltzoff, & Greenwald, 2011; Jugovic, 2017) and seems to have power already in early childhood (Baron et al., 2014). How exactly stereotypes existing in a society influence academic self-concepts is only partly understood. It seems as if the stereotypes can be internalized in the way described by Baron and colleagues (2014) in their Balanced Identity Theory.

Stereotypes do not only work from the inside of a person but also in a person's surroundings. This can be understood in terms of the Rosenthal effect. Rosenthal and Jacobson (1968) argue based on a study that teachers' stereotypes impact their ways in which they support their students' learning. If teachers implicitly adopt stereotypes about certain groups (e.g. white, middle-class boys are 'sciencey' people (Archer et al., 2014; Carlone et al., 2015)), they tend to project this stereotype to individual students which results not only in a different attitude towards these students but also in different support behavior. This has been shown for science: teachers' gender stereotypes do have an impact on students' science self-concepts. They increase the existing gender gap (A. E. Thomas, 2017). This relation between teachers' stereotypes and students' self-concepts could be mediated by teacher support behavior which has been shown to have important effects on science self-concept (Tas, Subaşı, & Yerdelen, 2019). If this is the case, a Rosenthal effect could be present (Rosenthal & Jacobson, 1968). Stereotypes occur mostly unnoticed, intuitively by the respective teachers and are, therefore, all the more powerful. This way, stereotypes not only influence the individual students from the inside but also from the outside, structured by teachers and other members of the culture.

2.3.4 Cultural differences

The sections above suggest that culture plays an important role in the formation of science self-concepts. The term 'culture' is used in various ways in everyday life (Mamlok-Naaman, Abels, & Markic, 2015). In the scientific discussion of the impact of culture on science self-concept, 'culture' is often employed referring to the nation-state, especially in cross-cultural comparisons, in which cultural differences in science self-concept between countries are investigated (e.g. Chiu, 2008). Sometimes, countries are put into larger groups such as 'East Asian' or 'Western' countries (e.g. Marsh et al., 2015). Some universal characteristics of science self-concept have been pointed out, such as the existence of the Big-Fish-Little-Pond-Effect (Marsh et al., 2015; Nagengast & Marsh, 2011, 2012). The I/E model of self-concept describing internal comparisons (between subjects) and external comparisons (with peers), seems to be valid across cultures although to different degrees (Chiu, 2008).

However, there are also differences in self-concept between countries. One study argued that the association between self-concept and achievement might depend on the cultural context (Lau, 2014) which was confirmed in two empirical studies (Wilkins, 2004; Yu, 2012). The authors show that in East Asian Regions, the association between the two variables is less strong than in Western countries. This seems to be a particular feature of East Asia and not true for other parts of Asia. For instance, studies conducted in South-East Asian countries showed that here, the association between science self-concept and achievement is present (Lay & Chandrasegaran, 2016; Ng et al., 2012). This seems to be a difference between East Asian and South-East Asian countries. Further, one study showed that gender disparities in science self-concept are larger in industrialized countries than in developing countries (Sikora & Pokropek, 2012). These findings show that the broader cultural context does play a role in students' science self-concepts.

In addition to the factors discussed so far, ethnic groups within a country have an impact on science self-concept. Here, the definition of culture usually refers to locally established concepts of students' cultural identities such as e.g. the U.S. American concept used in the census (U.S. Census Bureau, 2017). This definition is based on self-identification of people as Black, White, Latino, Asian, etc. while the categories are not mutually exclusive. In contrast, the German concepts of migration background employed in the censuses[6] (Statistisches Bundesamt, 2013) are not based on self-identification. Rather, the assignment of a migration background is based on predefined criteria such as e.g. a person's nationality, the parents' places of birth, etc. Despite these differences between the German and the American concepts, both allow differentiating between dominant and non-dominant ethnic groups within a country.

In general, academic self-concepts are more positive among students who belong to the dominant ethnic group of a country (Dean, 2013). The same trend shows regarding science self-concepts: students from non-dominant ethnic groups tend to have lower science self-concepts than students from the dominant ethnic group, which has been shown in various countries (in the U.K.: DeWitt et al., 2011; in the U.S.: Leslie et al., 1998; Riegle-Crumb et al., 2011; Simpkins, Price, & Garcia, 2015; in Australia and New Zealand: Woods-McConney, Oliver, McConney, Maor, & Schibeci, 2013). One exception seems to be students with an Asian background in the U.K. (DeWitt et al., 2011) who tend to have more positive science self-concepts than students belonging to the dominant ethnic group. This contrasts the finding that on average, science self-concepts are less positive in East Asian countries. It indicated that students' cultural backgrounds do not simply reflect the situation in the corresponding regions but can take a new dynamic when these students live in another country.

A potentially powerful explanation of these phenomena could be based on an analysis of the social positions of ethnic groups within a country. In countries with a history of violent racial conflicts and oppressions, the descendants of the marginalized ethnic groups tend to show more negative science self-concepts. It is, therefore, reasonable

[6] In the census, there are two definitions of migration background which are being used alternately in each round.

to assume that the historical structures of oppression and violence show their effects until today. This has, for instance, been shown for Black and Latino students in the U.S. who have more negative science self-concepts than Caucasian students (Riegle-Crumb et al., 2011; Simpkins et al., 2015) and for Indigenous students in Australia and New Zealand (Woods-McConney et al., 2013). Besides ethnicity-based stereotyping, which is an important hindrance for students of some ethnic minorities in science (Horna & Richards, 2018), one of the most important explaining factors is the socioeconomic status which tends to be lower among students belonging to a non-dominant ethnic group (Simpkins et al., 2015). The inequalities in science self-concept are thus not only due to narratives but also to economic inequalities that have negative effects for groups that historically experienced violent forms of oppression.

The review in this section shows that science self-concepts can reflect social and historical structures of oppression and, therefore, be a tool for investigations of social inequalities in the field of science. More generally, it suggests that science self-concept is a sociocultural phenomenon that needs to be examined more holistically. It is possible only to a certain extent to isolate the relationships of science self-concept with gender and with achievement from the cultural context. These relations are essentially embedded in social contexts.

2.3.5 Interventions

Changing the science self-concept of secondary school students is aimed at in several intervention studies. Many of these adopt the narrative of the 'leaky pipeline' in science (a review of interventions: van den Hurk, Meelissen, & van Langen, 2019): many students who initially show interest in science do not pursue a career in this field. They drop out of the pipeline. This narrative has been criticized (e.g. by Mendick, Berge, & Danielsson, 2017) because it argues from an economic point of view, focusing on workforce supply to support the economy. Following the rationale of the 'leaky pipeline', the reason for supporting social equality would be that underrepresented groups in certain areas of science and engineering constitute potential new scientists. Equality issues are considered if this serves the economy. However, this rationale is seldom adopted in this drastic way. An alternative to the narrative of the 'leaky pipeline' is to focus on the equal representation of all social groups in the field of science as it is aimed at in the Science Capital Teaching Approach (Godec, King, & Archer, 2017). This approach is, nevertheless, very little science-specific and could be applied to any other subject.[7]

From a methodological or technical point of view, intervention studies in this field encounter important challenges. This is due to the fact that self-concepts are relatively stable over time (Marsh, Trautwein, Lüdtke, Baumert, & Köller, 2007; Wigfield et al., 1997). However, long-term interventions are work-intense and require stably employed researchers which usually limits their number. In this field, some intervention studies of short duration exist (e.g. Şentürk & Özdemir, 2014). Although positive effects on self-concepts are reported in many cases, only a small number of studies track the students' science self-concepts a reasonably long time after the intervention which would allow providing insights into long-term effects. In one study, a summer science program for girls from non-dominant ethnic groups proved to be ineffective possibly due to a confrontation with the reality of and discriminatory

[7] This was discussed and agreed on with Spela Godec during a personal meeting at the Institute of Education of the University College London in March 2019.

structures in the field of science as the authors discuss (Jayaratne, Thomas, & Trautmann, 2003).

One aspect that several intervention studies have focused on is to change students' frames of reference. This is based on the finding that social comparison processes and the reputation of being a good student in science play an important role in the formation of self-concept (North & Ryan, 2018). This could be interesting in light of the Big-Fish-Little-Pond-Effect which predicts more positive self-concepts for students in low-ability groups (Marsh, 1987). Repeating a school year could, therefore, have a positive impact on science self-concept because the classmates in a lower grade have probably less science knowledge than those in higher grades. However, the inverse was found: grade repetition tends to have negative effects on students' science self-concepts (Ehmke et al., 2010), possibly due to the fact that grade repetition takes place only if teachers agree on a students' insufficient achievement, a decision with consequences that not only touch a students' academic path but probably also his or her academic self-concept.

Single-sex education promises to both change the reference group and to provide a space in which gender stereotypes might potentially be less influential. However, this measure has no clear effects on science self-concept. Positive (Kessels & Hannover, 2008), mixed (Sampson, Gresham, Leigh, & McCormick-Myers, 2014), and no effects (Brown & Ronau, 2012) on students' science self-concepts have been reported on. This type of intervention appears to be scarcely promising. However, valid data is rare in this field: selection bias is very probable to occur (only certain students are sent by their parents to single-sex schools) and conducting experiments with randomized assignment is very difficult (long-term studies would be needed and this constitutes major changes in the school environment which could be opposed by parents).

Several studies aim at improving the science self-concepts of girls. Increasing the female science teaching staff is not effective (Gilmartin et al., 2007) because the students perceive their female teachers as role models only if they have experience in science besides teaching (Gilmartin et al., 2007). In contrast, far-reaching curriculum reforms can have positive effects on girls' science self-concepts, as shown for physics by Häussler and Hofman (2002). Two changes were made: the students' curriculum was adapted to the fields of interest of both boys and girls, and the teachers were provided with a special training focusing on how to support girls in their development of positive physics self-concepts. Positive effects on girls' self-concepts were documented. This shows that probably only long-lasting and far-reaching changes have a significant impact on science self-concepts.

It is not entirely clear if inquiry-based learning improves students' science self-concepts. In a study based on the global PISA data, there was evidence that it does improve science self-concept (Cairns & Areepattamannil, 2019). However, this study assessed the level of inquiry-based learning based on self-report data on the frequency of the use of experiments in class. This is rather a measure of hands-on science experiences in class which is not identical to inquiry-based learning as a specific teaching method. These findings are thus to be taken with precaution. In contrast, no effect on self-concept was found in a study using an experimental design in which in some classes, inquiry-based learning was introduced while in the control group no inquiry-based learning was used (Potvin, Hasni, & Sy, 2017). In addition to these interventions in school, out-of-school environments could be interesting for improving students' science self-concept as shown in a study in which secondary school students designed chemical experiments that they presented in pubs and restaurants (Beeken & Budke, 2018).

For the design of adequate interventions, employing a mixed methods research design could be insightful. Qualitative data can allow identifying concrete social mechanisms and thinking patterns associated with science self-concept. This could advance research in science education because this domain is more application-focused in nature and aims at improving science learning. It would also mean emancipating science self-concept research in science education from educational psychology which tends to be less application-focused.

2.3.6 Available instruments

Almost all studies about science self-concept analyze data from Likert scales. For chemistry, there is no validated scale that would allow investigating the self-concepts of secondary school students. For higher education, the chemistry self-concept inventory (CSCI) (Bauer, 2005) and the self-concept subscale of the attitude towards the subject of chemistry inventory (ASCI I and II) (Bauer, 2008; revised version: Xu & Lewis, 2011) are scales with good psychometric properties that are theoretically grounded in Marsh's self-description questionnaire III which constitutes a standard in self-concept research in higher education (Marsh, 1992a). These instruments are, however, designed for research with young adults.

For investigating chemistry self-concepts of secondary school students, one option is to adapt one of the chemistry-specific scales (CSCI, ASCI I and II) to the situation of secondary school students. An alternative is to adapt one of the existing science self-concept scales for secondary school students to the field of chemistry. The first option is probably more challenging because the items need to be adapted both linguistically and regarding the content so that they cater to the situation of adolescents. The second option would mean to merely substitute the word 'science' with 'chemistry' without requiring further changes. The chances of developing an adequate scale with good measurement properties that is adapted to the target group and the field of chemistry seem to be good. This second option is, therefore, preferable in the situation where no chemistry-specific instrument for investigating secondary school students' self-concepts exists.

A great variety of science self-concept scales for secondary school students exists. These vary in quality: some instruments have very good psychometric properties which have been shown repeatedly in independent samples, while for others no such data is available which does not allow for a judgment of their quality and, therefore, excludes them from scientific discourse. The most widely used instruments are the scales employed in the PISA and TIMSS studies and the subscales of Marsh's self-description questionnaire. The PISA and TIMSS scales are influential because many researchers use the large data sets from these studies for re-analyses (e.g. Areepattamannil, 2012; Grabau & Ma, 2017).

The quality of these three scales varies. The TIMSS 2007 (Martin et al., 2008) scale contains negatively worded items that tend to produce biased results (Marsh et al., 2013), especially in cross-cultural studies (Chiu, 2008). An analysis of the TIMSS 2007 data showed that this bias is also produced by the TIMSS 2007 scale (Marsh et al., 2013). This scale, therefore, does not constitute a good basis for investigations of the chemistry self-concepts of secondary school students. Although Marsh's self-description questionnaire II (1992b) contains negatively worded items, too, which could potentially lead to biased results, repeated factor analyses using independent samples did not confirm this. They showed good model fit for the particular academic self-concepts represented in the subscales (Marsh, 1989, 1990c, 2005). This scale is, therefore, a promising alternative for an adaptation to the context of chemistry. The

PISA 2006 scale (OECD, 2009b) has one advantage over Marsh's self-description questionnaire II. It does not contain any negatively worded items and thereby reduces the risk of measurement bias. Self-concept is conceptualized as part of the larger construct of science engagement. Documentation about the item construction process apart from statistical calculations could not be found which puts the theoretical foundation into question. However, the items resemble the positively worded items of Marsh's theoretically well-grounded self-description questionnaire II (Marsh, 1992b). This indicates that the theoretical basis of the construct might be similar. Further, it is sufficiently short and precise and its psychometric properties have proven to be good: in numerous analyses of the data for each participating country, the model fit ranged between acceptable and very good according to the criteria defined by Hu and Bentler (1999) and the data showed very good internal consistency (OECD, 2009b). This means that in science self-concept research with secondary school students, Marsh's SDQ II (Marsh, 1992b) and the PISA 2006 science self-concept scale (OECD, 2009b) are thoroughly tested instruments with good psychometric properties. The advantage of the PISA scale over Marsh's instrument is the fact that it does not contain negatively worded items. Further, it is available in multiple languages which allows for investigations in a wide range of regions of the world while still being able to be discussed within the scientific community with its dominant language English. If a study is conducted in a community in a language other than English, the researchers in the scientific community still know the source of the scale, its advantages and shortcomings, and the results can be compared to those from investigations in other regions of the world. This way, the quality of the study can be judged more accurately which is of utmost importance. It is, therefore, a very good option to choose this scale for an adaptation to the context of chemistry.

Besides these three well-known scales, several other scales exist. Some of these are used in individual research projects and do not give details about the theoretical basis of the scale, the sources the items are based on, or the scale's psychometric properties. This seems to be true even for some large-scale studies. For example, a documentation of the construction of the self-concept scale used in the ASPIRES study could not be found, except for the authors' statement that it is based on established scales (DeWitt et al., 2011). Other difficulties can arise in longitudinal studies in which the self-concept scale is repeatedly modified as in the case of the large-scale NELS study which is problematic if the self-concept data of different phases are compared (as e.g. in Chang, Singh, & Mo, 2007). Hardy (2014) provides scales for self-concepts of the individual science subjects. However, the items seem to assess self-efficacy rather than self-concept. Academic self-efficacy constitutes a person's beliefs about his or her ability to fulfill particular tasks in achievement situations (Bong & Skaalvik, 2003). It is, therefore, a measure of the perceived *control* over the course of events (Bandura, 1989, 1997). For measuring academic self-efficacy, the scales present particular problems and the participants are asked to state in how far they would expect to succeed to solve the problem (Bong & Skaalvik, 2003). Academic self-concept, in contrast, is a more generalized theory about a person's abilities (Bong & Skaalvik, 2003). It does not refer to control beliefs regarding specific tasks but to a general conception of one's performance in a certain field. Although the two constructs are conceptually related, they do not constitute the same type of psychological construct (Bong & Skaalvik, 2003). Hardy's (2014) scale seems to be more appropriate for self-efficacy research but not for self-concept research. This confusion appears not only in this particular case but it occurs in other cases as well (e.g. in Ferguson & Hull, 2019; Wender, 2004). Neither of these scales present convincing options for measuring chemistry self-concept. In conclusion, the best option is, therefore, the adaptation of a subscale of Marsh's SDQ II (1992b) or, preferably, of the PISA 2006 science self-concept scale (OECD, 2009b) to fit the context of chemistry education in secondary school.

3 | RESEARCH GOALS AND QUESTIONS

The review of the literature shows that little research has focused on secondary school students' chemistry self-concepts, compared to the attention that science and physics self-concepts have received which is also true for the German context. Based on the finding that students of ethnic minorities tend to have more negative science self-concepts (e.g. Riegle-Crumb et al., 2011), the present research project aimed to understand:

> *How does the cultural diversity present in Germany affect secondary school students' chemistry self-concepts?*

This is the central goal of the present research project. Thus, the first and guiding empirical research question (EQ) was:

> (EQ1) What role do secondary school students' cultural backgrounds play in the formation of chemistry self-concepts?

Students' cultural backgrounds were conceptualized as their migration backgrounds because this concept allows capturing cultural diversity due to the migratory movements in Germany. The definition of migration background as it had been employed in the official 2013 census in Germany (Statistisches Bundesamt, 2013) was used. This defines that "a person has a migration background if this person or at least one of his or her parents does not possess German citizenship by birth" (Statistisches Bundesamt, 2013, p. 4, translated). According to this definition, a person has a migration background not only if this person migrated to Germany but also the parents' migratory movements are taken into account. This conceptualization of the students' cultural backgrounds does not account for other aspects of culture such as e.g. religion, social class, hybrid cultures (Bhabha, 1994) and is in this respect limited. However, the concept of migration background has proven to be a powerful tool in the description of the social structure and social inequalities in Germany (e.g. Färber, Arslan, Köhnen, & Parlar, 2008) and it is particularly useful for research in secondary schools with mostly underage students (Gresch & Kristen, 2011). This is due to the fact that in Germany, many students are German citizens but grow up with relatives who migrated to Germany. The concept of citizenship, for instance, would not differentiate between these students and those whose parents possess the German citizenship by birth (Gresch & Kristen, 2011). The existing social disparities such as the differences in achievement would go unnoticed. Looking at migration background allows differentiating between these students' situations.

Since gender differences regarding science self-concepts of secondary school students have been shown repeatedly (article 1, see appendix; Rüschenpöhler & Markic, 2019a), and since gender is a cultural construct (Rubin, 1975), this variable was considered as well. The analyses regarding EQ1 were conducted first in a pilot study (article 2, see appendix; Rüschenpöhler & Markic, 2019b) and then in the main study (article 3, see appendix; Rüschenpöhler & Markic, 2020a) to test the validity of the findings from the pilot study. The assumption was that chemistry self-concept would be influenced by the students' cultural backgrounds. In particular, science education literature suggested that (h1) students with a migration background have more negative chemistry self-concepts than students without a migration background. This hypothesis was based on the finding that students from most non-dominant ethnic groups tend to have lower science self-concepts (e.g. Riegle-Crumb et al., 2011). Further, the science education literature suggested that (h2) gender would be related to chemistry self-concept. The assumption was that there would be the gender gap in favor of boys that had been reported on in science self-concept literature (e.g. Mujtaba & Reiss, 2016).

In addition to the description of differences that might exist between boys and girls of different cultural backgrounds, the research project aimed to provide explanations for the observed phenomena. The thesis assumed that the home environment influences the development of students' chemistry self-concepts. This assumption was based on two arguments: first, if differences between students with different migration backgrounds would be found in the German context, mechanisms in the home environment could be the reason for this because many students with a migration background are second-generation immigrants and have not lived in another country. Their migration background is thus due to their parents' and not their personal migration history. Second, several empirical studies had shown that the home environment plays an important role in the formation of students' science self-concepts (e.g. Silinskas & Kikas, 2019; Simpkins et al., 2015). A conceptualization of how this influence could be exerted seems to be currently absent from the discussion in science self-concept literature. Therefore, a theoretical research question (TQ) needed to be addressed:

> (TQ) How could the influence of the home environment on students' chemistry self-concepts be conceptualized?

The goal was to develop a concept that would allow understanding the interplay between the cultural environment at home and chemistry self-concept in the German context. For this, the concept of science capital was transposed to the context of chemistry. This was done in article 4 (see appendix; Rüschenpöhler & Markic, 2020b). Based on this new concept, it was possible to address the second empirical research question in article 5 (see appendix; Rüschenpöhler & Markic, 2020c):

> (EQ2) How is students' chemistry capital at home related to their chemistry self-concepts?

Regarding this second empirical research question (EQ2), the hypothesis was that (h3) if students possess chemistry capital at home, they would develop more positive chemistry self-concepts.

In addition to these empirical and theoretical questions, a methodological research question (MQ) needed to be addressed. This was based on the observation that self-concept research is prone to bias when conducted in culturally diverse settings (Byrne, 2002).

> (MQ) How could academic self-concept research proceed to control for measurement bias in culturally diverse settings?

The goal was thus to develop an approach for culture-sensitive academic self-concept research. This was an essential part of the whole research project and, therefore, an overarching research question. The foundations of this approach were laid in the pilot study where the culture-sensitivity of the approach was evaluated (article 2, see appendix; Rüschenpöhler & Markic, 2019b). The main study used the approach as well but applied a different theoretical lens.

4 | METHODS

The research project was divided into two phases (fig. 1). In the first phase, a pilot study was conducted in which an approach to culture-sensitive academic self-concept research was developed to address the prevailing methodological difficulties in academic self-concept research. This approach was tested in a study investigating the impact of culture on chemistry self-concepts of secondary school students in Germany. This study followed a concurrent triangulation mixed methods design (Creswell, Plano Clark, Gutmann, & Hanson, 2003) and is described in more detail in article 2 (see appendix; Rüschenpöhler & Markic, 2019b).

The pilot phase was followed by the main study which was conducted in three steps. In the first step, the hypotheses developed in the pilot study were tested (article 3, see appendix; Rüschenpöhler & Markic, 2020a). In the second step, an analytical framework was developed for investigating the home environments' impact on chemistry self-concepts since this thesis assumed that this environment exerts a strong influence. This analysis based on qualitative data can be found in article 4 (see appendix; Rüschenpöhler & Markic, 2020b). The third step of the main study consisted in the integrated analysis of both data types in a mixed methods design. This study aimed to understand the relation between chemistry self-concept and the home environment in more depth (see appendix, article 5; Rüschenpöhler & Markic, 2020c).

4.1 Pilot study

4.1.1 Instruments

Chemistry self-concept was measured using a Likert scale with nine items based on the model of self-concept by Shavelson et al. (1976). In the pilot study, these items were newly developed due to the lack of an instrument for measuring chemistry self-concept of secondary school students. Additionally, semi-structured qualitative interviews were conducted (Qu & Dumay, 2011). In these interviews, psychological processes associated with chemistry self-concepts were investigated with a special focus on learning, performance and social goal orientations. Further, the interviews allowed triangulating the quantitative self-concept data. This triangulation permitted assessing potential bias due to cultural differences. If students talked in the interviews about their abilities in chemistry, these oral statements could be compared to their self-concept scores. This provided insights into the validity of the questionnaire data.

4.1.2 Sample

116 secondary school students from six schools in the northwestern part of Germany participated in the study. In this part of Germany, it depends on the school type when chemistry content is introduced in class. The data were, therefore, collected in grades 7-10 in classes in which chemistry had already been taught. The students were on average 15 years old, 54.3 % were female and 54.3 % had a migration background according to the definition employed in the 2013 census (Statistisches Bundesamt, 2013). The students with a Turkish or a Kurdish migration background were assembled in one group because all students who identified as Kurdish also stated to

have a Turkish migration background. This was the largest group of students with a migration background, making up 23.3 % of the total sample.

The sample for the interviews was drawn from the students who participated in the questionnaire study. 43 students volunteered to be interviewed. Most students were interviewed in pairs, i.e. together with a classmate. 60.5 % were female, 55.8 % had a migration background and the students with a Turkish migration background made up 20.9 % of the sample. Data collection in both parts of the study conformed to the declaration of Helsinki (World Medical Association, 2013).

4.1.3 Analysis

Quantitative analysis. After a reliability analysis of the questionnaire data using Cronbach's *a*, two-way ANOVAs were conducted. First, the self-concepts of boys and girls with and without a migration background were compared, and then, the self-concepts of students without a migration background and with a Turkish migration background were investigated.

Qualitative analysis. The interviews were analyzed using Mayring's (2014) summarizing qualitative content analysis in which the interview content was organized in three steps. This analysis focused on the students' learning and performance goal orientations, their social goal orientations, and statements about their chemistry self-concepts, in the framework of Hattie's (2008) model of the self. More information on the pilot study can be found in article 2 (see appendix; Rüschenpöhler & Markix, 2019b).

4.2 Main study

4.2.1 Instruments

For the main study, quantitative data was again collected using a questionnaire while qualitative data was collected in semi-structured interviews. In the questionnaire, the students' chemistry self-concepts, three indicators of learning goal orientations in chemistry (need for cognition, persistence, incremental theory of intelligence), three indicators of social support in chemistry (student support, teacher support, sense of belonging), and the perception of their linguistic abilities in chemistry class were measured. All scales except for the language scale were based on instruments available in both English and German that are established in their respective fields. The items were slightly adapted to fit the context of chemistry class and based on 6 point Likert scales. The language scale was newly developed because no appropriate measure could be found. The instrument was tested in three classes (*N*=68), after which two items from the language scale were deleted because it concerned aspects in chemistry that had not been covered in grade 8. More information, as well as an English version of the research instrument, can be found in article 3 (see appendix; Rüschenpöhler & Markic, 2020a).

The interviews were semi-structured (Qu & Dumay, 2011), following an interview guide. The goal of the interviews was to gain insights into the role that chemistry plays in the students' lives at home and in school. The interview guide was tested in a pilot study with four students from grades 8 and 9 from one school. These interviews are not part of the main study. After slight modifications based on the experiences from the four interviews, the interview guide was divided into the following sections: the students' chemistry experiences in school, the role chemistry plays at home, and thoughts about their future engagement in chemistry. More information about the interviews can be found in article 4 (see appendix; Rüschenpöhler & Markic, 2020b).

4.2.2 *Sample*

The questionnaire was filled in by 585 students from 30 classes in grades 8-10 attending 10 different schools of the three traditional German school types (*Gymnasium*, *Realschule*, *Hauptschule*). All items were read aloud in class in order to help students understand the items in case of difficulties in reading comprehension. The students were between 12 and 18 years old (*M*=15), 45.5 % were female, 47.6 % had a migration background. 12.3 % of the total sample had a Turkish or Kurdish migration background.

Individual interviews were conducted with 48 of the students who had filled in the questionnaire. Participation was voluntary in nature and all students were encouraged to participate in the interview study, regardless of their chemistry achievement and their attitudes towards the subject. This was done to gain insight into a broad range of student perspectives on chemistry. The students were aged 13-18 (*M*=15), 48 % were female and 83 % had a migration background. Data collection in both parts of the study conformed to the declaration of Helsinki (World Medical Association, 2013).

4.2.3 *Analysis*

Quantitative analysis. After data collection, the analyses were conducted in two phases. In analysis phase I (fig. 2), the questionnaire and interview data were analyzed separately. First, Cronbach's *a* was calculated and confirmatory factor analyses were conducted for each scale of the questionnaire. This was followed by a two-way ANOVA in which the impact of gender and culture on chemistry self-concept was investigated. For this analysis, only the subsamples of boys and girls without a migration background and with a Turkish migration background (*N*=316) were used in order to test the hypothesis from the pilot study. Then, a multiple linear regression model was tested using the total sample of 585 students. With this model, the relations of chemistry self-concept with the students' learning goal orientations in chemistry, their perception of social support in chemistry, and the perception of their abilities regarding chemistry language were investigated. More information on these analyses can be found in article 3 (see appendix; Rüschenpöhler & Markic, 2020a).

Qualitative analysis. In the second part of analysis phase I (fig. 2), the interviews were transcribed and analyzed using thematic analysis (Braun & Clarke, 2006). The analysis procedure was divided into several steps, using different coding techniques defined by Saldaña (2016) and drawing causal networks (Miles, Huberman, & Saldaña, 2014) with case descriptions for each case. An extended description of the analysis procedure can be found in article 4 (see appendix; Rüschenpöhler & Markic, 2020b).

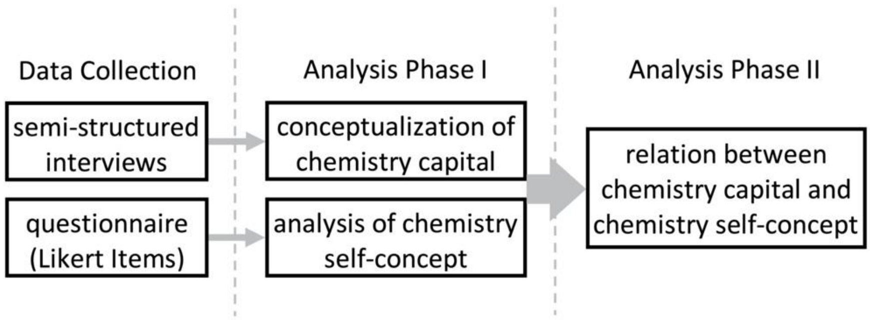

Figure 2. Overview of the analysis procedure of the main study (see article 5, appendix; Rüschenpöhler & Markic, 2020c).

Mixed methods analysis. In analysis phase II (fig. 2), the data from both parts of the study were used in a mixed methods analysis with one point of interface. The goal of this analysis was to understand the relation between the home environment and chemistry self-concept. For this analysis, the interview and questionnaire data from all students who participated in the interviews were used (*N*=48). Due to the sample size, inferential statistics could not be conducted and Bayesian methods were not suitable either. Since this was the first study investigating this relationship, an informative prior could not be defined on empirical grounds that would have allowed conducting the analyses despite the small sample size. In order to gain first insights, descriptive statistics were, thus, conducted and displayed in boxplot diagrams. The trends showing in these diagrams were then analyzed with reference to the interview data to understand what might be happening. This type of analysis was conducted for the relation with chemistry self-concept and some related variables (indicators of learning goal orientations and the perception of abilities in chemistry language). Further details on the analysis procedure can be found in article 5 (see appendix; Rüschenpöhler & Markic, 2020c).

5 | RESULTS

In this section, the results are presented according to the four research questions (see chapter 3). The section starts with empirical findings on the effects of gender and migration background on chemistry self-concept (EQ1, chapter 5.1). This is followed by a conceptualization of chemistry capital as an analytical tool for modeling the influence of the home environment on students' chemistry learning (TQ, chapter 5.2). The relation of chemistry capital in the home environment and students' chemistry self-concept (EQ2) is explored in chapter 5.3. Finally, methodological reflections and an evaluation of the mixed methods research design for culture-sensitive academic self-concept research is presented (MQ, chapter 5.4).

5.1 EQ1. The effects of culture and gender on chemistry self-concept

Both in the pilot study and the main study, the relationships between chemistry self-concept, cultural background and gender were analyzed (EQ1). To do so, quantitative and qualitative analysis techniques were used.

5.1.1 Quantitative data analysis

Based on findings from science self-concept literature (article 1, see appendix; Rüschenpöhler & Markic, 2019a), it was expected that students with migration backgrounds would tend to show more negative chemistry self-concepts (h1). In addition, knowing that gender is a cultural construct and that it has a strong influence on science and technology self-concepts (article 1, see appendix; Rüschenpöhler & Markic, 2019a), this variable was included in the analyses as well. Based on the literature, the hypothesis was that a gender gap would show in favor of boys.

The findings in the pilot study were surprising as some of them did not comply with the initial hypotheses (article 2, see appendix; Rüschenpöhler & Markic, 2019b). After assessing the reliability of the scale (Cronbach's a=.86), screening the Q-Q-plots, and conducting a Shapiro-Wilk test (not significant at the .05 level), an ANOVA was conducted, comparing boys and girls with and without a migration background. The effect of migration background was not significant (p=.209): students with a migration background did not have significantly lower chemistry self-concepts than students without a migration background. Hypothesis 1 (h1) which had predicted that students with a migration background would have significantly lower chemistry self-concepts was, therefore, not confirmed. However, the effect of gender was significant (p=.046). This result confirmed hypothesis 2 (h2), according to which it was assumed that differences in chemistry self-concepts would show between boys and girls. In addition, the interaction effect of gender and migration background was significant (p=.013), a finding that could not be explained based on science self-concept literature. This first ANOVA was conducted to get an overview of the distribution of chemistry self-concepts.

Besides the comparison of the self-concepts of boys and girls with and without a migration background, the specific culture groups were of interest. In a second ANOVA, the self-concepts of boys and girls with a Turkish migration background were compared to those of students without a migration background[8]. Here, the gender gap (p=.035) and the interaction effect of gender and cultural background (p=.028) were at a significant level, too, while the effect of the students' cultural background alone was not significant (p=.127). This suggested that gender relations might differ between the students with a Turkish migration background and those without a migration background. Among students with a Turkish migration background, girls tend to be more confident in their abilities than boys while the inverse seems to be true among boys and girls without a migration background. However, the sample sizes in these analyses were small (N_{total}=116) and could, therefore, only provide first insights.

Due to these limitations, the analyses were repeated in the main study using an independent, larger sample (N=585) (article 3, see appendix; Rüschenpöhler & Markic, 2020a). After the assessment of scale reliability (Cronbach's α=.91) and the factor structure in confirmatory factor analysis (good fit; SRMR=.026, CFI=.971), an ANOVA was conducted using the subsample of students with a Turkish migration background and without a migration background (N=316). Since Levene's test was significant for gender (p<.01) and the interaction of gender and culture (p<.05), a robust analysis with a bootstrap was conducted using the modified one-step estimator of location and Mahalanobis distances available in the WRS2 package in R (Mair, Schoenbrodt, & Wilcox, 2017). Only the interaction effect of gender and culture was significant (p<.05). The main effects of gender (p=.843) and culture (p=.089) were not at a significant level. This confirms the finding from the pilot study that gender relations in chemistry self-concept might not be the same in the groups of students with a Turkish migration background and students without a migration background. The hypotheses (h1) and (h2) could not be confirmed. Instead, an unexpected interaction effect of gender and migration background appeared in both the pilot and the main study, when looking at students with a Turkish migration background and without a migration background.

5.1.2 Qualitative data analysis

As part of the pilot study, qualitative interviews with 43 of the 116 students were conducted (article 2, see appendix; Rüschenpöhler & Markic, 2019b). These interviews were based on Hattie's (2008) model of the self in which the self is conceptualized as a chooser of different self-processes through which the self is protected, promoted, and preserved. The goal was to investigate whether boys and girls with different cultural backgrounds differ in the self-processes associated with their chemistry self-concepts. Initially, the focus was laid on learning and performance goal orientations because according to Hattie (2008), these are highly important in educational contexts. In the process of data analysis, social goal orientations were included as well because these appeared to be highly relevant to a part of the students in the interviews. In the following, the results will be presented only of the boys and girls with a Turkish migration background and without a migration background because these were the largest groups. The presentation of the results is thus based on 28 out of 43 interviews.

In the groups of students in which rather negative chemistry self-concepts prevail, i.e. among boys with a Turkish migration background (N=5) and girls without a migration background (N=12), the patterns of psychological processes appeared to be quite similar. The students in both groups tended to express rather weak learning goal

[8] The students with a Turkish migration background were chosen because they constituted the largest group among the students with a migration background in the sample. The other groups were too small for this type of analysis.

orientations but stronger performance goal orientations (article 2, see appendix; Rüschenpöhler & Markic, 2019b). In some cases, the performance goal orientations were reflected in entity theory of intelligence beliefs (Dweck, 2000), i.e. some students had the impression that they are unable to improve their abilities in chemistry which is part of the performance goal mindset. They perceived their abilities as predefined and fixed. Most striking in these two groups, though, were the social goal orientations and, in particular, the fact that some of these students expressed feelings of alienation in chemistry class. Some of these students described quite drastically how they feel unwelcome in chemistry class with their individual personalities and with the competencies they have. The boys with a Turkish migration background and the girls without a migration background, thus, seemed to share some similarities in their patterns of learning, performance, and social goal orientations.

In contrast, the similarities were far smaller among students with positive chemistry self-concepts. The interview data suggested that there might be two culturally different patterns of goal orientations in the groups of students with rather positive chemistry self-concepts. The boys without a migration background (N=7) and the girls with a Turkish migration background (N=4) from this sample seemed to differ in their social goal orientations: their social relations with their chemistry teacher and their peers seemed to be of little salience in chemistry class for the boys without a migration background. They talked about the social context only to a minor extent and none of these boys mentioned that he had experienced feelings of social insecurity. In contrast, the social dimension appeared to be highly relevant for the girls with a Turkish migration background. The teacher seemed to be an important point of reference in chemistry learning to some of these girls. In addition, they liked to share their learning experiences with family and friends at home. Apart from these differences regarding the students' social goal orientations in these two groups, these students shared certain similarities. In both groups, learning goal orientations and a focus on chemistry content seemed to be strongly present. In comparison to the girls without a migration background and the boys with a Turkish migration background, performance goal orientations seemed to be less important. The boys without a migration background and the girls with a Turkish migration background, who both tend to have rather positive chemistry self-concepts, thus, both seemed to have a strong focus on learning while they differ in their social goal orientations in chemistry.

5.2 TQ. Chemistry capital as an analytical lens

How could these differences between boys and girls with and without a migration background be produced? Besides the description of differences, the goal of this research project was to develop a deeper, more culturally embedded conceptualization of the discovered phenomena. The assumption was that the students' families, or, more precisely, their home environments would play an important role because only a small number of students who have a migration background are first-generation immigrants who migrated to Germany and who have lived in another country before. The majority are second-generation immigrants whose parents have migrated to Germany. The question was thus how the influence of the home environment on students' chemistry self-concepts could be conceptualized (TQ).

To answer this question, an analytical tool was developed. The literature review (article 1, see appendix; Rüschenpöhler & Markic, 2019a) had shown that only very few studies in science and technology self-concept research consider the influence of parents. Those that examine this potential influence had shown that the parents do play a role in science self-concept formation (Liou, Wang, & Lin, 2019; Makwinya & Hofman, 2015; Simpkins et al., 2015). However, these studies did not conceptualize this influence further. They showed that the role of parents is important, but they did not explain how this influence works using a model.

Article 4 (see appendix; Rüschenpöhler & Markic, 2020b) proposes a conceptualization of how the home environment influences students' chemistry self-concepts (TQ). The model is based on the assumption that many students with a migration background are influenced by other cultures predominantly at home through family members and other significant persons. To understand the mechanisms of how the home environment influences chemistry learning, the concept of chemistry capital was developed in the main study based on science capital research (e.g. Archer et al., 2014). Chemistry capital is interesting because it is resource-oriented, i.e. it allows focusing on all entities that support students' success in the field of chemistry. Further, it is more subject-specific than science capital. This could, in the long term, lead to application-focused research because it identifies concrete mechanisms through which students' success in the field of chemistry can be supported. In the following (chapters 5.2.1–5.2.4), the findings from this study will be described which served as the basis for the conceptualization of chemistry capital. Then, in the last part of this chapter (5.2.5), the value of this conceptualization for the analysis of the role of the home environment in the formation of self-concepts will be discussed.

The conceptualization was based on the qualitative interview data from the main study. In the analysis of the interviews, the goal was to conceptualize the flows of chemistry capital the students reported on, in order to understand through which sources and mechanisms students acquire chemistry capital. The analyses revealed that chemistry capital depends to a large extent on the chemistry capital the students have access to at home. Due to this important role the home environment plays, four groups of students could be distinguished based on the chemistry capital they have access to at home. For each group, conceptual maps are available that visualize the flows of chemistry capital (fig. 3-6).

5.2.1 Group 1. Students with chemistry capital

The first group was composed of students who possess chemistry capital at home (fig. 3). This was true only for a small group of students (6 out of 48). Five out of these six students attended *Gymnasium*, the German school type preparing for academic careers.

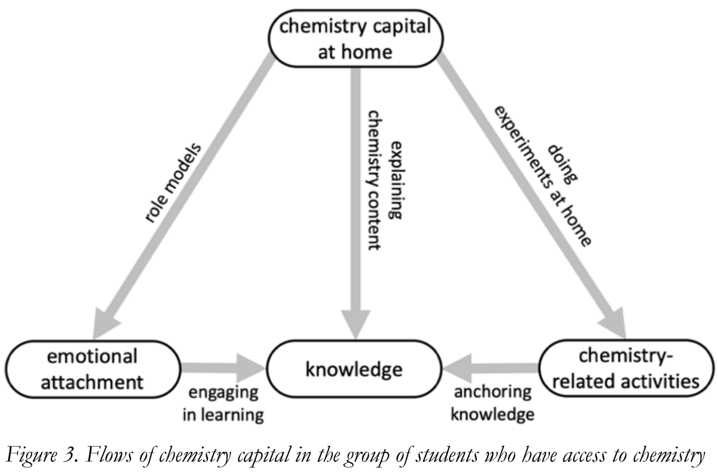

Figure 3. Flows of chemistry capital in the group of students who have access to chemistry capital at home. Reprinted with permission (article 4, see appendix; Rüschenpöhler & Markic, 2020b).

One student attended *Realschule*. In these students' homes, chemistry is part of everyday life. All six students reported that they have a person at home who is competent and willing to support the students' chemistry learning. If there is something these students did not understand in class, they always have a person at home who can explain chemistry content and who can notice and correct the students' misconceptions. Other than a resource of knowledge, these students find role models in their homes. They experience people who are excited about chemistry, who attribute a personal value to chemistry and who can explain the subject's relevance. For these people, chemistry is a precious part of their lives. For the students, this can inspire a reflection about the personal and societal value of chemistry and lead to a strong emotional attachment. One girl, for instance, shows a remarkable emotional persistence: although she currently hates chemistry, she is convinced that one day she will grow to like the subject. This is due to her mother's influence: she showed her daughter concrete contexts in which chemistry has a great utility value for society, in this case for waste treatment because the mother works as a scientist in this field. The girl does not give up learning chemistry although she experiences a lot of doubts regarding her abilities in the subject. Apart from the role chemistry capital at home plays in the emotional attachment and the acquisition of knowledge, it also becomes apparent regarding chemistry-related activities. Some students in this group conduct experiments at home, accompanied by close relatives or friends of the parents. These activities can constitute an integral part of social relationships as one case showed in particular. This boy conducts experiments with his grandfather in a special place in a garden house where the grandfather stores chemicals and other equipment. Conducting chemistry can become a favorite pastime of two generations in this group, be it parents with their children or grandparents with their grandchildren.

5.2.2 Group 2. Students with general educational capital

The second group was composed of students who have access to subject-unspecific, general educational capital at home (fig. 4). This was the case for a very small group of students in this sample (4 out of 48). Three of these students attended *Gymnasium*, one attended *Realschule*. The support the students receive is not chemistry-specific but still

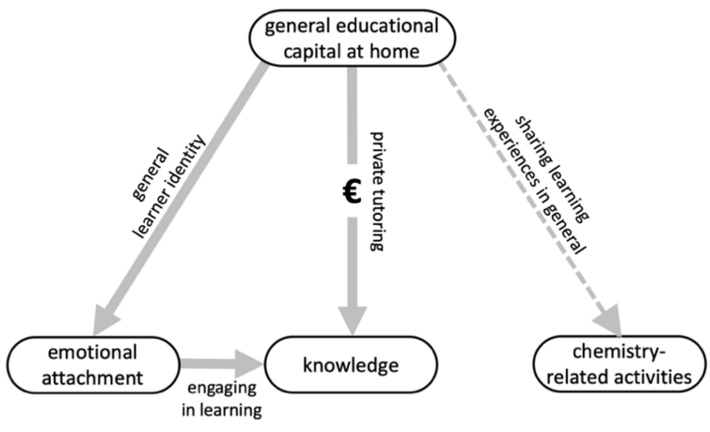

Figure 4. Flows of chemistry capital in the group of students who have access to general educational capital at home. Reprinted with permission (article 4, see appendix; Rüschenpöhler & Markic, 2020b).

plays an important role in the students' acquisition of chemistry capital. In these students' homes, the acquisition of knowledge is highly valued. Talking about chemistry content is welcomed at home because it enriches conversations and thereby deepens social relationships. Significant others such as parents or grandparents seem to adopt a general learner identity and to share this passion for learning with their children. This can contribute to chemistry learning as one case showed very impressively: one of the interviewees engaged in chemistry learning in order to be able to explain new chemistry content to her family. This allows her to engage in deep, meaningful conversations that she and her family enjoy very much. In addition to this emotional support, some parents are willing to pay for private tutoring and they share general learning experiences with their children such as watching and discussing documentaries together.

5.2.3 Group 3. Students with very little capital with exchange value in chemistry

The third group was composed of students who possess little capital at home that has exchange value in the field of chemistry (fig. 5). 9 out of 48 students from this sample fell into this category. Five attended *Realschule*, three *Gymnasium*, and one *Hauptschule*. In these home environments, some attempts are made to support the students' chemistry learning but these are not always successful because there seems to be a lack of knowledge about how chemistry capital can be acquired. In two cases, the attempt to support the students' chemistry learning failed. In one of these cases, the student's cousin possessed chemistry capital but simply lived too far away for the young people to keep in contact regularly and to share chemistry capital. Another student received a notebook as a gift from his godmother which contained the periodic system of elements on the cover. With this, the godmother intended to support his chemistry learning but neither the student nor the godmother understood the periodic table and so they did not know how to use the notebook. However, in the case of one girl, chemistry-related support was successful. This girl's mother accompanied her child's learning process with the help of the chemistry textbook. They discussed the content and thereby acquired chemistry knowledge together. There was little educational capital present in this home environment but the capital that existed was used very effectively. Besides this, some students reported on conflicts between their parents' world views and the world view adopted in chemistry class. Some parents did not know the concept of the particle structure of matter or they reject this idea, telling their children that this theory is wrong. This means that for some students in this group,

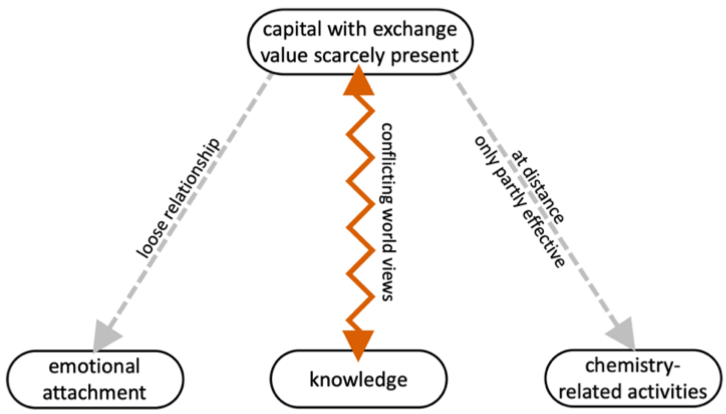

Figure 5. Flows of chemistry capital in the group of students who have scarcely any chemistry capital at home. Reprinted with permission (article 4, see appendix; Rüschenpöhler & Markic, 2020b).

sharing core ideas from chemistry class can lead to tensions at home. Close relatives have only loose relations to chemistry.

5.2.4 Group 4. Students whose home environments are shaped by the absence of chemistry capital

The fourth group was composed of students in whose home environments chemistry capital with exchange value seems to be absent (fig. 6). This was true for 29 out of 48 students in this sample. Almost all students attending *Hauptschule* (10 out of 11) fell into this category, while 14 students attended *Realschule* and four *Gymnasium*. These students do not have access to chemistry capital with exchange value at home. On the contrary, some of the students in this group experienced serious conflicts and barriers in the communication about chemistry at home. Some students explained chemistry at home as they would explain a foreign language since neither the core concepts of chemistry were known, nor the German terms for the substances and materials. Conflicts between the world view from chemistry class and the perspective of the students' religions became apparent in some cases. Some of these students reported on serious arguments they had with close relatives about what they had learned in chemistry because it was perceived as incompatible with their religious world views. This can pose obstacles to the students' chemistry learning because accepting chemistry knowledge means adopting the world view of chemistry and thereby risking a distance in the relationships with their families. Many students in this group perceived chemistry as irrelevant. One student explained that the chemical concepts do not make sense to her because they do not play a role in her private life. It can be assumed that some students implicitly 'choose' to perceive chemistry as irrelevant because this prevents conflicts in their private life. Not engaging in chemistry learning could, for some students, mean protecting the relationships with their families. The situation of some students in this group is aggravated by the fact that many of them were taught chemistry by teachers who do not hold a university degree in chemistry. This was the case for all students attending *Hauptschule* in the main study: all of these students were taught by teachers who did not study chemistry. This deprives the students of a source of chemistry capital which would be important for the students in particular since they

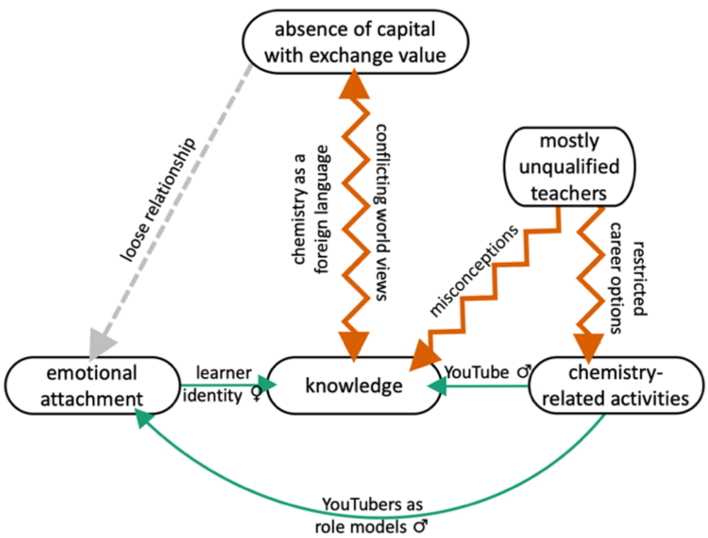

Figure 6. Flows of chemistry capital in the group of students in whose home environments chemistry capital with exchange value seems to be absent. Reprinted with permission (article 4, see appendix; Rüschenpöhler & Markic, 2020b).

do not have access to chemistry capital at home. For some students, this absence of a chemistry teacher who would hold a university degree in chemistry results in restricted career options. Two girls in this sample aspired to a job in which chemistry knowledge is a prerequisite. Both of them estimated their chances to enter this career path to be rather low because they learned little about chemistry at school. Moreover, some students showed serious misconceptions during the interviews.

In contrast to these patterns, there were also exceptional cases of students who did not follow this trend. Three students in this group developed strong individual chemistry capital even though they seemed to have no chemistry capital at home. Two of these students acquired chemistry capital through YouTube. These two boys followed a young, male YouTuber (Techtastisch, n.d.) who displays a 'nerdy' science identity (Archer et al., 2014). In his YouTube channel, the boys found both a resource of chemistry knowledge and a potential role model. One of these students even applied for jobs as a chemical production technician because he wanted chemistry to be an integral part of his working life after school. The YouTuber constitutes a source of chemistry capital for these students. This source seems to be relatively independent of the students' social position. The YouTuber acts as a virtual role model, provides knowledge, and inspires chemistry-related activities. The third student who developed individual chemistry capital was a girl who deployed a remarkably strong learner identity. She was excited about chemistry because she loved to 'brood' over things and chemistry was something she liked to think about and to turn around in her thoughts. However, in contrast to the two boys, she did not have an external source of chemistry capital. Her brooding over chemistry took place only when she was alone, in her private room, and without any further stimuli. She, therefore, does not have access to a role model or some kind of virtual relation to a person who is deeply connected with chemistry. Her acquisition of chemistry capital is a solitary enterprise.

5.2.5 The potential of the concept of chemistry capital for this analysis

The concept of chemistry capital was developed in this research project as a tool for understanding the role of the home environment in the formation of chemistry self-concepts. It allows discerning the resources individual students have access to that help them succeed in the field of chemistry. It was shown that resources in the family play a crucial role in the students' acquisition of individual chemistry capital because they support the acquisition of knowledge, the development of positive attitudes towards chemistry, and chemistry-related activities. Further, this approach allows identifying concrete mechanisms through which the home environment and other factors support the students' success in the field of chemistry.

This could guide application-focused research. It was assumed that this identification of entities that could be worked on in interventions could also lead chemistry self-concept research to more practical output. Science and technology self-concept research still lack practical impact (article 1, see appendix; Rüschenpöhler & Markic, 2019a). Since self-concept and related beliefs and emotions are part of a students' chemistry capital, the assumption was that the analytical perspective of chemistry capital could inspire interventions supporting students in developing positive chemistry self-concepts. For instance, the data suggested that some students experience serious conflicts when talking about chemistry at home. These can be due to the perceived incompatibility between the world view of chemistry and more spiritual world views. Moreover, these conflicts could reflect shifts in domestic power relations if students introduce chemical concepts at home that are unknown to the elder generation. Based on this knowledge, interventions could be planned that aim, for example, at supporting the students and their families in conflict resolution and in finding a way of speaking about chemistry at home that does not harm their personal relationships.

The qualitative data in this study suggest that the chemistry capital at home plays an important role in the development of students' emotional attachment to the subject. Therefore, the assumption was that chemistry capital at home would be positively related to chemistry self-concepts. Evidence supporting this hypothesis was given in the interview data, for example in the case of the girl who hates chemistry but who remains open to rethinking her attitude towards chemistry. Her kind of emotional persistence and the openness to rethinking one's concepts could play a role in the formation of chemistry self-concepts. Also, the fact that students who have access to chemistry capital at home receive support in their chemistry learning could have a positive effect on chemistry self-concept because it is to be expected that these students achieve better in chemistry than their classmates. According to the I/E model of self-concept, this would give these students an advantage regarding their external comparison processes. The hypothesis was, therefore, that chemistry capital at home would be positively correlated with chemistry self-concept (h3).

5.3 EQ2. The relation of chemistry capital with students' chemistry self-concepts

5.3.1 The relation of chemistry self-concept with chemistry capital at home

The third hypothesis (h3) was that if students possess chemistry capital at home, they would develop more positive chemistry self-concepts. A linear relationship indicating a positive correlation was expected to show between the two variables. However, hypothesis 3 (h3) could not be confirmed. This became clear in the mixed methods analysis of the main study (article 5, see appendix; Rüschenpöhler & Markic, 2020c) when inspecting the distribution of the chemistry self-concept data in the four groups of students with different chemistry capital at home (fig. 7). No trend seems to exist between the two variables that could be described in clear mathematical terms (linear or curvilinear relationship). Rather, it seems like the chemistry self-concepts are distributed randomly across the four groups. To further understand what is happening, differences and similarities between cases of students with very positive (fig. 7; a, c, d, f) and very negative self-concepts (fig. 7; b, e, g) were investigated across all groups.

Three out of the students with very positive chemistry self-concepts (a, c, f; see fig. 7) share a positive attitude towards chemistry, have career aspirations in a field that requires chemistry, and they engage in chemistry-related activities. This suggests that chemistry self-concept is independent of chemistry capital or that the relation between the two variables is more complex than it was assumed in the design of the present study. However, these three students differ in the type of chemistry-related activities they engage in: student (a), who possesses chemistry capital, likes doing experiments with his grandfather, an activity in which the grandfather transmits chemistry capital to his grandson. There is thus an unequal relationship in which the grandson learns from his grandfather. Student (c) watches documentaries with a parent. This activity is not chemistry specific but concerns also different topics and subjects. Chemistry capital is, therefore, not transmitted from one person to another but the two are in an equal relationship in which both learn from the documentaries. Student (f) does not have a partner in real life with whom he could exchange or acquire chemistry capital. His source of chemistry capital is a YouTuber and his chemistry-related activity consists in watching this YouTuber's videos. At home, these three students experience very different contexts. In terms of the internal and external frame of reference model (Marsh, 1986), academic self-concepts are formed through internal and external comparison processes. The fact that the three students (a, c, f; fig. 7) engage in chemistry-related activities in very different social constellations could change their frames of reference because they could compare their abilities in chemistry with the people with which they engage in the activities. However, the impact of these social contexts on chemistry self-concept cannot be defined based on the data in this study. For student (d) (fig. 7), for instance, the home environment seems not to be a relevant frame of reference for comparison processes in this development of a chemistry self-concept. He compares his abilities only to his classmates. In his home environment, he does not have a person with whom he could share chemistry-related activities and to whom he could compare his abilities. Therefore, it appears natural to him to only consider comparisons with his classmates. His chemistry self-concept is very positive but shows an entirely different pattern: he neither has related career aspirations nor very positive attitudes towards chemistry.

Regarding the students with rather negative chemistry self-concepts (b, e, g; fig. 7) across the groups, a clear relation between chemistry self-concept and chemistry capital did not become apparent either. One of the students (e) is very interested in chemistry while another (g) thinks the subject is boring and the third student (b) is not sure if she hates chemistry or if she thinks it is interesting. The hypothesis that chemistry capital at home has a positive impact on the development of the students' chemistry self-concepts was, therefore, not supported by the data.

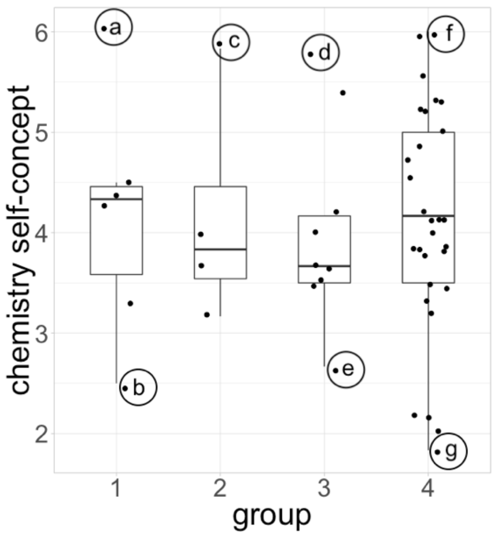

Figure 7. Boxplot diagram of the distribution of chemistry self-concept in the four groups with different chemistry capital in the home environment. High values for self-concept represent positive self-concepts (article 5, see appendix; Rüschenpöhler & Markic, 2020c).

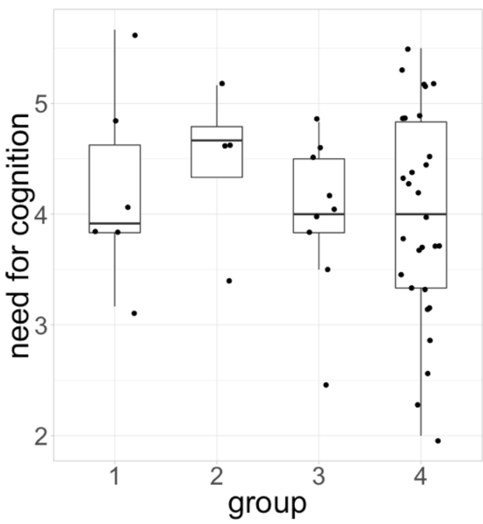

Figure 8. The distribution of need for cognition in chemistry in the four groups with different chemistry capital in the home environment. High values represent a strong need for cognition in chemistry (article 5, see appendix; Rüschenpöhler & Markic, 2020c).

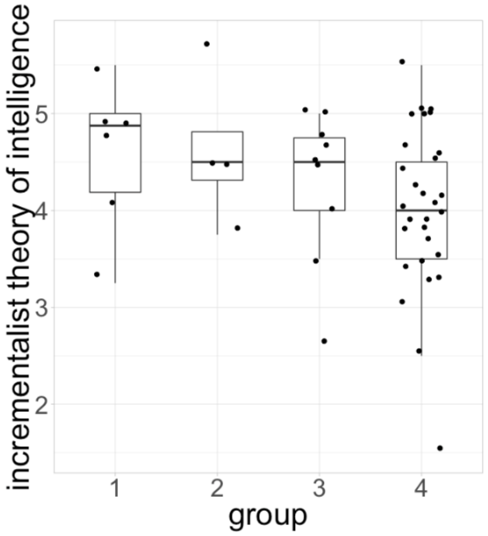

Figure 9. The distribution of the incremental theory of intelligence in chemistry in the four groups with different chemistry capital in the home environment. High values represent a strong incremental theory of intelligence (article 5, see appendix; Rüschenpöhler & Markic, 2020c).

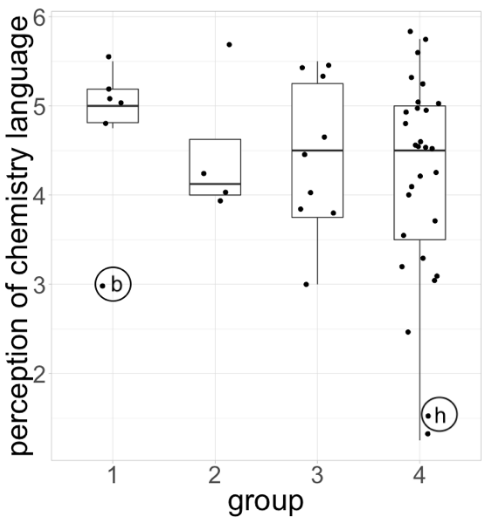

Figure 10. The students' perception of their linguistic abilities in chemistry in the four groups with different chemistry capital in the home environment. High values represent confidence in linguistic abilities (article 5, see appendix; Rüschenpöhler & Markic, 2020c).

5.3.2 The relation of learning goal orientations and the perception of chemistry language with chemistry capital

The relations of chemistry capital with learning goal orientations and the students' perceptions of their abilities regarding chemistry language were investigated as well. This was done since the quantitative analyses in the main study (article 3, see appendix; Rüschenpöhler & Markic, 2020a) had shown correlations of these variables with chemistry self-concept. Regarding the students' learning goal orientations, two indicators appeared to be interesting. For the need for cognition, in the chemistry capital groups, the mean values were almost equal (fig. 8) except for group 2 where the students scored higher on the need for cognition scale. The students in group 2 thus tend to have a stronger desire to engage in deep thinking in chemistry which indicates a strong learning goal orientation. This difference is interesting because the acquisition of knowledge is highly valued in these students' homes. Sharing learning experiences reinforces social relationships and enriches conversations in this group. One student explained that she puts a lot of energy into learning chemistry content in school because this newly acquired knowledge is welcomed at home and her relatives are very curious about it. This suggests the existence of an interplay between the home environment and the students' learning goal orientations.

The students' theory of intelligence beliefs (fig. 9) seemed to differ between the four groups of students with different chemistry capital indicating that a linear trend might exist. The students who possess chemistry capital at home tend to believe quite strongly that they can improve their abilities in chemistry. In contrast, in the group of students who do not possess any chemistry capital with exchange value at home, the mean value for incremental theory of intelligence is much lower which indicated that the students believe less strongly that they can improve their abilities in chemistry. In group four, the dispersion at the lower end of the spectrum is much more pronounced. The relationship between the two variables might be described accurately in a linear model. Learning goal orientations could thus be related to the chemistry capital the students possess at home.

Regarding the relation between chemistry capital in the home environment and the students' perceptions of their linguistic abilities in chemistry, a clear linear trend could not be identified even though the highest mean value occurs in group 1 in which the students possess chemistry capital in the home environment (fig. 10). A look at the dispersion of the data in the four groups, however, appears interesting. The dispersion seems to be the largest in group 4 and the smallest in group 1 if student (b) is treated as an outlier. This trend could, of course, be due to the differences in sample size in these four groups and, therefore, due to measurement bias. This would require further investigation.

The qualitative data provide valuable insights into the relation between chemistry capital in the home environment and the students' perception of their linguistic abilities. It seems as if having difficulties with the language in chemistry means different things in the four groups. Student (b) has a very negative chemistry self-concept (fig. 7) and also thinks badly of her linguistic abilities in chemistry (fig. 10). However, her problems with the language in chemistry are at a quite sophisticated level. She sometimes does not understand certain texts in her chemistry book. But she has a parent whom she always consults in such situations and who can support her reading comprehension in chemistry. In contrast, student (h), who also doubts her linguistic abilities in chemistry, does not have such a person at home. Her parents learned German as a second language and do not work in a chemistry-related field. Her difficulties with the language of chemistry are at a far more basic level. She sometimes has the impression that in chemistry class, "they speak a different language than me" which reflects a general impression of being foreign in chemistry class. She perceives the linguistic difficulties not in specific situations, e.g. regarding a particular text she did not understand, but her impression not to understand the language of chemistry is like being confronted with a foreign language. Having chemistry capital at home, again, seems to play a role in the frame of reference according to which difficulties are defined and also abilities are evaluated.

5.4 MQ. Development and evaluation of the approach to culture-sensitive academic self-concept research

The last core piece of this work which concerned the whole research project consisted in the development and evaluation of a culture-sensitive chemistry self-concept research approach. This was based on the finding in the literature review which showed that a culture-sensitive approach to science and chemistry self-concept research is lacking (article 1, see appendix; Rüschenpöhler & Markic, 2019a). This means that if the established methods are used in self-concept research in culturally diverse societies, bias cannot be controlled for. Since in German schools, students with various migration backgrounds work together, a way was needed to control for bias when investigating chemistry self-concept. To achieve this, a mixed methods approach to culture-sensitive academic self-concept research was developed and tested in a preliminary study (article 2, see appendix; Rüschenpöhler & Markic, 2019b). It is designed for academic self-concept research and can, therefore, be employed in various disciplines. In the main study, a mixed methods approach was employed as well.

5.4.1 Integrating qualitative data into academic self-concept research

Byrne (2002) had argued that in self-concept research, mixed methods approaches would allow controlling for bias in contexts where cultural diversity is present.

However, in science and technology self-concept research, the use of qualitative methods is rare (article 1, see appendix; Rüschenpöhler & Markic, 2019a) and in the sample of articles drawn for the literature review, there was no study about science self-concept that responded to Byrne's concern. It was, therefore, not possible to draw on an existing approach to culture-sensitive self-concept research in the design of the present study.

In the pilot study, a concurrent triangulation mixed methods approach (Creswell et al., 2003) was chosen. With this design, qualitative data were (re-)integrated into academic self-concept research (for more details see article 2 in the appendix; Rüschenpöhler & Markic, 2019b). The mixed methods design operates with questionnaire data from items of the Likert type and additional qualitative interviews. The Likert scale data provide insights into the quantitative dimension of self-concept, i.e. its strength. The qualitative data serve two purposes: first, if students start to talk about their abilities in chemistry during the interviews, this allows comparing their oral statements with the quantitative data. This triangulation helps to reflect if the chosen Likert items are appropriate or if there is a dimension of self-concept or another aspect that was not considered in the questionnaire. Besides this control function, the interview data further allow deepening the understanding of the self-concept data. The students' narratives can potentially provide insights into the role of chemistry self-concept in the students' experiences with chemistry in their home environments, regarding their science identities and many more aspects. This is particularly interesting because self-concept research has its origins in the Anglo-American regions where the narratives linked to academic self-concepts might be not the same as in other regions. When conducting studies with students from other regions of the world, investigating the students' narratives linked to their academic self-concepts can help to better understand the role self-concept plays in these students' lives.

For the main study, a mixed methods design was chosen as well but not with the purpose to triangulate the data (control function) but with the aim to examine chemistry self-concept from the sociological perspective of chemistry capital (deepening of the understanding) (article 5, see appendix; Rüschenpöhler & Markic, 2020c). The particular type of mixed methods design could not be adequately described with the taxonomy by Creswell and colleagues (2003) because it did not fall into the predefined categories. Guest (2013) proposed to describe mixed methods research with a focus on the points of interface where the data types are mixed instead of employing taxonomies classifying entire research projects. He proposed to analyze the time and the purpose of mixing. For the main study, data collection was concurrent, and the point of interface was at data analysis (time) and served to deepen the understanding of chemistry self-concept from a sociological point of view.

5.4.2 Evaluation of the approach

The concurrent mixed methods approach to culture-sensitive academic self-concept research employed in the pilot study proved to be suitable to uncover both measurement and conceptual non-equivalence (Byrne et al., 2009). This conclusion was drawn based on the empirical data used in the pilot study (article 2, see appendix; Rüschenpöhler & Markic, 2019b).

The triangulation suggested that no substantial measurement bias occurred. For assessing the presence of measurement bias, two aspects were considered: first, the content of the students' oral descriptions of their abilities was compared to their self-concept scores. In the present study, this was done by comparing the oral statements with the deviations from the average chemistry self-concept score. For instance, if students who have above average self-concept scores describe their abilities in a positive way in the interviews, this was judged to be a situation in which the data correspond to each other. This was the case in the pilot study where no mismatches were detected. Second, the salience of self-concept was assessed. If one group of students (e.g. boys without a migration background) talked a lot about self-concept in the interviews while the inverse was true for another group (e.g. girls with a Turkish migration background), this could indicate that the construct is not equally salient in both groups. However, this was not the case in the pilot study. Measurement bias seemed not to play an important role.

Conceptual non-equivalence seemed to be present in the pilot study and this in two respects. First, the relation between chemistry self-concept and gender seemed to differ when comparing boys and girls without a migration background and with a Turkish migration background. Second, the salience of the social goal orientations differed between the four groups. In particular, the interview data suggested that for the girls with a Turkish migration background, who on average showed strong chemistry self-concepts, the social embeddedness of chemistry learning is an important issue. These girls seemed to think about chemistry learning as embedded in their social context – their relation to the chemistry teacher and to their peers appeared to be an important issue for these girls. In addition, the phenomenon of sharing chemistry learning experiences by showing photos from class to family and friends was reported on in this group only. This is remarkable when looking at the boys without a migration background who on average had comparably strong chemistry self-concepts. These boys did not talk about the social context in class or their relationships with family and friends when asked about their chemistry experiences in the interviews. The social context appeared to be related very differently to chemistry self-concept in these two groups. This suggests that conceptual non-equivalence seems to be present when examining the relations of chemistry self-concept with variables such as gender and the perception of the social structure in which chemistry is embedded.

Apart from the assessment of these two types of non-equivalence, the mixed methods approach to academic self-concept research inspired the quest for explanations of the discovered phenomenon. The qualitative data provide a basis for trying to gain a deeper understanding of the reasons for the conceptual non-equivalences discovered in the pilot study: the quantitative data inspired the hypothesis that chemistry might be associated differently with masculinity while the qualitative data suggested that it is easier for girls with a Turkish migration background to integrate chemistry learning in their social selves, while this seems to be very difficult for girls without a migration background and a lot of other students.

In the main study, this deepening of the understanding of chemistry self-concept was aimed for, using the sociological perspective of chemistry capital. A relationship between chemistry self-concept and chemistry capital that could be described quantitatively using linear or curvilinear models was not found. However, the mixed methods approach in the main study allowed exploring similarities and differences between cases and developing possible explanations for the discovered phenomena.

6 | DISCUSSION

The starting point for this research project was the observation that important social inequalities exist in the field of science in Germany: in secondary education, there are substantial achievement gaps in science to the detriment of students with a migration background (OECD, 2016d). This kind of gap is present in many countries but to varying degrees. Students from the same country of origin achieve substantially better in some other countries than Germany (Zoido, 2013). Besides, females are underrepresented in science-related fields on the job market in Germany (OECD, 2009a) which reflects gender-related inequalities in the field of science.

These differences were examined through the lens of self-concept research because self-concept is widely acknowledged as a central variable for understanding career choices and achievement. The focus was then narrowed down to the chemistry self-concepts of secondary school students because chemistry has been identified as an important gate-keeper for the pursuit of careers in science in this area (Cohen & Kelly, 2019). In the following, central findings from the present research project are critically scrutinized (6.1). This is followed by a discussion of the theoretical and methodological advances made in this research project towards more culture-sensitive chemistry self-concept research (6.2). Then, the potential practical impact will be discussed (6.3) and finally, the limitations of this work will be considered (6.4).

6.1 Empirical findings about chemistry self-concepts of secondary school students in Germany

The first core part of the present research project was empirical and aimed at gaining knowledge about the chemistry self-concepts of secondary school students in Germany. Subject-specific knowledge in the evaluated literature was limited to chemistry self-concepts of young adults in higher education. Therefore, mainly general science education literature had to be referred to when deriving hypotheses about the role that culture might play in the chemistry self-concepts of secondary school students in Germany.

Three hypotheses were proposed, based on the reviewed literature.

(h1) It was assumed that students with a migration background would have lower chemistry self-concepts than students without a migration background. Similar findings had been made in several studies regarding the science self-concepts of students from ethnic minorities (e.g. Simpkins et al., 2015).

(h2) The second hypothesis concerned gender relations. Gender is an interesting construct because gender conceptions are cultural in nature (Rubin, 1975) and, therefore, reflect cultural patterns. Regarding science and physics self-concept in Western countries, a gender gap in favor of boys had been reported on numerous times (e.g. in Germany: Jansen et al., 2014; in the United States of America: Riegle-Crumb et al., 2011). It thus seemed reasonable to assume to find similar gender relations in chemistry self-concept as well.

(h3) A further assumption was that students who possess chemistry capital in their home environments show more positive chemistry self-concepts. This assumption was based on literature showing the importance of parents in the development of science self-concepts (e.g. Makwinya & Hofman, 2015).

Surprisingly, the empirical data collected in the course of the project revealed a different pattern. A gender gap in chemistry self-concepts of secondary school students in Germany appeared only in the pilot study. The main study, which was larger dimensioned and thus has greater statistical power, did not confirm this. Here, gender did not show a significant effect on chemistry self-concept. The hypothesis that students with a migration background have more negative chemistry self-concepts could not be confirmed: in both the pilot and the main study, no significant effect of migration background on chemistry self-concept could be detected. The first two hypotheses (h1 and h2) were thus not confirmed.

Instead, an unexpected effect became apparent: an interaction effect of culture and gender appeared when looking at students with a Turkish migration background and students without a migration background. This was true for both the pilot and the main study and can, therefore, be considered sufficiently supported by empirical data.

Since this finding of an interaction effect of gender and cultural background was unexpected based on the body of literature, the resulting follow-up question was how to explain it. The qualitative data from the interviews in the pilot study suggested that the girls with a Turkish migration background might tend to integrate chemistry into their social lives more easily than the girls without a migration background. What possible causes could lead to and explain this effect?

Literature on gender differences in science in Turkish society provides one possible explanation. Turkey is one amongst the few countries in which slightly more women than men are working in science-related fields (OECD, 2009a). Although this gender gap in favor of women is very small, it indicates that science might not be associated as strongly with masculinity than in many other contexts, especially in the Western countries and also in Germany, where much more men than women tend to work in science-related fields (OECD, 2009a). In Turkey, this absence of the gender gap in favor of males in science shows in student performance as well: in Turkey, school girls outperform boys in science which showed in the PISA (Batyra, 2017a) and TIMSS studies (Batyra, 2017b). This provides further evidence supporting the hypothesis that science might be associated differently with gender in Turkey and Germany.

If this is true, the question arises of how these gender conceptions could have possibly been transported to second-generation immigrants, i.e. young people who have spent all their lives in Germany. Only slightly more than 30 % of people from Turkey living in Germany are first-generation immigrants (calculation based on table 5 from Statistisches Bundesamt, 2013). The remaining 70 % are people who are born in Germany. Among children and adolescents, the proportion of first-generation immigrants is probably far smaller. How could these students possibly be influenced by gender relations in science that exist in Turkey?

It can be assumed that this takes place in the students' private lives where many of them are in close contact with people who have lived in Turkey themselves. For many students, their parents play an important role at home. To analyze the transmission processes of knowledge, beliefs, values, emotions, etc. with possible influence on chemistry self-concept between parents (or other significant people in the home environment) and the students, the concept of chemistry capital was developed and is now available. Although this first investigation suggested that no linear relationship exists between chemistry self-concept and chemistry capital in the home environment, it provides valuable insights into the influence of the students' home environments on their personal connections with chemistry. Different explanations of this finding are discussed in more detail in article 5 (see appendix; Rüschenpöhler & Markic, 2020c). To date, however, the relation between chemistry self-concept and chemistry capital in the students' home environments is not sufficiently clear. The question of how students with a Turkish migration background who have lived all their lives in Germany could possibly be influenced by the gender relations in Turkey remains open.

One interesting path could be the analysis of chemistry-related *symbolic* capital (Bourdieu, 1994) that exists in the students' home environments. Symbolic capital has not yet been conceptualized for the field of science or chemistry capital research. According to Bourdieu (1994), symbolic capital is the prestige of certain entities in a specific field. For instance, it could be hypothesized that in the home environments of students with a Turkish migration background it is prestigious to be a young woman interested in and good at science and chemistry. Young women who are engaged in science would then possess more symbolic capital if they live in this type of home environment than in a home environment in which people rather disapprove of females who are engaged in science. The present research project does not provide evidence for or against this hypothesis because symbolic capital was not considered. However, chemistry capital provides a framework for further conceptual advances in this regard.

Further, the findings from the qualitative interviews also raise the question if there might be structural inequalities in the German school system (article 4, see appendix; Rüschenpöhler & Markic, 2020b). *Hauptschule* is a traditional school type that still exists in some regions in Germany. It has comparatively low entry requirements and students with a migration background tend to be overrepresented in this type of school (Göttsche, 2018). Middle-class students without a migration background are overrepresented at *Gymnasium* while at *Hauptschule*, far more students with a working-class and a migration background are present (Carey, 2008). In the main study of this research project, the students attending Hauptschule were all taught chemistry by teachers who do not hold a respective university degree. This is especially problematic because most students attending *Hauptschule* in the sample lived in a home environment in which chemistry capital was present only to a very limited extent. The fact that their teachers were not certified for teaching chemistry seemed to aggravate these students' situations. For two students, this led to doubts whether they could apply for their preferred apprenticeships because these require chemistry knowledge. There is evidence that at *Hauptschule*, the ratio of lessons provided by teachers who do not hold a university degree in the respective subject they teach is far higher than at *Realschule* or *Gymnasium* (Richter, Kuhl, Haag, & Pant, 2013). This points to one mechanism through which the strong social stratification present in the German school system (Carey, 2008) might be perpetuated. If access to lessons held by certified chemistry teachers is much more restricted at *Hauptschule* than it is at *Gymnasium*, it deprives many working-class students and many students with a migration background of a potential source of chemistry capital because these groups are overrepresented at *Hauptschule*. These groups probably already possess less chemistry capital in their home environments than the average middle-class student at *Gymnasium* where most chemistry lessons are taught by certified chemistry teachers. This could be a mechanism that aggravates the existing social disparities in the German school system (e.g. a dispersion of science achievement which is significantly larger than the OECD average or the fact that 27.5 % of students from schools other than *Gymnasium* – the school types in which students with a migration background are overrepresented –

lack basic scientific literacy, a phenomenon which is almost absent at *Gymnasium* (PISA 2018, Schiepe-Tiska et al., 2019)).

It is important to note that the present research project cannot provide an answer to the question if the German school system systematically disadvantages students with little chemistry capital in chemistry education. For this, data of a different type would be needed, for instance, an overview of chemistry and science lessons provided by teachers who hold a university degree in chemistry using a representative sample of schools. This type of data would allow finding an answer to the question of structural inequalities. In terms of chemistry capital, it could be insightful to examine and compare differences in the chemistry capital of the teachers with and without a university degree in chemistry and the transmission of chemistry capital to their students. The situation of teachers without a chemistry degree seems not to have inspired much research in Germany, implying that the transmission processes of chemistry capital from these teachers to their students remain insufficiently understood. Analyses of this type will, however, probably only have effects on the situation in schools if they inform the communication with policymakers.

6.2 Conceptual and methodological issues

The second core part of this research project was conceptual and methodological. The review of the science self-concept literature revealed that research in this field faces methodological difficulties. One problem is that a multitude of different instruments of varying quality is available. Choosing an appropriate instrument wisely is now facilitated by the overview provided in article 1 (see appendix; Rüschenpöhler & Markic, 2019a). Another problem is that science self-concept research does not follow the recommendations for culture-sensitive self-concept research expressed by several scholars (e.g. Byrne, 2002; Byrne et al., 2009; van de Vijver & Poortinga, 2005). This is especially problematic because, in this field, comparisons between the data of different nations and cultural groups are very common. A practical approach to culture-sensitive academic self-concept research was needed because, in Germany, students with many different cultural backgrounds learn chemistry in school together. The impact of this cultural diversity on academic self-concept research was unknown.

This challenge to develop an approach to culture-sensitive academic self-concept research was addressed in the present research project. A concurrent triangulation mixed methods approach (Creswell et al., 2003) to culture-sensitive chemistry self-concept research is suggested and now available (article 2, see appendix; Rüschenpöhler & Markic, 2019b). It constitutes a methodological advance for academic self-concept research by proposing a way to deal with methodological challenges that cultural diversity poses to the existing academic self-concept research. Using interviews in addition to a Likert questionnaire with good measurement properties (for advice see article 1, see Rüschenpöhler & Markic, 2019a), allows triangulating self-concept data. This triangulation provides the opportunity for investigating measurement and structural equivalence which cannot be controlled for using the established methods only. In this regard, the mixed methods approach to culture-sensitive self-concept research advances the field by proposing a control mechanism for two types of bias identified by Byrne and colleagues (2009).

The strength of the approach lies in the revision of the theoretical foundation of academic self-concept research. The fact that in science self-concept research, the Shavelson and Marsh models (Marsh, 1990c; Shavelson et al., 1976) dominate the field (article 1, see appendix; Rüschenpöhler & Markic, 2019a), poses challenges to culture-sensitive academic self-concept research because on the one hand, this provides a solid basis for conducting self-concept research but on the other hand, this can narrow the focus of investigations. It can, therefore, be beneficial to reconsider the theoretical basis this research field is built upon, discussing foundational theories like James' (1890) as well as more recent developments in related fields that are distinct from but still connected with self-concept research, such as Hattie's theory of the self (2008). This consideration of the theoretical foundations and new theoretical perspectives can help to assess the research field's power and its deficits.

The pilot study used Hattie's theory of the self (2008). This theory shifts the attention towards the 'I', the active part of the self, according to James' (1890) distinction between the 'I' and the 'Me'. For culture-sensitive investigations of academic self-concept, this perspective can provide valuable insights because it allows focusing on the interplay between the 'I' constructing the 'Me'. The patterns in these construction processes follow rationales that could be embedded in cultural contexts. With Hattie's theory, a process-oriented psychological perspective is introduced to academic self-concept research. By considering alternative perspectives on academic self-concept, it opens academic self-concept research data to critical scrutiny and inspires reflections on the cultural embeddedness of the findings.

One downside of using Hattie's theory of the self is the fact that it is very complex. It shifts the focus towards a wide range of psychological processes that constitute the self. The spectrum of these processes is not limited and, therefore, of a complexity that impedes the construction of scientific investigations. Therefore, the pilot study focused on selected psychological processes. A priori, learning and performance goal orientations were chosen because these are important in educational settings (Hattie, 2008). A posteriori, social goal orientations were added because these appeared to be relevant to the students who participated in the interviews. This goal-oriented approach could be useful also in other fields of academic self-concept research because learning, performance, and social goal orientations are not only important in chemistry education but in other academic fields as well.

The second step consisted in the development of a sociocultural perspective on chemistry learning with the aim to further investigate the role of culture in the formation of chemistry self-concept. The intention was to conceptualize the school contexts and the home environments in which the students' chemistry self-concepts are embedded. This was based on the assumption that in Germany, where many students are second-generation immigrants, processes in the students' home environments could play a role in the formation of the individual chemistry self-concepts, i.e. that home environments contribute to the development students' beliefs about their abilities in chemistry. The concept of chemistry capital is now available as a conceptual tool to investigate this type of influence (article 4, see appendix; Rüschenpöhler & Markic, 2020b). This conceptual framework aims to enrich chemistry self-concept research with a sociocultural perspective. With its roots in sociological theory (Bourdieu, 1979, 1986), it could provide a framework for investigating the sociocultural structures in which the mental phenomenon of chemistry self-concept could be embedded. The underlying assumption is that chemistry self-concept, although being psychological in nature, depends on the sociocultural context. This assumption is based on the findings about gender and culture differences in self-concept. Chemistry capital constitutes an analytical lens for investigating the transmission processes of all types of capital in the Bourdieusian sense between home, school and the individual student, including the transmission of emotional and cognitive capital. This analytical perspective could open the analysis of the distribution of self-concepts to a more context-oriented perspective, shifting the focus from the individual student to the sociocultural structures in which certain patterns of self-concepts appear, e.g. the gender gap in science self-concept that has been reported on numerous times. This can produce slight shifts in the perceived responsibility for certain self-concepts: instead of only identifying groups of students whose chemistry self-concepts need to be improved, the lens of chemistry capital can potentially help to identify mechanisms that are beneficial for positive chemistry self-concepts. The goal of chemistry capital research would be to find ways of supporting such productive mechanisms for students who possess only little chemistry capital with exchange value, and to change teaching practice in a way that takes the students' different home environments into account (see chapter 6.3).

Several theoretical and methodological aspects remain to be answered: the mixed methods approach to culture-sensitive academic self-concept research allows reflecting on two types of bias defined by Byrne and colleagues (2009). The third type of bias, i.e. bias occurring in the interpretation process (Byrne et al., 2009) could not be controlled for. This type of bias refers to the interpretation of differences found in the data of empirical studies. What guides researchers in the definition of the reasons that create these differences? It has been argued that these interpretations are often based on intuition. For instance, it is common to explain differences in the social domain with culture but this is uncommon in the cognitive domain (Byrne et al., 2009). For dealing adequately with bias in the interpretation process, researchers in self-concept research but also in other fields would need a deepened knowledge about human interpretation processes.

Further, a clear link between chemistry self-concept and chemistry capital could not be shown in the present research project. The reasons for this are not yet known. It could be due to methodological limitations in the research process of the present project, i.e. the small sample in the final mixed methods analysis and the lack of an adequate instrument that would allow for quantitative data analyses. Alternatively, it is equally possible that chemistry capital does not provide an adequate framework for analyzing the sociocultural embeddedness of chemistry self-concept. This question remains open. Article 5 provides an extensive discussion of the various alternative explanations for the results (see appendix; Rüschenpöhler & Markic, 2020c).

6.3 Potential practical applications

Culture-sensitive research is important to understand central phenomena in chemistry education while taking into account the existent cultural diversity. However, the ultimate goal is to make chemistry education more equitable. This means that either chemistry teaching practice or the structures in which chemistry education takes place should benefit from this kind of research. Although the present research project is not application-focused in itself, it has the potential to advance culture-sensitive chemistry education.

In Germany, culture-sensitive chemistry teaching is a topic that seems to have been covered only marginally. Tajmel presented "Grundzüge" (Tajmel, 2017) of an approach to physics education which takes the history of migration in Germany into account. The term 'Grundzüge' can be translated into English as 'basics' or 'fundamentals'. It is astonishing that just two years ago, the basics of this field of research needed a specification. The authors she referred to in the design of the basics are mostly either from other countries than Germany or other disciplines than science education. This suggests that the field remains explored to a little extent although, in the field of language-sensitive teaching, important advances have certainly been made (e.g. Leisen, Kruczinna, & Bennung, 1999; Tolsdorf & Markic, n.d.). Markic (2018) argued that culture-sensitive chemistry teaching in Germany can be based on the concept of intercultural communication. The approach focuses on the learning of scientific language and intercultural communication in chemistry class and was tested in an empirical study with concrete teaching material developed in Participatory Action Research (Eilks & Ralle, 2002). The teaching module about healthy eating from this study engaged students in dialogues about food in different cultures and seemed to increase their openness towards eating styles in different cultures. However, the conceptions of culture-sensitive chemistry teaching and the definition of the concrete problems that need to be solved in the German context require attention. The culture-sensitive teaching approaches from other countries can constitute valuable resources but it is essential to question in how far the approaches apply to Germany or if they solve problems that are not embedded in the German context.

One attempt to conceptualize culture-sensitive chemistry teaching has been developed in a project for first-generation immigrant students in secondary school who newly arrived to Germany (Rüschenpöhler & Baginski, accepted). This concept is based on concrete teaching material (Rüschenpöhler, 2017, 2018) and concrete teaching experiences that have been made over several years. The goal is to support newly arrived students in chemistry classes using the concept of 'teaching culture sensitivity' (Rüschenpöhler & Baginski, accepted). It argues that the local 'teaching cultures' in German chemistry classes need to be made explicit for the students. Some newly arrived students have experienced very different ways of teaching and learning chemistry in other countries or they have had no chemistry education at all in the schools they attended before. 'Teaching culture sensitive' chemistry education is, therefore, based on techniques for explicating ways of thinking and acting, linguistic structures that are being used in this specific local context, and behaviors that are expected from the student in this local context of chemistry class. In this approach, the goal is to combine learning chemistry content with language-sensitive chemistry teaching, supporting the use of other languages than German in chemistry class and the explication of the 'hidden rules' in chemistry class – i.e. the norms and values that usually remain unsaid.

This latter concept could be used as a step towards a teaching concept for culture-sensitive chemistry education in Germany. However, it is limited in three regards: (i) it is designed for working with newly arrived immigrants in the regular school system which is only a small part of students. Further, it is relatively new and, therefore, lacks (ii) theoretical precision and a positioning in relation to concepts of culture-sensitive teaching in Germany and other regions of the world and it lacks (iii) a clear conceptualization of the tools for teachers and the ways of thinking and acting that can lead to more culture-sensitive chemistry teaching.

Chemistry capital research could be useful to advance this approach – the practical approach of 'teaching culture sensitive' chemistry education and the theoretical lens of chemistry capital could complement each other. Both are resource-oriented (based on Baginski's (2016) ideas; more explicit in Rüschenpöhler & Baginski, accepted) which could facilitate the mutual exchange. Chemistry capital research could benefit from a foundation in practical applications. Although there is a science capital teaching approach (Godec et al., 2017), this remains quite subject-unspecific and would profit from concrete applications. 'Teaching culture sensitive' chemistry education, in turn, is deeply rooted in practice which means that its theoretical foundation could benefit from further clarifications. From the perspective of chemistry capital, making the 'hidden rules' of chemistry class explicit – as it is done in the 'teaching culture sensitive' approach (Rüschenpöhler & Baginski, accepted) – can be interpreted as explaining the specific forms of capital that are recognized as valid in a local context of chemistry education in a particular class or school. 'Teaching culture sensitive' chemistry education could further benefit from the perspective of chemistry capital if it is used as a source of inspiration for developing new ways that allow students to fully participate in and benefit from chemistry teaching, irrespective of their cultural background. Also, chemistry capital could help to systematize the developed teaching methods and tools. This approach could also benefit from the insights gained on gender relations in chemistry-self-concept if gender is acknowledged as the cultural category it is.

When developing culture-sensitive chemistry teaching approaches, the education of chemistry teachers needs to be considered as well. A preliminary study (Rüschenpöhler, Markic, & Schneider, submitted) explored German chemistry teachers' views on the role of culture in their chemistry teaching. The sample size was small (N=7) in this study because deep, explorative interviews were conducted and analyzed qualitatively. The findings are, therefore, not representative of chemistry teachers in general. However, the study shows three aspects that could be trends in the chemistry teacher community in Germany: (i) at the level of subject-unspecific pedagogy, the teachers tended to express a culture-sensitivity and an interest in working with students with diverse cultural backgrounds. (ii) In contrast to this, they perceived chemistry teaching and learning as independent of culture (a "culture-free zone", Rüschenpöhler et al., submitted). Culture appeared as a variable that is irrelevant in chemistry teaching. (iii) They did not know any material or teaching approaches that would allow for culture-sensitive chemistry teaching. Regarding these three findings, it is important not to interpret this as a deficit on the side of the teachers. Rather, the findings reflect the current state of research in chemistry education. For the German context, little knowledge is available about culture-sensitivity in chemistry education and this shows also in the teachers' views on the role of culture in chemistry education. Any approach to culture-sensitive chemistry teaching for the German context, therefore, needs to consider the education of teachers.

6.4 Limitations

This work is limited in several regards. The first aspect concerns the sampling in the pilot and main studies. For certain analyses, the samples in the pilot and main studies were relatively small, in particular regarding the qualitative studies. In the pilot study (article 2, see appendix; Rüschenpöhler & Markic, 2019b), the overall sample size for the qualitative interviews was good (N=43) but focusing on and differentiating between students with a Turkish migration background and students without a migration background and further differentiating between boys and girls limited the sample sizes in the subgroups to 4-12 students. The insights gained in the qualitative analyses are, therefore, exploratory in nature and do not claim generalizability. A similar situation occurred in the qualitative interview analyses in the main study (article 4, see appendix; Rüschenpöhler & Markic, 2020b). Here, the overall sample size was good with N=48. However, the necessary differentiation between students with disparate chemistry-specific or general educational capital in their respective home environments caused sample sizes in the subgroups to be unequal and, in some cases, small: the groups of students with chemistry capital (*N*=6) and general educational capital (*N*=4) in the home environment became too small to allow for a generalization of the findings. Moreover, the selection of the students in the pilot and the main studies was neither randomized nor designed to draw representative samples, resulting in samples not suitable to represent the overall population of students in German secondary schools. The intention of the research project was rather to gain insights into the variety of situations the students learn chemistry in, focusing on their resources for the field of chemistry. A special focus was put on the school type with the lowest entry requirements (*Hauptschule*) because educational research in Germany tends to focus rather on education at *Gymnasium*. One reason for this is the fact that at *Hauptschule*, it is more difficult to obtain parental permissions for conducting research – a fact which is caused inter alia by linguistic barriers – leading to a lesser scientific understanding of the situations of students attending *Hauptschule*.

In subsequent research, quantitative analyses based on representative data could serve to validate and to further develop the concept of chemistry capital. A chemistry capital scale with multiple choice items based on the findings from the present research project would allow conducting quantitative analyses of the distribution of chemistry capital among secondary school students. For instance, the presence of the transmission processes from the home environments to the students in the respective groups could be investigated. This would be an important step in chemistry capital research. An appropriate scale would allow assessing the impact of practical interventions on students with different levels of chemistry capital in the home environment. Moreover, it could be used to investigate the existing support structures in the German school system that are open to students with different levels of chemistry capital. Further, the concept of symbolic chemistry capital remains defined only very broadly. This could be interesting in further research for understanding the interaction effect of culture and gender on students' chemistry self-concepts because symbolic capital conceptualizes the role of prestige which could differ in the field of chemistry between boys and girls without a migration background and with a Turkish migration background.

Besides these concerns, the research project presents an approach to deal with only two out of the three types of bias defined by Byrne and colleagues (2009). Structural and measurement non-equivalence can be evaluated using the presented mixed methods approach for culture-sensitive academic self-concept research. However, it is important to note that even technically correct use of the approach does not ensure discovery of all conceivable bias. Although the communication with other researchers in an investigation group – as it was done in the course of the present research project – may help to identify and reflect potential sources of bias, this also depends on the researchers' knowledge and mindsets. This is particularly true for bias occurring in the interpretation of the results. For this type of bias, the mixed methods approach does not present a defined technical procedure and this might be a goal that can be attained only partly. If research is to be more culture-sensitive, the researcher's personal background and his or her foreknowledge and stance on this aspect probably play an important role.

7 | CONCLUSION

The present research project probably differs in many ways from established academic self-concept research. Quantitative methods were used but only in a part of the research. In other parts, qualitative methods and techniques of mixing the data were used which is uncommon in science self-concept research. Also, the theoretical models used for the investigations of chemistry self-concept differ. Hattie's (2008) process-oriented model of the self is more complex and less precise than the established models by Shavelson, Marsh, and colleagues (Marsh, 1986; Shavelson et al., 1976). The newly defined concept of chemistry capital is based on Bourdieu's (1979, 1986) sociological theory and, therefore, rooted in a different discipline than self-concept research which originates from psychology. The advantage of considering these different approaches in chemistry self-concept research lies in the inspiration and the new insights they can provide. However, the downside is that research becomes more explorative because new approaches need to be developed and tested.

The results in this project, therefore, differ in certain parts from those produced in established academic self-concept research. Some results from the present research project are no clear-cut answers. Rather, this project opens a range of questions. Do structural inequalities exist in chemistry education in Germany? What are the problems that culture-sensitive chemistry teaching approaches should solve in Germany? How are cultural narratives and conceptions (e.g. gender) and symbolic capital transmitted from the elder generation to students with a migration background who have grown up in Germany? How could the acquisition of chemistry capital be supported? Further, in culture-sensitive research, the question of the adequacy of interpretations needs to be addressed (Byrne et al., 2009), a field that was not covered in the present project and that would profit from further research. In other parts, in contrast, the results are quite clear. The interaction effect of gender and Turkish migration background on chemistry self-concept has been shown in two independent samples (articles 2 and 3, see appendix; Rüschenpöhler & Markic, 2019a, 2020b), a pattern that could be due to differences in the conceptions of masculinity in Germany and Turkey. For further research, both types of results – the questions and the answers – can enrich the scientific discourse.

For further research, the present work opens several interesting pathways. In the field of application-focused research, a great variety of subsequent studies would be desirable because science self-concept research lacks knowledge about concrete interventions based on the insights from self-concept research (article 1, see appendix; Rüschenpöhler & Markic, 2019a). Science self-concept research needs to develop ways of translating its findings into practice. The findings from the present research project can inform teaching approaches designed to support students in their development of positive chemistry self-concepts: these could benefit from an adoption of strategies for language-sensitive chemistry teaching because the students' perception of their linguistic abilities in chemistry are correlated with their chemistry self-concepts (article 3, see appendix; Rüschenpöhler & Markic, 2020a). Also, a reflection of task-choice behavior guided by the teacher could help the students to develop stronger learning goal orientations and, thereby, a more positive chemistry self-concept since these are correlated as well (article 3, see appendix; Rüschenpöhler & Markic, 2020a). For instance, in an empirical study at Ludwigsburg University of Education, strategies for conversations with girls who have negative science self-concepts are currently being investigated. The goal is to establish strategies for teachers for supporting girls in developing positive science self-concepts in everyday situations in the science classroom and to integrate this in teacher education.

The research about chemistry capital showed that chemistry capital in the home environment plays an important role regarding the students' chemistry learning and their self-perceptions in chemistry (articles 4 and 5, see appendix; Rüschenpöhler & Markic, 2020a, 2020c). This reflects the existing social disparities in the German school system. In this context, concepts for culture-sensitive chemistry teaching require more attention because students with a migration background are overrepresented at *Realschule* and *Hauptschule* (Göttsche, 2018), the school types in which almost 30 % of students do not attain basic scientific literacy (Schiepe-Tiska et al., 2019). Culture-sensitive chemistry teaching could reduce the existing dispersion in science achievement in Germany which is associated with the school type. Resource-oriented approaches for culture-sensitive chemistry teaching should, for instance, consider that girls with a Turkish migration background tend to have rather strong chemistry self-concepts and use this as a way of engaging the students in deep chemistry learning. The findings from the qualitative analysis in the main study (article 4, see appendix; Rüschenpöhler & Markic, 2020b), call for the development of strategies for dealing with differences between world views in the students' home environments and chemistry class, e.g. concerning the perceived opposition between religion and chemistry. Working with parents could be a way of providing opportunities for the acquisition of chemistry capital in the whole family (article 4, see appendix; Rüschenpöhler & Markic, 2020b). The crux in culture-sensitive teaching seems to be the definition of concrete challenges that the approaches intend to address since 'culture' is a highly complex term and approaches to culture-sensitive teaching need a clear problem-centered approach. Only if research provides concrete, practical solutions to well-defined challenges in everyday teaching practice, teachers will be able to see aspects in chemistry teaching that are embedded in local cultural structures and not as a culture-free zone (Rüschenpöhler et al., submitted).

Moreover, diversification of chemistry-related YouTube channels could open the field of chemistry and science to a greater diversity of students. The research on chemistry capital shed light on the potential of YouTubers in the development of chemistry capital for students living in a home environment with very little chemistry capital: following a YouTuber can lead to the acquisition of individual chemistry capital, a mechanism that could, in certain cases, reduce social inequalities (article 4, see appendix; Rüschenpöhler & Markic, 2020b). However, many very popular chemistry-related YouTube channels (e.g. simpleclub, Giesecke & Schork, n.d.; Techtastisch, n.d.) appeal to a nerdy science identity which white middle-class boys can adopt much easier than female, working-class or ethnic minority students (Archer, Dewitt, et al., 2015; Archer et al., 2013; Carlone et al., 2015). There are exceptions such as the female YouTuber maiLab (Nguyen-Kim, n.d.) but the field could benefit from a greater diversification of the young people presenting chemistry content on YouTube. It would be important to also provide role-models for female students without migration background, for male students with a Turkish migration background, and for those who possess little chemistry capital in their home environment.

Besides these practical considerations, further research is needed regarding the relation of chemistry capital with chemistry self-concept – as well as with other important outcome variables than chemistry self-concept, such as chemistry achievement and aspirations. This would help to understand the sociocultural structures in which chemistry self-concept (achievement, aspirations,…) is embedded. The present research showed that chemistry capital might not have a linear relationship with chemistry self-concept. Rather, chemistry capital in the home environment might constitute a different frame of reference in relation to which chemistry self-concept items are interpreted (article 5, see appendix; Rüschenpöhler & Markic, 2020c). This hypothesis requires further investigation. Moreover, the internal structure of chemistry capital and its distribution in the different school types and among students of different sociocultural backgrounds of chemistry need to be investigated. Knowledge about the transmission processes between the social environment and the chemistry student can guide the design of adequate intervention studies. Knowledge about the distribution of chemistry capital can serve to understand mechanisms through which the social inequalities are perpetuated in the German school system, for instance, the impact of teaching chemistry without holding a chemistry degree on students' career choices (article 4, see appendix; Rüschenpöhler & Markic, 2020b). This type of study requires a chemistry capital scale for assessing students' chemistry capital in quantitative terms because this would allow covering larger, representative samples. Further, the aspect of symbolic capital has not been investigated and could provide valuable insights into chemistry self-concept research (article 5, see appendix; Rüschenpöhler & Markic, 2020c).

REFERENCES

Acar, Ö. (2019). Investigation of the science achievement models for low and high achieving schools and gender differences in Turkey. *Journal of Research in Science Teaching*, *56*(5), 649–675. https://doi.org/10.1002/tea.21517

Aikenhead, G. S. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education*, *27*(1), 1–52. https://doi.org/10.1080/03057269608560077

Aikenhead, G. S. (1997). Toward a First Nations cross-cultural science and technology curriculum. *Science Education*, *81*(2), 217–238. https://doi.org/10.1002/(SICI)1098-237X(199704)81:2<217::AID-SCE6>3.0.CO;2-I

Aikenhead, G. S. (2001). Students' ease in crossing cultural borders into school science. *Science Education*, *85*(2), 180–188. https://doi.org/10.1002/1098-237X(200103)85:2<180::AID-SCE50>3.0.CO;2-1

Aikenhead, G. S., & Jegede, O. J. (1999). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching*, *36*(3), 269–287. https://doi.org/10.1002/(SICI)1098-2736(199903)36:3<269::AID-TEA3>3.0.CO;2-T

Archer, L., Dawson, E., DeWitt, J., Seakins, A., & Wong, B. (2015). "Science capital": A conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching*, *52*(7), 922–948. https://doi.org/10.1002/tea.21227

Archer, L., & DeWitt, J. (2017). *Understanding young people's science aspirations. How students form ideas about "becoming a scientist."* Retrieved from http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=1336938

Archer, L., Dewitt, J., & Osborne, J. (2015). Is science for us? Black students' and parents' views of science and science careers. *Science Education*, *99*(2), 199–237. https://doi.org/10.1002/sce.21146

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012a). "Balancing acts"': Elementary school girls' negotiations of femininity, achievement, and science." *Science Education*, *96*(6), 967–989. https://doi.org/10.1002/sce.21031

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012b). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal*, *49*(5), 881–908. https://doi.org/10.3102/0002831211433290

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013). 'Not girly, not sexy, not glamorous': Primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture & Society*, *21*(1), 171–194. https://doi.org/10.1080/14681366.2012.748676

Archer, L., DeWitt, J., & Willis, B. (2014). Adolescent boys' science aspirations: Masculinity, capital, and power. *Journal of Research in Science Teaching*, *51*(1), 1–30. https://doi.org/10.1002/tea.21122

Areepattamannil, S. (2012). First- and second-generation immigrant adolescents' multidimensional mathematics and science self-concepts and their achievement in mathematics and science. *International Journal of Science and Mathematics Education*, *10*(3), 695–716. https://doi.org/10.1007/s10763-011-9319-7

Baginski, K. (2016). "Magnet. Ich verstehe. Ich hatte im Irak.": Erfahrungen und Kompetenzen aus den Herkunftsschulen erkennen und nutzen. *Fremdsprache Deutsch*.

Bandura, A. (1989). Human agency in social cognitive theory. *American Psychologist*, *44*(9), 1175–1184.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W.H. Freeman.

Baron, A. S., Schmader, T., Cvencek, D., & Meltzoff, A. N. (2014). The gendered self-concept: How implicit gender stereotypes and attitudes shape self-definition. In P. J. Leman & H. R. Tenenbaum (Eds.), *Gender and development* (pp. 109–132). East Sussex: Psychology Press.

Batyra, A. (2017a). *Gender gaps in student achievement in Turkey: Evidence from the Programme for International Student Assessment (PISA) 2015*.

Batyra, A. (2017b). *Gender gaps in student achievement in Turkey: Evidence from Trends in International Mathematics and Science Study (TIMSS) 2015*.

Bauer, C. F. (2005). Beyond "student attitudes": Chemistry self-concept inventory for assessment of the affective component of student learning. *Journal of Chemical Education*, *82*(12), 1864–1870. https://doi.org/10.1021/ed082p1864

Bauer, C. F. (2008). Attitude toward chemistry: A semantic differential instrument for assessing curriculum impacts. *Journal of Chemical Education*, *85*(10), 1440–1445. https://doi.org/10.1021/ed085p1440

Beeken, M., & Budke, M. (2018). "PubScience—the long night of experiments": Students present chemical experiments in dining facilities. *Journal of Chemical Education*, *95*(8), 1323–1330. https://doi.org/10.1021/acs.jchemed.7b00835

Bhabha, H. K. (1994). *The location of culture*. London, New York: Routledge.

Bøe, M. V., & Henriksen, E. K. (2013). Love it or leave it: Norwegian students' motivations and expectations for postcompulsory physics. *Science Education*, *97*(4), 550–573. https://doi.org/10.1002/sce.21068

Bong, M., & Skaalvik, E. M. (2003). Academic self-concept and self-efficacy: How different are they really? *Educational Psychology Review*, *15*(1), 1–40.

Bourdieu, P. (1979). *La distinction: Critique sociale du jugement*. Paris: Éditions de Minuit.

Bourdieu, P. (1986). The forms of capital. In J. G. Richardson (Ed.), *Handbook of theory and research for the sociology of education* (pp. 241–258). New York, NY: Greenwood.

Bourdieu, P. (1994). *Raisons pratiques: Sur la théorie de l'action* (Seuil). Paris.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Brown, S. L., & Ronau, R. R. (2012). Students' perceptions of single-gender science and mathematics classroom experiences: Students' perceptions of single-gender classrooms. *School Science and Mathematics*, *112*(2), 66–87. https://doi.org/10.1111/j.1949-8594.2011.00121.x

Byrne, B. M. (2002). Validating the measurement and structure of self-concept: Snapshots of past, present, and future research. *American Psychologist*, *57*(11), 897–909. https://doi.org/10.1037/0003-066X.57.11.897

Byrne, B. M., Oakland, T., Leong, F. T. L., van de Vijver, F. J. R., Hambleton, R. K., Cheung, F. M., & Bartram, D. (2009). A critical analysis of cross-cultural research and testing practices. *Training and Education in Professional Psychology*, *3*(2), 94–105. https://doi.org/10.1037/a0014516

Cairns, D., & Areepattamannil, S. (2019). Exploring the relations of inquiry-based teaching to science achievement and dispositions in 54 countries. *Research in Science Education*, *49*(1), 1–23. https://doi.org/10.1007/s11165-017-9639-x

Capobianco, B. M., Yu, J. H., & French, B. F. (2015). Effects of engineering design-based science on elementary school science students' engineering identity development across gender and grade. *Research in Science Education*, *45*(2), 275–292. https://doi.org/10.1007/s11165-014-9422-1

Carey, D. (2008). *Improving Education Outcomes in Germany* (OECD Economics Department Working Papers No. 611). https://doi.org/10.1787/241675712618

Carlone, H. B., Webb, A. W., Archer, L., & Taylor, M. (2015). What kind of boy does science? A critical perspective on the science trajectories of four scientifically talented boys. *Science Education*, *99*(3), 438–464. https://doi.org/10.1002/sce.21155

Chandrasena, W., Craven, R. G., Tracey, D., & Dillon, A. (2014). Seeding science success: Psychometric properties of secondary science questionnaire on students' self-concept, motivation, and aspirations. *Australian Journal of Educational & Developmental Psychology*, *14*, 186–201.

Chang, M., Singh, K., & Mo, Y. (2007). Science engagement and science achievement: Longitudinal models using NELS data. *Educational Research and Evaluation*, *13*(4), 349–371. https://doi.org/10.1080/13803610701702787

Cheong, Y. F., Pajares, F., & Oberman, P. S. (2004). Motivation and academic help-seeking in high school computer science. *Computer Science Education*, *14*(1), 3–19. https://doi.org/10.1076/csed.14.1.3.23501

Cheung, D. (2018). The key factors affecting students' individual interest in school science lessons. *International Journal of Science Education*, *40*(1), 1–23. https://doi.org/10.1080/09500693.2017.1362711

Chiu, M.-S. (2008). Achievements and self-concepts in a comparison of math and science: Exploring the internal/external frame of reference model across 28 countries. *Educational Research and Evaluation*, *14*(3), 235–254. https://doi.org/10.1080/13803610802048858

Cohen, R., & Kelly, A. M. (2019). Community college chemistry coursetaking and STEM academic persistence. *Journal of Chemical Education*, *96*(1), 3–11. https://doi.org/10.1021/acs.jchemed.8b00586

Creswell, J. W., Plano Clark, V. L., Gutmann, M. L., & Hanson, W. E. (2003). Advanced mixed methods research designs. In A. Tashakkori & C. Teddlie

(Eds.), *Mixed methods in social & behavioral research* (pp. 209–240). Thousand Oaks, CA: Sage.

Cvencek, D., Meltzoff, A. N., & Greenwald, A. G. (2011). Math-gender stereotypes in elementary school children. *Child Development*, *82*(3), 766–779. https://doi.org/10.1111/j.1467-8624.2010.01529.x

Dean, L. M. (2013). *Factors that influence minority student enrollment at various levels of postsecondary education*. Ann Arbor, MI: ProQuest LLC.

DeWitt, J., & Archer, L. (2015). Who aspires to a science career? A comparison of survey responses from primary and secondary school students. *International Journal of Science Education*, *37*(13), 2170–2192. https://doi.org/10.1080/09500693.2015.1071899

DeWitt, J., Archer, L., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2011). High aspirations but low progression: The science aspirations-careers paradox amongst minority ethnic students. *International Journal of Science and Mathematics Education*, *9*(2), 243–271. https://doi.org/10.1007/s10763-010-9245-0

Dweck, C. S. (2000). *Self-theories: Their role in motivation, personality, and development*. Philadelphia, PA: Psychology Press.

Eccles, J. S. (1983). Expectancies, values, and academic choice: Origins and changes. In J. Spence (Ed.), *Achievement and achievement motivation* (pp. 87–134). San Francisco: W. H. Freeman.

Eccles, J. S. (2011). Gendered educational and occupational choices: Applying the Eccles et al. model of achievement-related choices. *International Journal of Behavioral Development*, *35*(3), 195–201. https://doi.org/10.1177/0165025411398185

Eccles, J. S., & Wang, M.-T. (2016). What motivates females and males to pursue careers in mathematics and science? *International Journal of Behavioral Development*, *40*(2), 100–106. https://doi.org/10.1177/0165025415616201

Ehmke, T., Drechsel, B., & Carstensen, C. H. (2010). Effects of grade retention on achievement and self-concept in science and mathematics. *Studies in Educational Evaluation*, *36*(1–2), 27–35. https://doi.org/10.1016/j.stueduc.2010.10.003

Eilks, I., & Ralle, B. (2002). Participatory action research within chemical education. In B. Ralle & I. Eilks (Eds.), *Research in chemical education: What does this mean?* (pp. 87–98). Aachen: Shaker.

Essex, J. (2016). Cultural inclusion in science education. In S. Abels & S. Markic (Eds.), *Science Education towards Inclusion* (pp. 67–90). New York: Nova Science.

Färber, C., Arslan, N., Köhnen, M., & Parlar, R. (2008). *Migration, Geschlecht und Arbeit: Probleme und Potenziale von Migrantinnen auf dem Arbeitsmarkt*. Opladen: Budrich.

Ferguson, S. L., & Hull, D. M. (2019). Exploring science career interest: Latent profile analysis of high school occupational preferences for science. *Journal of Career Development*, *46*(5), 583–598. https://doi.org/10.1177/0894845318783873

George, R. (2006). A cross-domain analysis of change in students' attitudes toward science and attitudes about the utility of science. *International Journal of Science Education*, *28*(6), 571–589. https://doi.org/10.1080/09500690500338755

Giesecke, A., & Schork, N. (n.d.). Kanalinfo. Retrieved December 4, 2019, from Chemie—Simpleclub website: https://www.youtube.com/user/TheSimpleChemics/about

Gilmartin, S., Denson, N., Li, E., Bryant, A., & Aschbacher, P. (2007). Gender ratios in high school science departments: The effect of percent female faculty on multiple dimensions of students' science identities. *Journal of Research in Science Teaching*, *44*(7), 980–1009. https://doi.org/10.1002/tea.20179

Glowinski, I., & Bayrhuber, H. (2011). Student labs on a university campus as a type of out-of-school learning environment: Assessing the potential to promote students' interest in science. *International Journal of Environmental and Science Education*, *6*, 371–392.

Godec, S., King, H., & Archer, L. (2017). *The science capital teaching approach: Engaging students with science, promoting social justice*. London: University College London.

Göttsche, F. (2018). Bevölkerung mit Migrationshintergrund. In Statistisches Bundesamt & Wissenschaftszentrum Berlin für Sozialforschung (Eds.), *Datenreport 2018: Ein Sozialbericht für die Bundesrepublik Deutschland* (pp. 28–42). Bonn: Bundeszentrale für politische Bildung.

Grabau, L. J., & Ma, X. (2017). Science engagement and science achievement in the context of science instruction: A multilevel analysis of U.S. students and schools. *International Journal of Science Education*, *39*(8), 1045–1068. https://doi.org/10.1080/09500693.2017.1313468

Greenwald, A. G., Banaji, M. R., Rudman, L. A., Farnham, S. D., Nosek, B. A., & Mellott, D. S. (2002). A unified theory of implicit attitudes, stereotypes, self-esteem, and self-concept. *Psychological Review*, *109*(1), 3–25. https://doi.org/10.1037/0033-295X.109.1.3

Gresch, C., & Kristen, C. (2011). Staatsbürgerschaft oder Migrationshintergrund?: Ein Vergleich unterschiedlicher Operationalisierungsweisen am Beispiel der Bildungsbeteiligung. *Zeitschrift Für Soziologie*, *40*(3), 208–227.

Guay, F., Ratelle, C. F., Roy, A., & Litalien, D. (2010). Academic self-concept, autonomous academic motivation, and academic achievement: Mediating and additive effects. *Learning and Individual Differences*, *20*(6), 644–653. https://doi.org/10.1016/j.lindif.2010.08.001

Guest, G. (2013). Describing mixed methods research: An alternative to typologies. *Journal of Mixed Methods Research*, *7*(2), 141–151. https://doi.org/10.1177/1558689812461179

Hänze, M., & Berger, R. (2007). Cooperative learning, motivational effects, and student characteristics: An experimental study comparing cooperative learning and direct instruction in 12th grade physics classes. *Learning and Instruction*, *17*(1), 29–41. https://doi.org/10.1016/j.learninstruc.2006.11.004

Hardy, G. (2014). Academic self-concept: Modeling and measuring for science. *Research in Science Education*, *44*(4), 549–579. https://doi.org/10.1007/s11165-013-9393-7

Hattie, J. (2008). Processes of integrating, developing and processing self information. In D. M. McInerney, H. W. Marsh, & R. Craven (Eds.), *Self-processes, learning, and enabling human potential: Dynamic new approaches* (pp. 51–85). Charlotte, NC: Information Age.

Häussler, P., & Hoffmann, L. (2002). An intervention study to enhance girls' interest, self-concept, and achievement in physics classes. *Journal of Research in Science Teaching*, *39*(9), 870–888. https://doi.org/10.1002/tea.10048

Horna, C., & Richards, A. J. (2018). Investigating physics self-belief of female African-American students. *The Physics Teacher*, *56*(7), 448–451. https://doi.org/10.1119/1.5055326

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Jack, B. M., She, H.-C., & Lin, H. (2016). Effects of self-evaluated value and cognition on leisure science engagement. *International Journal of Science Education, Part B: Communication and Public Engagement*, *6*(4), 341–354. https://doi.org/10.1080/21548455.2016.1222104

James, W. (1890). *The principles of psychology* (F. Burkhardt, F. Bowers, & I. K. Skrupskelis, Eds.). Cambridge, MA: Harvard University Press.

Jansen, M., Schroeders, U., & Lüdtke, O. (2014). Academic self-concept in science: Multidimensionality, relations to achievement measures, and gender differences. *Learning and Individual Differences*, *30*(11), 11–21. https://doi.org/10.1016/j.lindif.2013.12.003

Jayaratne, T. E., Thomas, N. G., & Trautmann, M. (2003). Intervention program to keep girls in the science pipeline: Outcome differences by ethnic status. *Journal of Research in Science Teaching*, *40*(4), 393–414. https://doi.org/10.1002/tea.10082

Jugovic, I. (2017). Students' gender-related choices and achievement in physics. *Center for Educational Policy Studies Journal*, *7*(2), 71–95.

Jurik, V., Gröschner, A., & Seidel, T. (2013). How student characteristics affect girls' and boys' verbal engagement in physics instruction. *Learning and Instruction*, *23*, 33–42. https://doi.org/10.1016/j.learninstruc.2012.09.002

Kessels, Ursula., & Hannover, Bettina. (2008). When being a girl matters less: Accessibility of gender-related self-knowledge in single-sex and coeducational classes and its impact on students' physics-related self-concept of ability. *British Journal of Educational Psychology*, *78*(2), 273–289. https://doi.org/10.1348/000709907X215938

Kind, P., Jones, K., & Barmby, P. (2007). Developing attitudes towards science measures. *International Journal of Science Education*, *29*(7), 871–893. https://doi.org/10.1080/09500690600909091

Koul, R., Lerdpornkulrat, T., & Poondej, C. (2017). Gender contentedness in aspirations to become engineers or medical doctors. *European Journal of Engineering Education*, *42*(6), 1422–1438. https://doi.org/10.1080/03043797.2017.1303450

Koutsoulis, M. K., & Campbell, J. R. (2001). Family processes affect students' motivation, and science and math achievement in Cypriot high schools. *Structural Equation Modeling*, *8*(1), 108–127. https://doi.org/10.1207/S15328007SEM0801_6

Lau, K. C. (2014). The science education of the East Asian regions: What we can learn from PISA. *Asia-Pacific Forum on Science Learning and Teaching*, *15*(2).

Lavonen, J., & Laaksonen, S. (2009). Context of teaching and learning school science in Finland: Reflections on PISA 2006 results. *Journal of Research in Science Teaching*, *46*(8), 922–944. https://doi.org/10.1002/tea.20339

Lay, Y. F., & Chandrasegaran, A. L. (2016). The predictive effects of motivation toward learning science on TIMSS grade 8 students' science achievement: A comparative study between Malaysia and Singapore. *EURASIA Journal of Mathematics, Science & Technology Education*, *12*(12), 2949–2959. https://doi.org/10.12973/eurasia.2016.02315a

Leisen, J., Kruczinna, R., & Bennung, R. (Eds.). (1999). *Methoden-Handbuch: Deutschsprachiger Fachunterricht (DFU)*. Goch: Pagina Verlag GmbH.

Leslie, L. L., McClure, G. T., & Oaxaca, R. L. (1998). Women and minorities in science and engineering: A life sequence analysis. *Journal of Higher Education*, *69*(3), 239–276. https://doi.org/10.1080/00221546.1998.11775134

Liou, P.-Y., Wang, C.-L., & Lin, J. J. H. (2019). Pathways of parental involvement through students' motivational beliefs to science achievement. *Educational Psychology*, *39*(7), 960–980. https://doi.org/10.1080/01443410.2019.1617410

Lu, Y.-Y., Chen, H.-T., Hong, Z.-R., & Yore, L. D. (2016). Students' awareness of science teachers' leadership, attitudes toward science, and positive thinking. *International Journal of Science Education*, *38*(13), 2174–2196. https://doi.org/10.1080/09500693.2016.1230792

Mair, P., Schoenbrodt, F., & Wilcox, R. (2017). *WRS2: Wilcox robust estimation and testing: R package version 0.9.2*. Retrieved from https://CRAN.R-project.org/package=WRS2

Makwinya, N. M., & Hofman, R. H. (2015). Gender disparities in sciences: The question of parental influence on children's self-concept and utility-value. *Journal of Education and Practice*, *6*(13), 70–75.

Mamlok-Naaman, R., Abels, S., & Markic, S. (2015). Learning about relevance concerning cultural and gender differences in chemical education. In I. Eilks & A. Hofstein (Eds.), *Relevant chemistry education: From theory to practice* (pp. 219–240). Rotterdam, Boston, and Taipei: Sense Publishers.

Markic, S. (2018). Learning language and intercultural understanding in science classes in Germany. In K.-S. Tang & K. Danielsson (Eds.), *Global developments in literacy research for science education* (1st edition). Berlin, Heidelberg: Springer.

Marsh, H. W. (1986). Verbal and math self-concepts: An internal/external frame of reference model. *American Educational Research Journal*, *23*(1), 129–149. https://doi.org/10.3102/00028312023001129

Marsh, H. W. (1987). The big-fish-little-pond effect on academic self-concept. *Journal of Educational Psychology*, *79*, 280–295. https://doi.org/10.1037/0022-0663.79.3.280

Marsh, H. W. (1989). Age and sex effects in multiple dimensions of self-concept: Preadolescence to early adulthood. *Journal of Educational Psychology*, *81*(3), 417–430. https://doi.org/10.1037/0022-0663.81.3.417

Marsh, H. W. (1990a). Causal ordering of academic self-concept and academic achievement: A multiwave, longitudinal panel analysis. *Journal of Educational Psychology*, *82*(4), 646–656. https://doi.org/10.1037/0022-0663.82.4.646

Marsh, H. W. (1990b). *Self-description questionnaire—I (SDQ I): Manual.* New South Wales: Macarthur.

Marsh, H. W. (1990c). The structure of academic self-concept: The Marsh/Shavelson model. *Journal of Educational Psychology*, *82*(4), 623–636. https://doi.org/10.1037/0022-0663.82.4.623

Marsh, H. W. (1992a). *Self-description questionnaire (SDQ) III: A theoretical and empirical basis for the measurement of multiple dimensions of latent adolescent self-concept. An interim test manual and research monograph*. Macarthur: University of Western Sydney, Faculty of Education.

Marsh, H. W. (1992b). *Self-description questionnaire (SDQ) II: A theoretical and empirical basis for the measurement of multiple dimensions of adolescent self-concept. A test manual and research monograph*. University of Western Sydney, Macarthur.

Marsh, H. W. (2005). *Self-concept theory, measurement and research into practice: The role of self concept in educational psychology*. London: British Psychological Society.

Marsh, H. W., Abduljabbar, A. S., Abu-Hilal, M. M., Morin, A. J. S., Abdelfattah, F., Leung, K. C., … Parker, P. (2013). Factorial, convergent, and discriminant validity of TIMSS math and science motivation measures: A comparison of Arab and Anglo-Saxon countries. *Journal of Educational Psychology*, *105*(1), 108–128. https://doi.org/10.1037/a0029907

Marsh, H. W., Abduljabbar, A. S., Morin, A. J. S., Parker, P., Abdelfattah, F., Nagengast, B., & Abu-Hilal, M. M. (2015). The big-fish-little-pond effect: Generalizability of social comparison processes over two age cohorts from Western, Asian, and Middle Eastern Islamic countries. *Journal of Educational Psychology*, *107*(1), 258–271. https://doi.org/10.1037/a0037485

Marsh, H. W., & Craven, R. G. (2006). Reciprocal effects of self-concept and performance from a multidimensional perspective: Beyond seductive pleasure and unidimensional perspectives. *Perspectives on Psychological Science*, *1*(2), 133–163. https://doi.org/10.1111/j.1745-6916.2006.00010.x

Marsh, H. W., & Hau, K.-T. (2004). Explaining paradoxical relations between academic self-concepts and achievements: Cross-cultural generalizability of the internal/external frame of reference predictions across 26 countries. *Journal of Educational Psychology*, *96*(1), 56–67. https://doi.org/10.1037/0022-0663.96.1.56

Marsh, H. W., & Shavelson, R. (1985). Self-concept: Its multifaceted, hierarchical structure. *Educational Psychologist*, *20*(3), 107–123. https://doi.org/10.1207/s15326985ep2003_1

Marsh, H. W., Trautwein, U., Lüdtke, O., Baumert, J., & Köller, O. (2007). The Big-Fish-Little-Pond Effect: Persistent negative effects of selective high schools on self-concept after graduation. *American Educational Research Journal*, *44*(3), 631–669. https://doi.org/10.3102/0002831207306728

Marsh, H. W., & Yeung, A. S. (1997a). Causal effects of academic self-concept on academic achievement: Structural equation models of longitudinal data. *Journal of Educational Psychology*, *89*(1), 41–54. https://doi.org/10.1037/0022-0663.89.1.41

Marsh, H. W., & Yeung, A. S. (1997b). Coursework selection: Relations to academic self-concept and achievement. *American Educational Research Journal*, *34*(4), 691–720. https://doi.org/10.3102/00028312034004691

Martin, M. O., Mullis, I. V. S., & Foy, P. (2008). *TIMSS 2007 International science report: Findings from IEA's trends in international mathematics and science study at the fourth and eighth grades*. Boston, MA: International Association for the Evaluation of Educational Achievement, TIMSS & PIRLS International Study Center.

Mason, L., Boscolo, P., Tornatora, M. C., & Ronconi, L. (2013). Besides knowledge: A cross-sectional study on the relations between epistemic beliefs, achievement goals, self-beliefs, and achievement in science. *Instructional Science*, *41*(1), 49–79. https://doi.org/10.1007/s11251-012-9210-0

Mayring, P. (2014). *Qualitative content analysis: Theoretical foundation, basic procedures and software solution*. Klagenfurt.

McInerney, D. M., Cheng, R. W., Mok, M. M. C., & Lam, A. K. H. (2012). Academic self-concept and learning strategies: Direction of effect on student academic achievement. *Journal of Advanced Academics*, *23*(3), 249–269. https://doi.org/10.1177/1932202X12451020

Mendick, H., Berge, M., & Danielsson, A. (2017). A critique of the stem pipeline: Young people's identities in Sweden and science education policy. *British Journal of Educational Studies*, *65*(4), 481–497. https://doi.org/10.1080/00071005.2017.1300232

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook* (Third edition). Thousand Oaks, CA: SAGE Publications, Inc.

Mohammadpour, E. (2012). A multilevel study on trends in Malaysian secondary school students' science achievement and associated school and student predictors. *Science Education*, *96*(6), 1013–1046. https://doi.org/10.1002/sce.21028

Möller, J., Pohlmann, B., Köller, O., & Marsh, H. W. (2009). A meta-analytic path analysis of the internal/external frame of reference model of academic achievement and academic self-concept. *Review of Educational Research*, *79*, 1129–1167. https://doi.org/10.3102/0034654309337522

Möller, J., Retelsdorf, J., Köller, O., & Marsh, H. W. (2011). The reciprocal internal/external frame of reference model: An integration of models of relations between academic achievement and self-concept. *American Educational Research Journal*, *48*(6), 1315–1346. https://doi.org/10.3102/0002831211419649

Möller, J., & Trautwein, U. (2015). Selbstkonzept. In E. Wild & J. Möller (Eds.), *Pädagogische Psychologie* (pp. 177–199). https://doi.org/10.1007/978-3-642-41291-2_8

Mubeen, S., & Reid, N. (2014). The measurement of motivation with science students. *European Journal of Educational Research*, *3*(3), 129–144. https://doi.org/10.12973/eu-jer.3.3.129

Mujtaba, T., & Reiss, M. J. (2014). A survey of psychological, motivational, family and perceptions of physics education factors that explain 15-year-old-students' aspirations to study physics in post-compulsory English schools. *International Journal of Science and Mathematics Education*, *12*(2), 371–393. https://doi.org/10.1007/s10763-013-9404-1

Mujtaba, T., & Reiss, M. J. (2016). "I fall asleep in class … but physics is fascinating": The use of large-scale longitudinal data to explore the educational experiences of aspiring girls in mathematics and physics. *Canadian Journal of Science, Mathematics and Technology Education*, *16*(4), 313–330. https://doi.org/10.1080/14926156.2016.1235743

Mujtaba, T., Sheldrake, R., Reiss, M. J., & Simon, S. (2018). Students' science attitudes, beliefs, and context: Associations with science and chemistry aspirations. *International Journal of Science Education*, *40*(6), 644–667. https://doi.org/10.1080/09500693.2018.1433896

Nagengast, B., & Marsh, H. W. (2011). The negative effect of school-average ability on science self-concept in the UK, the UK countries and the world: The big-fish-little-pond-effect for PISA 2006. *Educational Psychology*, *31*(5), 629–656. https://doi.org/10.1080/01443410.2011.586416

Nagengast, B., & Marsh, H. W. (2012). Big fish in little ponds aspire more: Mediation and cross-cultural generalizability of school-average ability effects on self-concept and career aspirations in science. *Journal of Educational Psychology*, *104*(4), 1033–1053. https://doi.org/10.1037/a0027697

Ng, K. T., Lay, Y. F., Areepattamannil, S., Treagust, D. F., & Chandrasegaran, A. L. (2012). Relationship between affect and achievement in science and mathematics in Malaysia and Singapore. *Research in Science & Technological Education*, *30*(3), 225–237. https://doi.org/10.1080/02635143.2012.708655

Nguyen-Kim, M. T. (n.d.). Kanalinfo. Retrieved December 4, 2019, from MaiLab website: https://www.youtube.com/channel/UCyHDQ5C6z1NDmJ4g6SerW8g/about

North, E. A., & Ryan, A. M. (2018). The association of peer academic reputations in math and science with achievement beliefs and behaviors during early adolescence. *The Journal of Early Adolescence*, *38*(6), 772–794. https://doi.org/10.1177/0272431617692441

OECD (Ed.). (2008). *Encouraging student interest in science and technology studies*. Paris: OECD Publishing.

OECD. (2009a). *Chart A4.6 Tertiary graduates in science-related fields among 25-34 year-olds in employment, by gender (2009)*. https://doi.org/10.1787/888932460192

OECD. (2009b). *PISA 2006 Technical report*. OECD Publishing.

OECD. (2016a). Figure I.7.6 Percentage of low performers in science, by immigrant background. In *PISA*: *Vol. 1. PISA 2015 Results: Excellence and equity in education* (p. 251). https://doi.org/10.1787/888933432926

OECD. (2016b). Figure I.7.10 Students' expectations of pursuing a career in science, by immigrant background. In *PISA*: *Vol. 1. PISA 2015 Results: Excellence and equity in education* (p. 256). Paris: OECD Publishing.

OECD. (2016c). *PISA 2015 results (volume I): Excellence and equity in education*. Paris: OECD Publishing.

OECD. (2016d). Table I.7.4a Differences in science performance between immigrant and non-immigrant students, and socio-economic status. In *PISA*: *Vol. 1. PISA 2015 Results: Excellence and equity in education* (p. 427). https://doi.org/10.1787/888933433226

Potvin, P., & Hasni, A. (2018). Encouraging students with different profiles of perceptions to pursue science by choosing appropriate teaching methods for each age group. *Research in Science Education*, *48*(6), 1339–1357. https://doi.org/10.1007/s11165-016-9605-z

Potvin, P., Hasni, A., & Sy, O. (2017). Using inquiry-based interventions to improve secondary students' interest in science and technology. *European Journal of Science and Mathematics Education*, *5*(3), 262–270.

Prieur, A., & Savage, M. (2013). Emerging forms of cultural capital. *European Societies*, *15*(2), 246–267. https://doi.org/10.1080/14616696.2012.748930

Qu, S. Q., & Dumay, J. (2011). The qualitative research interview. *Qualitative Research in Accounting & Management*, *8*(3), 238–264. https://doi.org/10.1108/11766091111162070

Richter, D., Kuhl, P., Haag, N., & Pant, H. A. (2013). Aspekte der Aus- und Fortbildung von Mathematik- und Naturwissenschaftslehrkräften im Ländervergleich. In H. A. Pant, P. Stanat, U. Schroeders, A. Roppelt, T. Siegle, & C. Pöhlmann (Eds.), *IQB-Ländervergleich 2012: Mathematische und naturwissenschaftliche Kompetenzen am Ende der Sekundarstufe I*. Münster New York München Berlin: Waxmann.

Riegle-Crumb, C., Moore, C., & Ramos-Wada, A. (2011). Who wants to have a career in science or math?: Exploring adolescents' future aspirations by gender and race/ethnicity. *Science Education*, *95*(3), 458–476. https://doi.org/10.1002/sce.20431

Rosenthal, R., & Jacobson, L. (1968). *Pygmalion in the classroom: Teacher expectation and pupils' intellectual development.* New York: Holt, Rinehart and Winston.

Rubin, G. (1975). The traffic in women: Notes on the "political economy" of sex. In R. Reiter (Ed.), *Toward an anthropology of women* (pp. 157–210). New York, NY: Monthly Review Press.

Rüschenpöhler, L. (2017). *„Fach + Sprache" – Grundkurs Chemie*. Retrieved from https://www.lehrlernwerkstatt.uni-bremen.de/download/17_11_22_F+S-Ausarbeitung_gesamt.pdf

Rüschenpöhler, L. (2018). Was passiert, wenn man Eis erhitzt? Auswertung einer quantitativen Datenreihe mit neu zugewanderten Schülerinnen und Schülern. *Unterricht Chemie*, *Themenheft: "Sprachsensibel Unterrichten," Band 168*, 22–25.

Rüschenpöhler, L., & Baginski, K. (accepted). Migrant*innen mit geringen Deutschkenntnissen im Chemieunterricht: Die Verwebung fachlichen, unterrichtskulturellen und sprachlichen Lernens im Projekt „Fach + Sprache" Chemie. In K. Peuschel, L. Otto, & S. Steinmetz, *Theorie, Praxis, Reflexion: Forschungsberichte aus dem Netzwerk Stark durch Diversität* (Waxmann).

Rüschenpöhler, L., & Markic, S. (2017). Kulturelle Unterschiede der Selbstkonzepte in der Chemie. In C. Maurer (Ed.), *Qualitätsvoller Chemie- und Physikunterricht—*

Normative und empirische Dimensionen. Gesellschaft für Didaktik der Chemie und Physik. Jahrestagung in Regensburg 2017 (Vol. 38). Regensburg.

Rüschenpöhler, L., & Markic, S. (2018a). Chemistry? Not my thing! Cultural differences in students' chemistry self-concepts. In I. Eilks, S. Markic, & B. Ralle (Eds.), *Building bridges across disciplines for transformative education and a sustainable future* (pp. 243–248). Aachen: Shaker Verlag.

Rüschenpöhler, L., & Markic, S. (2018b). Cultural influence on student self-concepts in chemistry: Questioning the traditional gender gap. In O. Finlayson, E. McLoughlin, S. Erduran, & P. Childs (Eds.), *Research, practice and collaboration in science education: Proceedings of the ESERA 2017 conference* (pp. 1547–1557). Dublin: Dublin City University.

Rüschenpöhler, L., & Markic, S. (2019a). Self-concept research in science and technology education: Theoretical foundation, measurement instruments, and main findings. *Studies in Science Education*, *55*(1), 37–68. https://doi.org/10.1080/03057267.2019.1645533

Rüschenpöhler, L., & Markic, S. (2019b). A mixed methods approach to culture-sensitive academic self-concept research. *Education Sciences*, *9*(3), 240-256. https://doi.org/10.3390/educsci9030240

Rüschenpöhler, L., & Markic, S. (2019c). Psychologische Muster in Chemie-Selbstkonzepten. In C. Maurer (Ed.), *Naturwissenschaftliche Bildung als Grundlage für berufliche und gesellschaftliche Teilhabe* (Vol. 39, pp. 129–132). Kiel: Universität Kiel.

Rüschenpöhler, L., & Markic, S. (2020a). Secondary school students' chemistry self-concepts: Gender and culture, and the impact of chemistry self-concept on learning behaviour. *Chemistry Education Research and Practice*, *21*(1), 209-219. https://doi.org/10.1039/C9RP00120D

Rüschenpöhler, L., & Markic, S. (2020b). Secondary school students' acquisition of science capital in the field of chemistry. *Chemistry Education Research and Practice*, *21*(1), 220-236. https://doi.org/10.1039/C9RP00127A

Rüschenpöhler, L., & Markic, S. (2020c). How the home environment shapes students' perceptions of their abilities: The relation between chemistry capital at home and students' chemistry self-concept. *International Journal of Science Education*. https://doi.org/10.1080/09500693.2020.1812010

Rüschenpöhler, L., Markic, S., & Schneider, M. (submitted). The culture-free zone of chemistry class: Chemistry teachers' views on the role of culture in chemistry learning and their strategies for dealing with it. *Chemistry Education Research and Practice*.

Saldaña, J. (2016). *The coding manual for qualitative researchers* (Third edition). Los Angeles, London: SAGE.

Sampson, P. M., Gresham, G., Leigh, M. M., & McCormick-Myers, D. (2014). Do you want single-gender science classrooms in your middle schools? *Teacher Education and Practice*, *27*(1), 190–202.

Schiepe-Tiska, A., Rönnebeck, S., & Neumann, K. (2019). Naturwissenschaftliche Kompetenz in PISA 2018: Aktueller Stand, Veränderungen und Implikationen für die naturwissenschaftliche Bildung in Deutschland. In K.

Reiss, M. Weis, E. Klieme, & O. Köller (Eds.), *PISA 2018 Grundbildung im internationalen Vergleich.* (pp. 211–240). Münster: Waxmann.

Şentürk, E., & Özdemir, Ö. F. (2014). The effect of science centres on students' attitudes towards science. *International Journal of Science Education, Part B*, *4*(1), 1–24. https://doi.org/10.1080/21548455.2012.726754

Sewell, W. H. (1999). The concept(s) of culture. In V. E. Bonnell & L. Hunt (Eds.), *Beyond the cultural turn: New directions in the study of society and culture* (pp. 35–61). Berkeley: University of California Press.

Shanahan, M. (2009). Identity in science learning: Exploring the attention given to agency and structure in studies of identity. *Studies in Science Education*, *45*(1), 43–64. https://doi.org/10.1080/03057260802681847

Shavelson, R. J., Hubner, J. J., & Stanton, G. C. (1976). Self-concept: Validation of construct interpretations. *Review of Educational Research*, *46*(3), 407–441. https://doi.org/10.3102/00346543046003407

Sheldrake, R. (2016). Students' intentions towards studying science at upper-secondary school: The differential effects of under-confidence and over-confidence. *International Journal of Science Education*, *38*(8), 1256–1277. https://doi.org/10.1080/09500693.2016.1186854

Shulruf, B., Hattie, J., & Dixon, R. (2011). Intertwinement of individualist and collectivist attributes and response sets. *Journal of Social, Evolutionary, and Cultural Psychology*, *5*(1), 51–65. https://doi.org/10.1037/h0099275

Sikora, J., & Pokropek, A. (2012). Gender segregation of adolescent science career plans in 50 countries. *Science Education*, *96*(2), 234–264. https://doi.org/10.1002/sce.20479

Silinskas, G., & Kikas, E. (2019). Parental involvement in math homework: Links to children's performance and motivation. *Scandinavian Journal of Educational Research*, *63*(1), 17–37. https://doi.org/10.1080/00313831.2017.1324901

Simpkins, S. D., Price, C. D., & Garcia, K. (2015). Parental support and high school students' motivation in biology, chemistry, and physics: Understanding differences among latino and caucasian boys and girls. *Journal of Research in Science Teaching*, *52*(10), 1386–1407. https://doi.org/10.1002/tea.21246

Skaalvik, E. M., & Rankin, R. J. (1990). Math, verbal, and general academic self-concept: The internal/external frame of reference model and gender differences in self-concept structure. *Journal of Educational Psychology*, *82*(3), 546–554. https://doi.org/10.1037/0022-0663.82.3.546

Statistisches Bundesamt. (2013). *Bevölkerung und Erwerbstätigkeit Bevölkerung mit Migrationshintergrund: Ergebnisse des Mikrozensus 2013*. Statistisches Bundesamt.

Tajmel, T. (2017). *Naturwissenschaftliche Bildung in der Migrationsgesellschaft: Grundzüge einer reflexiven Physikdidaktik und kritisch-sprachbewussten Praxis*. Wiesbaden: Springer VS.

Tas, Y., Subaşı, M., & Yerdelen, S. (2019). The role of motivation between perceived teacher support and student engagement in science class. *Educational Studies*, *45*(5), 582–592. https://doi.org/10.1080/03055698.2018.1509778

Taskinen, P. H., Schütte, K., & Prenzel, M. (2013). Adolescents' motivation to select an academic science-related career: The role of school factors, individual interest, and science self-concept. *Educational Research and Evaluation*, *19*(8), 717–733. https://doi.org/10.1080/13803611.2013.853620

Techtastisch. (n.d.). *Techtastischer Kanaltrailer*. Retrieved from https://youtu.be/akalsyYH9Dw,

Thomas, A. E. (2017). Gender differences in students' physical science motivation: Are teachers' implicit cognitions another piece of the puzzle? *American Educational Research Journal*, *54*(1), 35–58. https://doi.org/10.3102/0002831216682223

Thomas, J. A., & Strunk, K. K. (2017). Expectancy-value and children's science achievement: Parents matter. *Journal of Research in Science Teaching*, *54*(6), 693–712. https://doi.org/10.1002/tea.21382

Tolsdorf, Y., & Markic, S. (n.d.). *Sammlung diagnostischer Instrumente zur Erfassung sprachlicher und fachlicher Fähigkeiten im Chemieunterricht*. Retrieved from http://www.idn.uni-bremen.de/chemiedidaktik/material/Zusammenfassung%20aller%20Diagnoseinstrumente.pdf

U.S. Census Bureau. (2017). *2006-2010 American community survey.*

van de Vijver, F. J. R., & Poortinga, Ype. H. (2005). Conceptual and methodological issues in adapting tests. In C. D. Spielberger, P. F. Merenda, & R. K. Hambleton (Eds.), *Adapting educational and psychological tests for cross-cultural assessment* (pp. 39–63). Mahwah, NJ: Lawrence Erlbaum.

van den Hurk, A., Meelissen, M., & van Langen, A. (2019). Interventions in education to prevent STEM pipeline leakage. *International Journal of Science Education*, *41*(2), 150–164. https://doi.org/10.1080/09500693.2018.1540897

Wan, Z. H., & Lee, J. C. K. (2017). Hong Kong secondary school students' attitudes towards science: A study of structural models and gender differences. *International Journal of Science Education*, *39*(5), 507–527. https://doi.org/10.1080/09500693.2017.1292015

Wandela, E. L. (2014). *Tanzania post-colonial educational system and perspectives on secondary science education, pedagogy, and curriculum: A qualitative study* (DePaul University). Retrieved from https://via.library.depaul.edu/soe_etd/71

Wang, C.-L., & Liou, P.-Y. (2018). Patterns of motivational beliefs in the science learning of total, high-, and low-achieving students: Evidence of Taiwanese TIMSS 2011 data. *International Journal of Science and Mathematics Education*, *16*(4), 603–618. https://doi.org/10.1007/s10763-017-9797-3

Wang, J., Oliver, J. S., & Staver, J. R. (2008). Self-concept and science achievement: Investigating a reciprocal relation model across the gender classification in a crosscultural context. *Journal of Research in Science Teaching*, *45*(6), 711–725. https://doi.org/10.1002/tea.20182

Wender, I. (2004). Relation of technology, science, self-concept, interest, and gender. *Journal of Technology Studies*, *30*(3), 43–51. https://doi.org/10.21061/jots.v30i3.a.7

Wigfield, A., Eccles, J. S., Yoon, K. S., Harold, R. D., Arbreton, A. J. A., Freedman-Doan, C., & Blumenfeld, P. C. (1997). Change in children's competence beliefs and subjective task values across the elementary school years: A 3-year study. *Journal of Educational Psychology*, *89*(3), 451–469. https://doi.org/10.1037/0022-0663.89.3.451

Wilkins, J. L. M. (2004). Mathematics and science self-concept: An international investigation. *The Journal of Experimental Education*, *72*(4), 331–346. https://doi.org/10.3200/JEXE.72.4.331-346

Woods-McConney, A., Oliver, M. C., McConney, A., Maor, D., & Schibeci, R. (2013). Science engagement and literacy: A retrospective analysis for indigenous and non-indigenous students in Aotearoa New Zealand and Australia. *Research in Science Education*, *43*(1), 233–252. https://doi.org/10.1007/s11165-011-9265-y

Woods-McConney, A., Oliver, M. C., McConney, A., Schibeci, R., & Maor, D. (2014). Science engagement and literacy: A retrospective analysis for students in Canada and Australia. *International Journal of Science Education*, *36*(10), 1588–1608. https://doi.org/10.1080/09500693.2013.871658

World Medical Association. (2013). World Medical Association declaration of Helsinki: Ethical principles for medical research involving human subjects. *Journal of the American Medical Association*, *310*(20), 2191. https://doi.org/10.1001/jama.2013.281053

Wylie, R. C. (1979). *The self-concept: Volume 2. Theory and research on selected topics* (Vols. 1–2). Lincoln: University of Nebraska Press.

Xu, X., & Lewis, J. E. (2011). Refinement of a chemistry attitude measure for college students. *Journal of Chemical Education*, *88*(5), 561–568. https://doi.org/10.1021/ed900071q

Yeung, A. S., Kuppan, L., Foong, S. K., Wong, D. J. S., Kadir, M. S., Lee, P. C. K., & Yau, C. M. (2010). Domain-specificity of self-concept and parent expectation influences on short-term and long-term learning of physics. *New Horizons in Education*, *58*(2), 54–72.

Yu, C. H. (2012). Examining the relationships among academic self-concept, instrumental motivation, and TIMSS 2007 science scores: A cross-cultural comparison of five East Asian countries/regions and the United States. *Educational Research and Evaluation*, *18*(8), 713–731. https://doi.org/10.1080/13803611.2012.718511

Zain, A. N. M., Samsudin, M. A., Rohandi, R., & Jusoh, A. (2010). Using the Rasch model to measure students' attitudes toward science in "low performing" secondary schools in Malaysia. *International Education Studies*, *3*(2), 56–63.

Ziegler, A., Finsterwald, M., & Grassinger, R. (2005). Predictors of learned helplessness among average and mildly gifted girls and boys attending initial high school physics instruction in Germany. *Gifted Child Quarterly*, *49*(1), 7–18.

Zoido, P. (2013). *What do immigrant students tell us about the quality of education systems?* (PISA in Focus No. 33; pp. 1–4). Paris: OECD.

APPENDIX

Overview of publications

The following five articles are an integral part of this thesis and, therefore, available in the appendix:

Rüschenpöhler, L., & Markic, S. (2019a). Self-concept research in science and technology education: Theoretical foundation, measurement instruments, and main findings. *Studies in Science Education*, *55*(1), 37–68. https://doi.org/10.1080/03057267.2019.1645533

Rüschenpöhler, L., & Markic, S. (2019b). A mixed methods approach to culture-sensitive academic self-concept research. *Education Sciences*, *9*(3), 240-256. https://doi.org/10.3390/educsci9030240

Rüschenpöhler, L., & Markic, S. (2020a). Secondary school students' chemistry self-concepts: Gender and culture, and the impact of chemistry self-concept on learning behaviour. *Chemistry Education Research and Practice*, *21*(1), 209-219. https://doi.org/10.1039/C9RP00120D

Rüschenpöhler, L., & Markic, S. (2020b). Secondary school students' acquisition of science capital in the field of chemistry. *Chemistry Education Research and Practice*, *21*(1), 220-236. https://doi.org/10.1039/C9RP00127A

Rüschenpöhler, L., & Markic, S. (2020c). How the home environment shapes students' perceptions of their abilities: The relation between chemistry capital at home and students' chemistry self-concept. *International Journal of Science Education*. https://doi.org/10.1080/09500693.2020.1812010

Further, the following publications have been produced in the research project:

Rüschenpöhler, L., & Markic, S. (2017). Kulturelle Unterschiede der Selbstkonzepte in der Chemie. In C. Maurer (Ed.), *Qualitätsvoller Chemie- und Physikunterricht—Normative und empirische Dimensionen. Gesellschaft für Didaktik der Chemie und Physik. Jahrestagung in Regensburg 2017* (Vol. 38). Regensburg.

Rüschenpöhler, L., & Markic, S. (2018a). Chemistry? Not my thing! Cultural differences in students' chemistry self-concepts. In I. Eilks, S. Markic, & B. Ralle (Eds.), *Building bridges across disciplines for transformative education and a sustainable future* (pp. 243–248). Aachen: Shaker Verlag.

Rüschenpöhler, L., & Markic, S. (2018b). Cultural influence on student self-concepts in chemistry: Questioning the traditional gender gap. In O. Finlayson, E. McLoughlin, S. Erduran, & P. Childs (Eds.), *Research, practice and collaboration in science education: Proceedings of the ESERA 2017 conference* (pp. 1547–1557). Dublin: Dublin City University.

Rüschenpöhler, L., & Markic, S. (2019c). Psychologische Muster in Chemie-Selbstkonzepten. In C. Maurer (Ed.), *Naturwissenschaftliche Bildung als Grundlage für berufliche und gesellschaftliche Teilhabe* (Vol. 39, pp. 129–132). Kiel: Universität Kiel.

Article 1

Self-concept research in science and technology – Theoretical foundation, measurement instruments, and main findings

Lilith Rüschenpöhler and Silvija Markic

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[9] The description of the author contributions follow the definitions provided by CRediT taxonomy (available online, https://www.casrai.org/credit.html, accessed on 17 September 2019).

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ARTICLE

Self-concept research in science and technology education – theoretical foundation, measurement instruments, and main findings

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ABSTRACT
This article gives an overview of the current state of science and technology self-concept research. Following a defined selection process, we analysed 74 peer-reviewed journal articles published from 1998 to 2017, which are indexed in the ERIC database and that deal with science and technology self-concepts (STSC) of school children and adolescents. In our analysis, we focus on the theoretical foundations, measurement instruments, and main findings from this area. (i) Theoretical foundations: today's research on STSC is mainly based on the Shavelson and Marsh models of self-concept, i.e. it follows the tradition of educational psychology. (ii) Measurement instruments: a number of established and validated measurement instruments are available. However, the existing methodological resources should be employed more rigorously. (iii) Main findings: Some findings are well documented, such as the positive relation with achievement, the gender gap, and the fact that students of non-dominant ethnic groups tend to have lower STSCs. Recommendations: in order to gain a deeper understanding of these phenomena, it could be fruitful to further elaborate connections with science identity research and to enrich STSC research with qualitative data.

KEYWORDS
Self-concept; science and technology; literature review; primary education; secondary education

Introduction

Self-concept research has received considerable attention in science and technology education over the last decades. The interest of many researchers is due to the close relation between self-concept and achievement (Marsh & Yeung, 1997b, 1997a) and career choices (Marsh et al., 2012). Students with positive science and technology self-concepts are more likely to choose a career in this field (Taskinen, Schütte, & Prenzel, 2013). However, despite all efforts, career aspirations to the fields of science and technology remain strongly gendered, classed, and racialised (DeWitt & Archer, 2015). This urges to assess self-concept research in science education. What has been achieved in the past? Where lie its strengths and what are the pitfalls? What could be promising new paths for research on self-concept in science and technology education?

In this article, we provide a cross-section analysis of current research on students' academic self-concepts in the fields of science, technology, and engineering. We limit

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our analysis to the science and technology self-concepts (STSCs) of school students because they are in a phase in which major career decisions still need to be made. STSC is therefore of major importance for these students in their decision-making process. In particular, we review STSC literature regarding three aspects: (i) we investigate the theoretical foundations of STSC research. With this analysis, we want to open the field for a reflection on its theoretical basis. (ii) We analyse the type of data used as well as the methods of data collection. With this, we want to provide an overview of available and well-tested instruments and methods for STSC researchers. (iii) We summarise the key findings available for STSC in order to give an overview of the knowledge base future STSC research can build upon.

We claim that STSC research still sticks to its roots in educational psychology and we suggest that elaborating connections with science identity research could open new opportunities. This is due to the fact that in both fields, researchers try to understand career choices (e.g. Archer et al., 2010) and tend to do so with different methods and different theoretical foundations.

Theoretical background

In this section, we will provide a brief overview of self-concept research in educational psychology. First, we will review central self-concept theories and then central findings about self-concept that have been made in educational psychology. This discussion will form the backdrop against which the literature on STSC will be analysed in this study.

Self-concept theories from educational psychology

We start this section with an overview of theories that have shaped self-concept research in educational psychology. Perhaps the best-known self-concept models in educational psychology are those of Marsh and Shavelson and colleagues. We will introduce these well-known models, but also show an alternative: Hattie's (2008) rope model takes a more process-oriented perspective on the self which could potentially open self-concept research to identity research. An extended discussion about the use of identity theories in science and technology education research is presented by Shanahan (2009).

Established self-concept models: the Shavelson and marsh line of research

Probably the most influential model of self-concept is the Shavelson model (Byrne, 2002). Here, self-concept is defined as 'a person's perception of himself' (Shavelson, Hubner, & Stanton, 1976). Based on an analysis of the methodological deficiencies and the lack of clarity in the theoretical foundation of self-concept research, Shavelson et al. (1976) proposed a model that emphasises a multidimensional, hierarchical structure of self-concept. It assumes a general self-concept that is the sum of all domain-specific self-concepts. The model takes up three dimensions of the self, i.e. the material, social, and spiritual selves since people have various self-concepts. For example, individuals possess physical, social, and academic self-concepts, which can be further subdivided into even smaller parts.

At first, researchers assumed that domain-specific academic self-concepts would be highly correlated so that it would be difficult to clearly distinguish between them. However, this did not prove to be the case. This was first shown by Marsh (1986, Marsh et al., 2012), who formulated the internal and external frame of reference model (I/E model). In the I/E model, it is assumed that two distinct frames of reference are relevant in the formation of self-concepts. On the one hand, comparisons with other peoples' skills are made, constituting the external frame of reference. On the other hand, internal comparisons between domains such as languages and mathematics are made. This means that students compare their own abilities in different areas and contrast them, leading to relatively low levels of correlation between mathematical and verbal self-concepts. Many studies (e.g. Marsh, 1986; Marsh & Hau, 2004; Möller & Köller, 2001; Möller, Pohlmann, Köller, & Marsh, 2009; Skaalvik & Rankin, 1990) confirmed that the verbal and mathematical self-concepts are almost totally uncorrelated, therefore providing evidence for the validity of the I/E model.

Since the emergence of the Shavelson and Marsh models of self-concept, much attention has been given to academic self-concepts. The power of this research lies in theoretically well-grounded instruments, which are quick and easy to administer (e.g. Marsh, 1992e; OECD, 2006), as well as in elaborate methods of data analysis. This means that large-scale studies can be conducted. Participation implies only small expenditures for individuals and the raw data can easily be transferred into numerical data which allow statistical analyses. By gaining insight into the self-concepts of larger groups, structural inequalities can be detected and the impact of political decisions that touch a great number of people can be investigated. In science and technology education, this helps researchers to differentiate between social groups which have confidence in their abilities and those who do not. This can, for instance, be used to evaluate interventions in schools.

Focus on self-processes: Hattie's rope model

While the Shavelson and Marsh models allow for an assessment of the strength of self-concept and provide precise measurement instruments for this, they do not allow to understand the individual dynamics underlying self-concept. This more individual, holistic view can be understood in terms of Hattie's (2008) rope model of the self. It emphasises the activities of the self: the self-processes. This focus on processes helps to understand how self-concept *works* in the self. It provides a framework to understand the rationales based on which self-concepts are formed. In this regard, Hattie's theory provides a new perspective on self-concept, a perspective that focuses on the inner processes that lead to the adoption of self-beliefs.

Hattie's model explains the strength of the self. According to Hattie, people choose strategies to protect, preserve, and promote the self. With these strategies, every person seeks intuitively to make his self grow stronger. And the self grows stronger as a person learns how his or her self works in different contexts. The focus in this model is therefore on internal strategies and choices. This makes it an approach based on inner action. The self is thought to be an entity that is constantly in the making (Hattie, 2008).

The self is thus composed of a number of psychological processes that help it become stronger. In order to achieve this, every person must develop a sense for context specificity, meaning that not every process works in all situations. For example, a learning goal orientation is said to have overall benefits on learning outcomes. However, this is not necessarily true for the individual self in every situation. If a student activates learning strategies in a subject he or she is not good at, there is the risk of experiencing failure. This can put the self in danger if this experience touches someone personally. It could also be a useful strategy to activate performance goals in these subjects to protect the self. On the other hand, learning goals might be more appropriate in subjects where the student's achievement is better in order to promote the self, because they are more likely to lead to success. Thus, the implementation of such self-strategies is extremely complex and the rationales behind these patterns are highly individual in nature. Every person needs to develop a situation-specific pattern of self-strategies in order to protect, promote, and preserve his or her self (Hattie, 2008).

Hattie's model can lead to research approaches that seek to understand the dynamics of self-concept and its meaning in his or her life. This opens self-concept research to identity research (for a discussion of science identity theory, see Shanahan, 2009). This could be of interest in science and technology education because it lays the focus on the processes of the self and thus the construction of identities. More precisely, with Hattie's model, we can study the strategies that lead the person to develop a certain self-concept. This allows for research aimed at understanding the rationales behind self-concept on a more individual level. As there is currently little research employing this model, there are no established methodological approaches. This implies higher expenditures of time and money in the development of new research methods if one wishes to use this model. However, the recognition of the individuality of self-processes means that fewer cases need to be studied more thoroughly. This enables investigations at a deeper level but makes it difficult to cover larger, representative samples.

Main findings about academic self-concept

In the following, we will summarise central findings from educational psychology about academic self-concept. These stem primarily from research based on the Shavelson and Marsh models of self-concept or one of their derivatives.

The relation with achievement

One central finding is the positive relationship between academic self-concept and achievement (e.g. Jansen, Schroeders, & Lüdtke, 2014; Marsh & Craven, 2006; Wylie, 1979). This relationship seems to be much stronger for domain-specific self-concepts and achievement than for general beliefs. This implies that domain-specific self-concepts can predict achievement more accurately than general self-concept beliefs (Marsh & Yeung, 1997b, 1997a).

Evidence points towards a causal relationship between the two variables which is reciprocal in nature. A positive self-concept has positive effects on achievement and success leads to a more positive self-concept. The two directions of the model are called skill development (self-concept influences the development of skills) and self-enhancement processes (achievement influences self-beliefs). Historically, these processes were discussed as two conflicting models, because they offer different explanations for the causal relationship between the two variables (Calsyn & Kenny, 1977). Today, the reciprocal effects model (REM) that integrates both processes is increasingly relied upon (Marsh, 1990a; Marsh & Craven, 2006). This model supposes that (on average) high achievement leads to a more positive evaluation of one's abilities and that a positive self-concept leads in turn to better achievement. It thus states that both skill development and self-enhancement processes are relevant for understanding the relationship between self-concept and achievement since they are reciprocal in nature. Subsequent research has confirmed the model (e.g. Marsh & Craven, 2006; Marsh, Hau, & Kong, 2002; Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2005; Valentine, DuBois, & Cooper, 2004), so that we can assume that it is the best available explanation for this phenomenon.

It is assumed that the relation between self-concept and achievement is mediated by other variables such as learning strategies. In fact, there is evidence that domain-specific self-concepts have a positive reciprocal relationship with deep learning strategies (McInerney, Cheng, Mok, & Lam, 2012), positive effects on motivation (Guay, Ratelle, Roy, & Litalien, 2010), the selection of tasks in school (Marsh & Yeung, 1997b), and many other variables.

The impact of self-concept on career choices

Career choice behaviour is related to domain-specific academic self-concepts (Eccles, 2011; Eccles & Wang, 2016). This is usually analysed in the expectancy-value framework (Eccles, 1983). According to Eccles' expectancy-value theory (1983; Wigfield & Eccles, 1992), two major considerations guide people in their career choices: (i) the extent to which they expect to succeed in a profession and (ii) the value they attribute to it. Self-concept falls under the first category and is considered a key variable for understanding career aspirations (Archer & DeWitt, 2017). This makes self-concept an important variable in science and technology education research if the goal is to understand career choice behaviour.

Development of self-concepts over time

Also, there seem to be typical patterns in the development of academic self-concepts over time. During childhood and adolescence, people experience important changes in their self-concepts. Two findings can be regarded as sufficiently validated: (i) the self-concepts of children and preadolescents are less differentiated than those of adolescents and adults. As self-concepts become more differentiated over time (Marsh, Craven, & Debus, 1998, 1991), the children's' self-concepts develop from relatively malleable to relatively stable, a process that is already well documented in educational psychology (e.g. Marsh, Trautwein, Lüdtke, Baumert, & Köller, 2007; Wigfield et al., 1997). (ii) On average, academic self-concepts decline in the transition from childhood to the beginning of adolescence (Harter, 1998, 1999; Marsh, 1989). One reason for this could be the fact that students develop a positive self-concept only in a certain number of areas due to identification processes. The development of identities during adolescence implies both an identification with certain domains and non-identification with others. In addition, the transition from primary to secondary school tends to have negative effects on academic self-concepts (Arens, Yeung, Craven, Watermann, & Hasselhorn, 2013). For researchers in science and technology education, this means that interventions aimed at influencing students' self-concepts about science and technology are probably most effective for younger children. These students are still in the process of developing their self-concepts and potentially more responsive than adolescents or adults whose beliefs about their abilities are relatively stable.

The effect of social comparisons: the Big-Fish-Little-Pond-effect

One of the best-documented discoveries is the existence of the Big-Fish-Little-Pond effect (BFLPE) (Marsh & Parker, 1984). The term BFLPE describes a frame of reference effect that is closely connected to the I/E model of self-concept. It shows the influence of the social context on a person's self-concept. Students in school environments with high average achievement levels evidence lower self-concepts on average when compared to students in environments where the achievement level is lower. The reason for this seems to lie in social comparisons. The students compare their abilities to those of their peers, which dampens gifted students' self-concepts if they attend a school where the average achievement level is high. Following the same rationale, positive effects for low achievers have been observed where the overall level of student ability is low. These effects have been shown by numerous studies (e.g. Marsh, 1990b, 1992a; Marsh et al., 2015; Marsh & Hau, 2003; Marsh, Köller, & Baumert, 2001; Marsh et al., 2008; Seaton, Marsh, & Craven, 2010). Therefore, the BFLPE has been widely accepted in the scientific community. Furthermore, the BFLPE has been shown to persist a few years after graduation from school (Marsh et al., 2007). Therefore, it can thus be described as being relatively stable over time (Marsh et al., 2008) among adolescents and young adults.

The impact of gender and culture

Academic self-concepts are subject to stereotypes (Baron, Schmader, Cvencek, & Meltzoff, 2014). Much research in educational psychology has investigated how gender stereotypes affect academic self-concepts, and especially so for mathematics and languages, based on evidence from the I/E model of self-concept. It was shown that girls have lower self-concepts in mathematics than boys even if the girls achieve better (Else-Quest, Hyde, & Linn, 2010).

These gender differences can be explained in terms of Balanced Identity Theory. It claims that every person seeks consistency in his or her associations of concepts – a psychological balance. Regarding gender, this means that if a person identifies strongly with his or gender group and a gender stereotype exists, then, the person will be likely to develop a corresponding self-concept. For example, if a girl identifies with being female and there is a stereotype that girls are not good at mathematics, she will be likely to develop a negative self-concept in mathematics. In terms of Balanced Identity Theory, the argument would be as follows: 'Me = Girl; Girls ≠ Mathematics; *therefore* Me ≠ Mathematics' (Baron et al., p. 113).

Gender stereotypes tend to be internalised at an early age. It could be shown for mathematics that primary school children associate mathematics with masculinity, that they have an implicit gender identity and tend to apply these stereotypes to themselves (Cvencek, Meltzoff, & Greenwald, 2011). It is supposed that these gender biases show already among pre-school children (Baron et al., 2014). Changing this situation seems to be very difficult, at least if interventions are addressed to adults. It has therefore been suggested to develop interventions for pre-school and primary school children because, at this age, the internalisation of gender stereotypes is probably not stable yet (Baron et al., 2014).

Besides gender, the students' cultural backgrounds seem to play a role. Students from non-dominant ethnic groups[1] tend to have lower academic self-concepts than those who belong to the dominant group (Dean, 2013). Also, interactions between race and gender have been discovered in some cases, suggesting that gender stereotypes can differ between subgroups. For example, African American males tend to have lower academic self-concepts than African American females while the inverse is true among Caucasian students (Dean, 2013). These findings show that cultural categories such as gender and ethnic groups impact students' beliefs about their individual abilities.

Methods

Research questions

Keeping in mind the theoretical background described above, we are interested in the current state of science and technology self-concept (STSC) research. We concentrate on the methods employed in STSC research, the theoretical foundation, and the main findings because these aspects can guide researchers who work with STSC in their research. Regarding the measurement instruments, the analysis aims to give a structured overview of STSC measures which can be employed in order to avoid the construction of new scales if sound instruments already exist. This is of interest because a multitude of self-concept measures exist in science and technology education research, an abundance which sometimes creates confusion about which instruments are available and which of these are well-tested. Further, we want to present central findings because this will give an overview of what has already been achieved and which questions remain open. Finally, we are interested in the theoretical foundations of STSC because this helps to understand the relation of STSC research to educational psychology and other fields of research. We limit the analysis to research about STSC in primary and secondary education because students in this phase still need to make major career decisions. The STSCs of theses students are therefore of special interest in science and technology education. In particular, we want to know:

(Q1) *Theoretical framework*. Which models of self-concept are used in STSC research?

(Q2) *Measurement*. Which instruments are available to measure STSC?

(Q3) *Results*. What are main findings presented about STSC?

Selection of articles and limitations in this process

In order to answer the above questions, we first defined a sample of articles which were supposed to portray contemporary research about STSC. During the selection process, we adapted the procedure which Potvin and Hasni (2014) used in their literature review on motivation, interest, and attitudes towards education in science and technology because they set retraceable criteria for defining a sample of articles. This methodological clarity opens up literature reviews to critical scrutiny, since the selection process can be replicated by other researchers. Just as Potvin and Hasni did in their review (2014), we used predefined criteria for the selection of the articles. Beyond that, we have classified these criteria into four categories that can be used in future literature reviews, in order to further systematise the selection process.

(1) *Database*. We defined ERIC as the reference source for choosing our articles, since it is one of the most influential databases for international educational research on science and technology education. ERIC includes the most important journals in science and technology education, but excludes articles not written in English. This certainly limits the representativeness of our sample because it does not capture local STSC research published in other languages which might differ from STSC research published at the international level. The sample can therefore only represent STSC research published at the international level. However, since major findings tend to be published in English to reach the international community, we decided to accept the bias produced by this choice.
(2) *Time period*. We included articles that had been published between 1998 and 2017, since we wanted to provide an analysis of contemporary trends in science self-concept research.
(3) *Publication type*. We analysed only journal articles that had undergone a peer-review in order to discuss findings and procedures that could be assumed to have been accepted in the scientific community. This excludes all articles in journals that use other selection processes, as well as book chapters and books. Based on current standards in international science education research, we assumed that publications in journals allow us to investigate the most important recent findings. However, this limits the representativeness of our sample if these sources favour some publication types over others (e.g. studies with quantitative data might be favoured). Despite this restriction, we believe that peer-reviewing has its benefits as a criterion for the degree of acceptance of ideas and results in the scientific community. Therefore, we decided to accept this risk. In addition, we limited our sample to articles that had been published in education journals or science and technology education journals and excluded all articles that reviewed literature.
(4) *Thematic focus*. Our search was limited to articles that mentioned 'self-concept' in the abstract or in the title and that related to science and technology in the title. We included only articles that focused on science and technology education of children and adolescents in primary and/or secondary school.

We carried out our search in ERIC on 29 June 2017. We used the following keywords and restricted the search to peer-reviewed journal articles:

> (title:'self-concept*' OR abstract:'self-concept*') AND (title:(science* OR biolog* OR chemistr* OR physics OR geolog* OR astronom* OR engineer* OR ecolog*)) AND (pubyear:(1998 OR 1999 OR 2000 OR 2001 OR 2002 OR 2003 OR 2004 OR 2005 OR 2006 OR 2007 OR 2008 OR 2009 OR 2010 OR 2011 OR 2012 OR 2013 OR 2014 OR 2015 OR 2016 OR 2017))

Since the search was carried out in summer 2017, the articles published hereafter are not part of our sample. In this first step, a sample of 94 articles was obtained. Then we scanned the titles and abstracts to exclude all articles that did not match the predefined age group (7), did not cover STSC (6), that did not focus on education or science and technology (4), were literature reviews (2) or covered a more general academic self-concept (1). A list of the remaining 74 articles which constituted our sample can be found in the appendix.

Analysis of the articles

In order to analyse the articles in our sample, an analysis grid was created, once again adapting the procedure developed by Potvin and Hasni (2014), but shaping the sections and questions to our needs. Our analysis grid comprised four sections. In Section (A), we collected general information about the articles in order to gain an overview of the articles' research interests. Here, we classified the articles according to their field of study (chemistry, science in general,…), the type of article (e.g. results of empirical research, literature review,…), and tried to formulate the purpose of the research in one sentence. Section (B) mapped the central findings presented in the articles. To do so, we marked the themes that were of central interest in the article (e.g. distribution of STSC regarding specific variables, relation to achievement,…) and specified the articles' contributions to the respective field. Part (C) focused on the theoretical foundation of science and technology self-concept research. Here, our aim was to find out which theoretical assumptions the research was based on. In this section, we first marked if an explicit definition of self-concept was given, and if yes, we marked which models of self-concept the articles referred to. In a personal comment, we briefly described for instance if the definition was clear, if STSC was only of minor concern in the article, etc. In Section (D), we categorised the research methods and procedures described by the authors in their articles. In a short comment, we described the sample, stating the number of participants and specific characteristics as for instance the age range or if the sample was drawn from multiple countries. We named the data source (e.g. PISA 2006 data, individual data sets,…), the employed research instrument, and the type of analysis that had been employed. In a comment, we further described the analysis procedure and commented on its appropriateness. Particular attention was paid to the measurement instruments the authors used to assess self-concepts. The complete grid can be found in the appendix of this article.

Presentation of the current state of STSC research

In this chapter, we will sum up the main findings of our literature review about science and technology self-concept (STSC) research and discuss them with further references to self-concept literature from educational psychology. Since we removed all literature reviews from the sample, almost all of the remaining 74 articles covered findings from empirical research. Only one article in our sample discussed an argument that had been made previously without referring to empirical data. Six studies (8 %) investigated the effects of interventions, while the vast majority of the studies covered STSC in relation to other variables (59; 80 %). Among the latter, some studies investigated self-concepts in more specialised fields such as physics (11; 15 %) or mathematics self-concepts (10; 14 %). Based on the three research questions we will discuss the theoretical framework the studies are based on, the methods used, and the main results obtained in the studies.

Theoretical foundations of STSC research

Current STSC research seems to be mostly based on the Shavelson and Marsh models of self-concept and thereby reflects the current mainstream in educational psychology. The articles in our sample referred most frequently to three models when defining self-concept: the I/E model (Marsh, 1986), the Shavelson, Hubner, and Stanton model (1976), and the Marsh and Shavelson model (1985). Hattie's rope model (2008) was not cited in any article. Although articles used STSC for an analysis of science identities [3, 5, 14, 29], none of these employed Hattie's model of self-concept. This seems to indicate a consensus in STSC research about which group of models self-concept is based upon.

This impression is confirmed by the remarkably high number of studies that did not refer to any specific self-concept model (54; 73 %). In many articles, self-concept was not even defined. This was mostly due to the number of variables these articles dealt with. Here, self-concept was not a major concern. It represented only one tool among many for evaluating interventions and educational settings [4; 15; 18; 22; 23; 48; 54; 55; 59] or for understanding course choices [3; 51], achievement [2; 28; 30; 32], and other variables [44; 50; 74]. Many studies investigated STSC as an auxiliary part of a larger construct such as science engagement [6; 16; 69], attitudes towards science [10; 13; 37; 73] or science identity [5; 14]. In these cases, where educational settings or broader concepts are the main focus and self-concept plays only a minor role, it is understandable that the authors did not define self-concept explicitly, even though it would be desirable. However, many good examples of studies in which STSC was not the main focus, but self-concept was still defined, could also be found [11; 17; 20; 29; 31; 40; 42; 56; 60; 61; 62; 68].

In articles where self-concept is the core of the research project, discussion of this variable tends to be more detailed. Many of these studies are less application-focused and show important overlaps with research in educational psychology. Therefore, the ratio of articles in which self-concept is defined and discussed more thoroughly was higher [1; 7; 9; 19; 21; 25; 26; 27; 33; 34; 35; 38; 39; 45; 46; 47; 49; 53; 57; 58; 63; 64; 70; 71; 72]. However, some articles provided unclear definitions of self-concept even though it is a key factor [12; 24; 41; 43; 65; 66]. In some cases, the definitions of self-concept are problematic, either confusing self-concept with a general self-value [8] or remaining rather vague [e.g. 21; 26; 42].

Science and technology self-concept measures

In most STSC studies, quantitative data were analysed which seems to be an adoption of the procedures employed in self-concept research in educational psychology. A total of 73 out of 74 studies which analysed empirical data (99 % overall) collected data about self-concept using a Likert questionnaire. Only one study analysed exclusively qualitative data [29]. An additional six studies opted for a Mixed Methods approach [3; 5; 14; 33; 37; 43; 71], which means that qualitative methods were effectively employed in 10 % of the studies. Most frequently, interviews were used in addition to Likert questionnaires. Only three of the studies used researchers' observations or their personal impressions of the intervention [29; 66; 71]. One study followed a quasi-experimental design [4].

PISA and TIMSS scales

In many cases (26 articles; 35 %), data were not collected individually for the study. The researchers employed secondary data such as the PISA and TIMSS data sets. In

PISA and TIMSS, self-concept is conceptualised as part of student engagement in science (OECD, 2009, pp. 55/56). The documentation of both studies did not state explicitly what definition of self-concept the scales are built upon. However, the items of both scales resemble those of Marsh's self-description questionnaire (see the following section). In 14 studies, TIMSS data was used [1; 2; 9; 32; 35; 36; 39; 41; 47; 51; 63; 64; 65; 67; 72], which make them slightly more popular in our sample than PISA, which was used in 11 studies [12; 16; 21; 30; 31; 45; 46; 49; 53; 57; 60]. One study used the PISA self-concept scale for data collection in an individual research project [61]. The TIMSS and PISA self-concept data are thus the most frequently analysed sources in STSC research. However, the TIMSS 2011 study has some methodological difficulties. Its negatively worded items lead to important bias, even though the correlations between self-concept and other variables measured in the study were quite similar across countries [for an extended discussion see 39]. Hence, critical scrutiny is needed whenever analysing TIMSS 2011 data. The confirmatory factor analysis that was conducted with the PISA 2006 data set (OECD, 2009, p. 323/324) revealed RMSEA values ranging between .035 and .074 among the participating countries. These are acceptable values in most cases, if the cutoff criteria is set at .06 (Hu & Bentler, 1999). The CFI ranges between .95 and .98 – values that are acceptable, too (Hu & Bentler, 1999). The internal consistency appears good with Cronbach's alpha varying between .85 and .95 in these samples. However, a more holistic, case-specific analysis of the scale would be desirable, since these cutoff criteria should be interpreted as rules of thumb (Marsh, Hau, & Wen, 2004).

Marsh's self-description questionnaires (SDQ)

The most frequently used scales for individual research projects turned out to be the subscales for science and mathematics from the self-description questionnaires (SDQ) developed by Marsh. SDQ I (Marsh, 1992b) was designed for research with preadolescent children. SDQ II (Marsh, 1992c) can be used with young adolescents. SDQ III (Marsh, 1992d) was designed for late adolescents and adults. All three measures provide several subscales, such as the mathematics or science self-concept scales. These subscales have established themselves in the field, because they show good measurement properties. Their construct validity is good, since they were grounded in the knowledge about the I/E model of self-concept. Multiple factor analyses have shown good model fit with the intended constructs (Marsh, 1989, 1990b, 2005) and the psychometric properties of the scales have been shown to be good (Marsh, Richards, & Barnes, 1986). In our sample, seven studies used one of these scales for their research. In five of the seven studies, an adapted version was used [6; 8; 27; 33; 70]. Only two studies used the scales as they appear in the literature [17; 40].

Fennema-Sherman scale for mathematics

Another scale that has established itself in education research is the Fennema-Sherman mathematics attitudes scale (Fennema & Sherman, 1976). The scale is called 'The Confidence in Learning Mathematics Scale' and therefore not embedded in the self-concept literature. This is probably due to the fact that the model by Shavelson, Hubner, and Stanton was published in the same year (1976). The authors therefore do not refer to this term although the scale is today interpreted as a self-concept scale. In our sample, it was used only once in its original form [4]. Two other studies adapted it for science education research [38; 59], which is not within the scope of the original instrument. Except for the high correlation between the mathematics anxiety scale and the confidence in learning mathematics scale (.79 – .89), the factor structure fell out as expected (Broadbooks, Elmore, Pedersen, & Bleyer, 1981; Fennema & Sherman, 1976).

Lesser-used scales

Three new scales were presented in the studies we sampled. Kind, Jones, and Barmby [26] provide an integrated attitude towards science scale that was used in four of the studies [37; 54; 55; 73]. This scale can be useful if several variables belonging to the attitude construct are to be assessed in one study. Capobianco, Yu, and French [5] have developed an engineering-specific identity scale, which includes an engineering self-concept measure. Hardy [19] presented a measure for science self-concept that was inspired by Marsh's SDQ. He assumes that separate self-concepts exist for the different science domains. His scale contains items concerning self-concepts in biology and physics, including scientific inquiry and the Nature of Science. This instrument is problematic in at least two respects. First, the assumption that students have self-concepts concerning the Nature of Science and scientific inquiry requires further investigation. Second, the scale's items more closely resemble the self-efficacy construct than they do the self-concept. Self-efficacy refers to what people believe they are able to do. In contrast, self-concept is an evaluation of one's competences and therefore not task-oriented in nature. The two constructs need to be distinguished between (Bandura, 1997; Bong & Skaalvik, 2003). This scale cannot therefore be recommended for use in further studies, unless evidence exists for the different subscales and proof of the items' distinction from self-efficacy beliefs is clear.

For some other national and international studies that were present in our sample, such as the ROSE [3], NELS [7; 34; 50], UPMAP [43; 44], LSAY [13], and ASPIRES [10] studies, individual self-concept scales were used. The scale for the ASPIRES study was grounded in established measures, but the exact genesis was not described in the present article. In the longitudinal NELS study, the self-concept scale was changed several times, which complicates longitudinal analyses immensely. In the German language, two scales (Hoffmann, Häussler, & Peters-Haft, 1997; Wünsche & Schneewind, 1989) are available for physics that have been used in several studies [18; 20; 23; 74].

Unclear scale construction

In some of the studies in our sample, measurement design difficulties occurred. In some cases, too few items were used [13; 14; 22]. One study used a self-efficacy scale and evidenced some confusion of the two concepts [66]. In many other cases, the development process of the scales was not discussed or the information provided did not allow for a clear understanding of the scale construction process [10; 11; 13; 15; 20; 29; 43; 44; 56; 58; 62; 71].

Main findings about science and technology self-concept

The relation of STSC with achievement

In our sample, 14 out of the 74 studies (19 %) investigated the relationship between self-concept and achievement, which places it as one of the most popular aspects [1; 2; 16;

28; 30; 31; 32; 33; 40; 41; 44; 47; 63; 67]. The positive relation between self-concept and achievement could be shown also for STSC by several studies in our sample [1; 2; 16; 28; 31; 40; 41; 47; 63; 67]. STSC seems to be one of the strongest predictors for achievement in the domains of science and technology [41]. This confirms the findings from educational psychology.

Despite the assumption of an overall positive relation, the I/E model predicts that individual students can have negative self-concepts in a domain, even if they show levels of high achievement. (Möller, Retelsdorf, Köller, & Marsh, 2011). This has also been shown in our sample using both qualitative [44] and quantitative methods [9; 70]. This partial dissociation between self-concept and achievement could be a trade-off in the development of a personal identity that could be temporary in nature. Here, it would be interesting to gain further insights in the narratives adopted by the students that allow for this dissociation. In particular, it could be insightful to analyse these phenomena using Balanced Identity Theory (Baron et al., 2014) in order to investigate how these students reach a balance despite this dissociation.

In contrast, some studies in our sample suggest that the relationship between achievement and self-concept might be weaker or even negative in some East Asian countries [30; 32; 67] which would oppose the insights provided in educational psychology. However, the findings do not necessarily support this claim. Keeping in mind that the response styles differ between collectivist and individualist cultures (Byrne et al., 2009), one could also assume that the differences are due to measurement bias, because Likert questionnaires do not work the same way in all cultures. This is especially true for self-concept research. It is therefore unclear if the deviation from the general positive association between achievement and self-concept is a substantive difference, or if it is due to measurement difficulties.

Potential mediating variables between STSC and achievement have been investigated as well. Here, the possible influence of self-concept on successful learning behaviour is often suggested but still lacks clear empirical evidence (Möller & Trautwein, 2015). In our sample, only two studies (3 %) dealt with the relationships between self-concept and behavioural patterns in class. The findings are mixed. While one study suggests that STSC might be positively associated with the students' verbal engagement in class [23], the link between STSC and adaptive types of behaviour remains unclear [8]. Regarding psychological patterns, STSC seems to be associated with a number of variables that play an important role in learning science in school. Overall, students with low self-concept tend to have more negative attitudes towards science [56], show positive thinking patterns less frequently [37], have lower interest levels in science [60], and be more prone to learned helplessness [74].

Further, investigating typical behavioural and thinking patterns of students with positive and negative self-concepts could be insightful in two regards. First, it could help us understand possible causal relationships between STSC and achievement in science and technology. Without an understanding of the underlying mechanisms, we can only speak of an association. Any suggestions that enhancing students' STSC might produce better achievement remain speculation. Second, knowledge about these mechanisms could help teachers in the often difficult task of understanding their students' behaviour. It can also inform their teaching practices. Given this outlook, it seems evident that more research regarding concrete student behaviour associated with self-concept would be of value.

The impact of STSC on career choices

In line with the expectancy-value theory from psychology, a positive association between STSC and career choices in the corresponding domains has been shown by several studies in our sample [11; 34; 60]. Eccles and Wang [11] elucidate how self-concepts interact with other factors towards science, technology, engineering, and mathematics (STEM) career choices: (i) a high self-concept in mathematics and a lower interest in working with people predict STEM career choices, (ii) family values have an impact on choosing a career in STEM only for girls, while boys seem to choose STEM careers independently of family values, (iii) the degree to which a person wants to work with and to help people predicts the choice of the subdomain in STEM. These values are positively associated with occupations in health, biological, and medical sciences. Girls are less likely to choose STEM careers than boys. But if they do, they most often opt for health and biology related occupations, rather than a career related to mathematics, physics, engineering, and computer sciences. This has also been documented by Sikora and Pokropek [57]. The expectancy-value theory not only affects career choices but course choices as well, a fact that has been shown for post-compulsory physics [43]. It seems reasonable to expect similar relations for the other STEM subjects. It can thus be concluded that STSC has an important impact on career choices. Furthermore, the science domain appears to be gendered with health and biology related fields being more frequently chosen by females than engineering, mathematics, physics, and computer science related fields.

A similar line of argumentation is employed in an article trying to explain students' choices of leisure time occupations [21]. Even though the authors do not refer to the expectancy-value model (Eccles, 1983; Wigfield & Eccles, 1992), the five factor model they test against a PISA data set relies heavily on Wigfield's and Eccles' assumptions. Jack, She, and Lin [21] show that two groups of factors have a positive influence on leisure science engagement. On the one hand, self-concept and self-efficacy are positively related to leisure engagement. These variables represent the self-beliefs in expectancy-value theory. The personal and general values of science represent the value aspect and were shown to be positively related to leisure science engagement as well. In the field of leisure science engagement, too, the expectancy-value theory thus seems to help understand students' choices. It emphasises the close relationship between STSC and choices for or against the introduction of science activities into the students' lives, be it in the students' free time, in school or on a professional level.

Furthermore, STSC seems to be a good overall predictor for science aspirations [10; 51]. This comes as no surprise, using the expectancy-value model (Eccles, 1983; Wigfield & Eccles, 1992) as a theoretical framework. However, looking more precisely at specific subgroups, the relation between STSC and science aspirations becomes more ambiguous. One study suggests that association between the two variables might be stronger for boys than for girls, since high-aspiring girls tend to have lower self-concepts than boys [44]. It seems like the overall association is positive, but to different degrees depending on gender and ethnicity. This is indicated by one study [51] showing a strong association between the two factors for White boys and Hispanic girls, and a weaker association for White and Black girls.

Development of STSC over time

The findings from educational and personality psychology regarding age differences in self-concept have been validated for STSC. One study showed that engineering self-concepts can be influenced more positively in preadolescents than in elder children [5]. This confirms the finding in educational psychology that self-concepts become more stable over time (e.g. Marsh et al., 2007; Wigfield et al., 1997). Another study provided evidence of the decline in motivational beliefs from childhood to adolescence [36]. Although the study did not analyse longitudinal data, it is reasonable to assume that the same relationship between age and self-concept exists as has been shown in general educational psychology, which was further confirmed by a third study of our sample [13].

The effect of the social context

Social environment also seems to play as important a role in the development of STSC as socioeconomic status does. But parent behaviour and beliefs may also have an impact on their childrens' STSCs. One study showed that students' perceptions of their parents' beliefs about the utility of science could be positively associated with STSC [38]. Also, learners' perception of parental support appears to be positively associated with students' STSC [58]. However, these studies relied only on student reports. Neither asked the parents, nor did they directly observe parental behaviour towards the children. The findings are thus to be taken with caution.

The impact of gender and culture on STSC

Gender differences are one of the most prominent topics in science and technology self-concept research. The existence of a gender gap in most Western societies is hardly contested among researchers. Numerous studies in our sample show that boys tend to have stronger science and technology self-concepts than girls in Germany [23], the U.S. [34; 51; 59], and England [44]. A similar pattern exists in Hong Kong [62], which is highly influenced by Western culture. Also, a study conducted in Tanzania found a gender gap [38]. However, this latter finding should be taken with caution, since the authors used data of a relatively small sample, where it is not clear if the data show a trend that is representative for the entire country's population. One study found no gender gap in a regression analysis of the Canadian and Australian data sets of PISA 2006 [68], which questions the universal character of the gender gap. However, evidence for the existence of a gender gap in favour of boys seems to be sufficient for many Western societies. One source of this gap seems to be the mechanisms of over- and underestimation in the students' minds. Boys tend to overestimate their abilities [23], while girls tend to doubt their abilities in science, even if they are high achievers [44]. These findings about the impact of gender on STSC confirm the assumption from educational psychology that self-concept is shaped by gender (Baron et al., 2014).

The gender gap in STSC seems to be anchored in cultural patterns. In some Asian countries, the case seems to be different [30]. For instance, no gender gap was found in a sample from Malaysia and Singapore [47]. One possible explanation for this could be a learning culture inspired by Confucian philosophy [30] with its emphasis on collectivist values. These include more humble attitudes and a weaker focus on the self (Triandis, 2001), which could mean that a smaller number of students overestimate their abilities and that self-concept is less important to them. This could, in turn, reduce the gender gap by placing more emphasis on the community instead of on the gender of individuals. Also, different conceptions of femininity and masculinity could play a role, since one qualitative study of our sample points out how girls conceptualise physics as a masculine subject. Identifying with the subject might be seen to endanger their identity as females [3]. If the conceptions of gender differ between East Asian and Western countries, this could be another possible explanation for the cultural differences in STSC gender gaps.

Investigating cultural differences is quite popular in contemporary STSC research, since gender stereotypes are not the only cultural patterns that might affect STSC. Out of the 74 articles, fourteen (19 %) engaged in cross-cultural comparisons. All of them processed quantitative data, mostly drawn from the TIMSS and PISA studies [9; 30; 32; 39; 45; 46; 47; 53; 57; 64; 67; 68; 69; 72]. One study described the so-called Chinese paradox, dealing with differences between students in some East Asian and Western countries. Following Lau [30], Chinese students tend to have lower STSC despite better performance than students in some Western countries. If we extrapolate this finding, it could be hypothesised that East Asian students tend to underestimate their abilities whereas Western students tend to overestimate them. Also, the positive association between a person's science self-concept and the personal value of science seems to be stronger among Western students [53]. Both patterns could be interpreted in terms of the opposition between collectivism and individualism where the importance of the individual and the community differ. In the individualist pattern, focusing on the individual implies that it seems more natural to tie personal values to one's abilities. In contrast, if more emphasis is put on the community, as in the collectivist pattern, people tend to value domains such as science if it is to the common good, regardless of one's personal abilities. This could be one possible explanation for the fact, that achievement and self-concept seem to be less closely tied in some East Asian countries.

Also, quite a large portion of the studies (11 studies, 15 %) covered differences in STSC between different ethnicities living in the same country [1; 2; 7; 8; 10; 22; 34; 47; 51; 58; 68]. The studies indicate that on average, students from non-dominant ethnic groups tend to have lower STSC than students of the dominant ethnic group in the U.S. [34; 51; 58], Australia, and New Zealand [68]. However, students with an Asian background living in Western countries seem not to follow this trend. Their STSC and science aspirations have been shown to be higher than those of all other student groups in the UK [10]. This makes clear that the differences cannot be directly attributed to the students' background cultures. Asian students living in Asia tend to have lower STSC than students in Western countries. But Asian students living in the UK seem to have higher self-concepts than their British peers.

Here, it may be fruitful to take a more holistic perspective and look at the students' social positions. Australia, New Zealand, and the U.S. all have important histories of racial conflicts and structures of social repression aimed at the same marginalised ethnic groups, whose children now show weaker STSC. Therefore, the findings could allow for the hypothesis that STSC tends to be lower in social groups that have experienced (or still experience) repression and social inequalities, as it has already been hypothesised by Aikenhead (1996, 2001)) and others. One important factor is the socioeconomic status [58] which tends to be lower in non-dominant ethnic groups that have experienced suppression. Since socioeconomic status is positively associated with STSC [28] and has been shown to be even one of the strongest predictors of Scientific Literacy [68], it is important to take a holistic view on possible factors influencing the STSC of students from non-dominant ethnic groups, including the groups' social positions and histories. However, the hypotheses described here can neither be accepted nor refuted at present. Further research would be necessary.

Ways to change STSC

Some studies investigated how students' STSC could possibly be changed through interventions or changes in educational settings. The most prominent measure intended to reduce the gender gap in STSC and achievement is the implementation of single-sex classrooms. An underlying assumption is that boys outperform girls and that the formation of single-sex classrooms could allow for a learning culture that would better meet the girls' needs. The argumentation can be grounded in the literature about the Big-Fish-Little-Pond effect which has been shown to be a constant effect across the different cultures and also in science education [35; 45; 46]. This effect underscores the fact that social comparisons influence individual self-concepts. When surrounded by high-achievers, a student's self-concept tends to be lower than if all peers are low-achievers. Following this line of argumentation, single-sex classrooms could provide benefits for girls, especially because the Big-Fish-Little-Pond effect in science seems to be more important for girls [49]. However, the effects are not clear. One study of our sample confirmed the hypothesis that single-sex classrooms enhance girls' self-concepts in science [24]. Another study found negative effects for girls, but positive effects for boys [52]. A third study concluded that single-sex schooling had no impact on science self-concept [4]. The question remains unresolved. It is very difficult to produce valid knowledge about the effects of single-sex schooling because selection biases are very likely to occur in this field among the teachers as well as among the students. Randomised controlled trials are also very difficult to handle.

Besides single-sex schooling, repeating a school year did not improve STSC or achievement [12]. It even weakened the students' self-concepts when compared to students with a similar achievement profile who did not repeat a grade. It might be advisable to concentrate research on topics that are more promising to reveal potential for change such as approaches in teacher training.

Changing the curriculum was investigated as another possible measure that could influence students' STSC. First insights into the impact of these changes can best be gained through the assessment of interventions. However, it is important to notice that self-concept is relatively stable over time (e.g. Marsh et al., 2007; Wigfield et al., 1997), especially in secondary school where all science and technology interventions in this sample were implemented. Unfortunately, most of the interventions were of very short duration, ranging from a museum visit lasting only a few hours to a three-week program [22; 54; 55; 66]. Even though these interventions claimed to have had a positive impact on self-concept, the long-term effects had not been evaluated. When assessing the effects of interventions on STSC, we need to look at long-term changes, because changes in self-concept touch a person's core. Processes of this kind probably need time to develop their full effect. It is therefore rather unlikely that short educational interventions can show lasting effects on a person's being. But if this was the case, such changes could only be proved with an assessment of self-concept that takes place a reasonable period of time after the intervention. One study did evaluate the long term-effects [55]. To the authors' surprise, the STSC of students from non-dominant ethnic groups had declined although the intervention had originally been designed to improve these students' STSC. However, these effects could also have been produced by other factors. In this study, the students took part in an out-of-school science project. This might have triggered self-reflexion on the realistic chances for a career in science as members of a non-dominant ethnic group. The negative changes would then be due to latent discriminatory structures in society and not to the intervention itself.

The studies concerning teachers' impact on their students indicate some very interesting lines for further research. The mere fact that science and technology teachers are female did not correlate positively with STSC among girls [14]. The qualitative part of this study revealed that the students did not perceive their science teachers as role models unless they had experience in science fields outside of school. Second, in one study, teacher beliefs about gender stereotypes predicted more positive self-concepts in boys and more negative self-concepts in girls [61], but this association would need further empirical validation. Third, there seem to be positive effects of cooperative learning environments for students with low STSC – they showed better achievement test results than comparable students in a traditional learning environment without cooperative methods [18]. Here too, the findings need further clarification. We do not know if the mode of instruction made a difference for all students with low self-concepts, or if it had positive effects for girls in particular, because they tend to have lower self-concepts.

One study merits closer scrutiny [22]. Here, the authors implemented a curriculum reform that goes beyond the short-term interventions described earlier. The aim of the study was to enhance gender equality in physics classrooms via an intervention that changed both the students' and the teachers' education. The authors adapted the content of physics classes to include areas of interest to both boys and girls. By doing this, the authors hoped to raise the interest level of both gender groups. In addition, the teachers received special training to show them how to help girls develop a positive physics self-concept in class. The intervention seemed to have positive effects on the girls' self-concepts and achievement without discriminating against the boys. Interventions of this kind could lead to real progress in the question of how STSC and gender differences could possibly be changed. This is because they employ a long-term strategy targeting both the curriculum and teacher training with measures that are grounded in the literature.

Conclusion

A sample of 74 peer-reviewed journal articles dealing with STSC in primary and secondary school students was analysed with special attention being paid to the central findings that have been made, the theoretical foundations and the employed methods.

In the following, we will discuss the findings and provide an outlook for further research about STSC.

Resolved questions in STSC research

During the past 20 years, important progress has been made in research about STSC. First, the developments in self-concepts during childhood and adulthood that had been discovered in educational psychology were confirmed: the average STSC declines from childhood to adolescence. Second, the positive relations between self-concept and career choices and achievement that had been found in educational psychology could be confirmed for STSC. Third, the gender gap that exists in most Western societies in STSC can be regarded as sufficiently grounded in literature: boys tend to have higher STSC than girls. Related to this, changes of the educational structure have been investigated, but the findings are not very promising: single-sex education and increasing the number of female science teachers seem not to be effective in closing the gender gap. Fourth, the STSCs of students from non-dominant ethnic groups tends to be lower compared to those of students who belong to the dominant ethnic group of a country. In these areas, the findings that had been made in educational psychology were scrutinised in the field of science and technology. This points towards the intimate relationship between research on STSC and educational psychology.

Open questions in STSC research

Some questions remain unresolved. Especially, certain processes lying behind the observed phenomena have not been sufficiently understood in STSC research, as for example the exact thinking patterns behind the gender gap. Also, we do not know why the STSCs of students from non-dominant ethnic groups tend to be lower. Here, identity research and cultural studies could possibly inform research in STSC. For example, conceptions of gender and identification processes could be one part of the puzzle for explaining the gender relations. Future research in this domain could benefit if it adopted identity theories and theories about the cultural formation of gender in order to gain a deeper understanding of the situation. Also, an approach that unites self-concept with identity research could shed light on cultural differences in STSC. The histories of the non-dominant ethnic groups in the country of concern also need to be considered. This includes an analysis of present and past racial conflicts and the individuals' social status.

Besides the mental processes lying behind the phenomena, the question of how STSCs can be changed through interventions still seems to lack concrete answers. If single-sex education and increasing the number of female science teacher does not help to close the gender gap, what can we actually do? If students of some non-dominant ethnic groups show systematically lower STSCs, what could we change to render education more equitable? There are teaching approaches that promise to provide pathways towards more equitable teaching, such as for instance the Science Capital Teaching Approach (Godec, King, & Archer, 2017) or Culturally Responsive Science Teaching (e.g. Codrington, 2014). The impact of these teaching approaches on STSC seems not to have been sufficiently investigated. Here, it would be interesting to analyse the actual teaching practices employed in the classroom and their impact on STSC. Both the thinking patterns and the practical implications require STSC research to connect with research fields other than only educational psychology. In addition, one thing seems to be clear: evidence suggests that interventions should take place at an early age in order to be effective. Until the age of about 7/8, students' STSCs are still malleable enough for interventions to show an effect.

Available measurement instruments for STSC

We found that almost all STSC research uses questionnaire data with Likert-type items and quantitative methods for the analysis. A number of established and validated measurement instruments are available for STSC, such as the SDQs (Marsh, 1992b, 1992c, 1992d) and the Fennema-Sherman scale (Fennema & Sherman, 1976). For global science self-concept, the PISA scale (OECD, 2006) also seems to be suitable. For mathematics self-concept, the PISA 2012 scale (OECD, 2013, p. 87) is available. Some subject-specific self-concept scales have already been used in our sample, too, but a further investigation of their psychometric properties would be desirable. Regarding this aspect, science and technology education research benefits greatly from the methods and instruments developed in educational psychology. The high quality of the instruments constitutes a great strength of contemporary STSC research.

However, the available instruments are not always used and new ones are developed instead, which impedes methodological clarity and comparability. In a considerable number of cases, the theoretical assumptions as well as the structure and the validity of new measurement instruments seemed not to be documented and the studies therefore lack clarity. The construction of a scale and its psychometric properties need to be described. It is indispensable that authors not only name their sources, but also describe which items of existing scales have been selected, on what grounds, and which alterations have been made. Further, it is imperative to make the instruments accessible to other researchers. These rules are sometimes neglected in STSC research, leading to results that cannot be discussed.

The need for a greater methodological variety in STSC

Using qualitative data is very uncommon in STSC research although the exclusive use of quantitative methods can create measurement problems. Schools in many countries and regions of the world are places shaped by cultural diversity. For this reason, quantitative data need to be interpreted very carefully and it has been suggested that quantitative research should employ additional qualitative data (Byrne, 2002; Byrne et al., 2009; van de Vijver & Poortinga, 2005). This kind of Mixed Methods design can help control the findings obtained with quantitative methods by providing a framework for the interpretation of the results. Research in a Mixed Methods design could provide valuable insights into STSC.

Another argument for considering Mixed Methods designs in STSC is the fact that the qualitative data could enhance the explanatory power. If research employed both qualitative and quantitative methods, it would be possible to investigate what a positive or a negative STSC means in the lives of concrete students and how it affects their individual thinking and the narratives they adopt. This could yield important information for the design of interventions because these could address concrete thinking patterns and narratives. This way, the results could be more meaningful in the concrete teaching contexts of science and technology classes at school. Research which targets change would require longitudinal data, long-term interventions and psychological experiments, all of which are rare in current STSC research. Regarding research methods as well, an emancipation from educational psychology could enhance the power of STSC research.

Theoretical foundation of STSC research

Research on STSC is mainly based on the Shavelson and Marsh models of self-concept. This constitutes a consensus in STSC research that follows the tradition of educational psychology in which these models dominate the field. Many studies failed to provide a definition of self-concept which can be interpreted as an implicit acceptation of the dominant self-concept models. This consensus in the theoretical foundations of STSC is a big advance for STSC research. It has the advantage that the theoretical foundations are not questioned and the researchers can explore how the concept of STSC can help us understand certain phenomena. This way, important findings have been made.

Sticking to the established models, however, has the drawback that phenomena such as gender relations or science career trajectories can only be partly understood. As discussed above, we believe that STSC research would benefit from an integration of qualitative data. Hattie's rope model (2008) could be a possible starting point for such qualitative studies about STSC. Using the rope model, it would be possible, for instance, to conduct interviews with students about their self-concepts that are not limited to the question of how they evaluate their abilities. Instead, the students' perspectives could be investigated, aiming at understanding the meaning of their STSCs in daily life, their unique experiences, and the feelings and narratives that are hidden behind their self-concepts.

Hattie's model shows the deep connection of self-concept research with identity research. The process orientation in his approach can help to understand the individual dynamics connected to self-concept. For STSC research, this means that recalling this connection could constitute a basis for thinking science and technology self-concept in its intertwinement with science identity. In order to advance both identity and self-concept research in science and technology education, it could be fruitful to further elaborate the connections between the two domains. This could advance our understanding of the mental and behavioural processes underlying phenomena such as the gender gap or the lower STSCs in non-dominant ethnic groups. A deepened understanding of STSC would acknowledge the dynamic nature of the self and possibly the collective narratives that are connected to STSC. This kind of research requires to look at STSC through the lens of identity construction.

Summary

With the present literature review, we aimed to provide an overview of science and technology self-concept (STSC) research literature. We analysed a sample of 74 articles dealing with STSC of school children and adolescents. At present, STSC research is deeply connected with research in educational psychology which is reflected in the theoretical foundations, the use of research methods, and the findings. In particular, STSC research is grounded in the Shavelson and Marsh models of self-concept and employs mostly quantitative methods. Some findings are well-grounded in the literature, such as the gender gap and the fact that students from non-dominant ethnic groups tend to have lower STSC than students of the dominant group. However, this close connection with educational psychology has its drawbacks. Practical implications and a deeper understanding of the employed narratives and the processes underlying self-concept are missing. STSC research found mixed evidence for single-sex schooling in reducing this gap. Other practical implications for the field of science and technology education seem to be absent. We argue that to achieve this, it could be fruitful to work with process-oriented models of self-concept such as the rope model by Hattie (2008), or to connect more deeply with science identity research. Further advances in STSC would also need a greater range of methodological approaches such as psychological experiments, identity research, and the evaluation of teaching interventions with both the established STSC research instruments and qualitative data.

Note

1. In this article, we employ the term of 'non-dominant ethnic group' to describe the groups of students that do not belong to a country's ethnic majority.

Disclosure statement

No potential conflict of interest was reported by the authors.

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References

Aikenhead, G.S. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education*, *27*(1), 1–52.

Aikenhead, G.S. (2001). Students' ease in crossing cultural borders into school science. *Science Education*, *85*(2), 180–188.

Archer, L., & DeWitt, J. (2017). *Understanding young people's science aspirations. How students form ideas about 'becoming a scientist'*. London, New York: Routledge.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). "Doing" science versus "being" a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education*, *94*(4), 617–639.

Arens, A.K., Yeung, A.S., Craven, R.G., Watermann, R., & Hasselhorn, M. (2013). Does the timing of transition matter? Comparison of German students' self-perceptions before and after transition to secondary school. *International Journal of Educational Research*, *57*, 1–11.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W.H. Freeman.

Baron, A.S., Schmader, T., Cvencek, D., & Meltzoff, A.N. (2014). The gendered self-concept: How implicit gender stereotypes and attitudes shape self-definition. In P.J. Leman & H.R. Tenenbaum (Eds.), *Gender and development* (pp. 109–132). East Sussex: Psychology Press.

Bong, M., & Skaalvik, E.M. (2003). Academic self-concept and self-efficacy: How different are they really? *Educational Psychology Review*, *15*(1), 1–40.

Broadbooks, W.J., Elmore, P.B., Pedersen, K., & Bleyer, D.R. (1981). A construct validation study of the Fennema-Sherman mathematics attitudes scales. *Educational and Psychological Measurement*, *41*(2), 551–557.

Byrne, B.M. (2002). Validating the measurement and structure of self-concept: Snapshots of past, present, and future research. *American Psychologist*, *57*(11), 897–909.

Byrne, B.M., Oakland, T., Leong, F.T.L., van de Vijver, F.J.R., Hambleton, R.K., Cheung, F.M., & Bartram, D. (2009). A critical analysis of cross-cultural research and testing practices. *Training and Education in Professional Psychology*, *3*, 94–105.

Calsyn, R.J., & Kenny, D.A. (1977). Self-concept of ability and perceived evaluation of others: Cause or effect of academic achievement? *Journal of Educational Psychology*, *69*(2), 136–145.

Codrington, J. (2014). Sharpening the lens of culturally responsive science teaching: A call for liberatory education for oppressed student groups. *Cultural Studies of Science Education*, *9*(4), 1015–1024.

Cvencek, D., Meltzoff, A.N., & Greenwald, A.G. (2011). Math-gender stereotypes in elementary school children. *Child Development*, *82*(3), 766–779.

Dean, L.M. (2013). *Factors that influence minority student enrollment at various levels of postsecondary education*. Ann Arbor, MI: ProQuest LLC.

DeWitt, J., & Archer, L. (2015). Who aspires to a science career? A comparison of survey responses from primary and secondary school students. *International Journal of Science Education*, *37*(13), 2170–2192.

Eccles, J. (2011). Gendered educational and occupational choices: Applying the Eccles et al. model of achievement-related choices. *International Journal of Behavioral Development*, *35*(3), 195–201.

Eccles, J.S. (1983). Expectancies, values, and academic choice: Origins and changes. In J. Spence (Ed.), *Achievement and achievement motivation* (pp. 87–134). San Francisco: W. H. Freeman.

Eccles, J.S., & Wang, M.-T. (2016). What motivates females and males to pursue careers in mathematics and science? *International Journal of Behavioral Development*, *40*(2), 100–106.

Else-Quest, N.M., Hyde, J.S., & Linn, M.C. (2010). Cross-national patterns of gender differences in mathematics: A meta-analysis. *Psychological Bulletin*, *136*(1), 103–127.

Fennema, E., & Sherman, J.A. (1976). Fennema-Sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males. *Journal for Research in Mathematics Education*, *7*(5), 324.

Godec, S., King, H., & Archer, L. (2017). *The science capital teaching approach: Engaging students with science, promoting social justice*. London: University College London.

Guay, F., Ratelle, C.F., Roy, A., & Litalien, D. (2010). Academic self-concept, autonomous academic motivation, and academic achievement: Mediating and additive effects. *Learning and Individual Differences*, *20*(6), 644–653.

Harter, S. (1998). The development of self-representations. In W. Damon & N. Eisenberg (Eds.), *Social, emotional, and personality development* (Vol. 3, pp. 553–617). New York: Wiley.

Harter, S. (1999). *The construction of the self: A developmental perspective*. New York: Guilford Press.

Hattie, J. (2008). Processes of integrating, developing and processing self information. In D. M. McInerney, H.W. Marsh, & R. Craven (Eds.), *Self-processes, learning, and enabling human potential: Dynamic new approaches* (pp. 51–85). Charlotte, NC: Information Age.

Hoffmann, L., Häussler, P., & Peters-Haft, S. (1997). *An den Interessen von Jungen und Mädchen orientierter Physikunterricht: Ergebnisse eines BLK-Modellversuchs*. Kiel: Institut für die Pädagogik der Naturwissenschaften an der Universität Kiel.

Hu, L., & Bentler, P.M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55.

Jansen, M., Schroeders, U., & Lüdtke, O. (2014). Academic self-concept in science: Multidimensionality, relations to achievement measures, and gender differences. *Learning and Individual Differences*, *30*, 11–21.

Marsh, H.W. (1986). Verbal and math self-concepts: An internal/external frame of reference model. *American Educational Research Journal*, *23*(1), 129–149.

Marsh, H.W. (1989). Age and sex effects in multiple dimensions of self-concept: Preadolescence to early adulthood. *Journal of Educational Psychology*, *81*(3), 417–430.

Marsh, H.W. (1990a). Causal ordering of academic self-concept and academic achievement: A multiwave, longitudinal panel analysis. *Journal of Educational Psychology*, *82*(4), 646–656.

Marsh, H.W. (1990b). The structure of academic self-concept: The Marsh/Shavelson model. *Journal of Educational Psychology*, *82*(4), 623–636.

Marsh, H.W. (1992a). Content specificity of relations between academic achievement and academic self-concept. *Journal of Educational Psychology*, *84*(1), 35–42.

Marsh, H.W. (1992b). *Self description questionnaire (SDQ) I: A theoretical and empirical basis for the measurement of multiple dimensions of preadolescent self-concept. A test manual and research monograph*. Macarthur: University of Western Sydney, Faculty of Education.

Marsh, H.W. (1992c). *Self description questionnaire (SDQ) II: A theoretical and empirical basis for the measurement of multiple dimensions of adolescent self-concept. An interim test manual and research monograph*. Macarthur: University of Western Sydney, Faculty of Education.

Marsh, H.W. (1992d). *Self description questionnaire (SDQ) III: A theoretical and empirical basis for the measurement of multiple dimensions of latent adolescent self-concept. An interim test manual and research monograph*. Macarthur: University of Western Sydney, Faculty of Education.

Marsh, H.W. (1992e). *Self-description questionnaire (SDQ) II: A theoretical and empirical basis for the measurement of multiple dimensions of adolescent self-concept. A test manual and research monograph*. Macarthur: University of Western Sydney.

Marsh, H.W. (2005). *Self-concept theory, measurement and research into practice: The role of self concept in educational psychology*. London: British Psychological Society.

Marsh, H.W., Abduljabbar, A.S., Morin, A.J.S., Parker, P., Abdelfattah, F., Nagengast, B., & Abu-Hilal, M.M. (2015). The Big-Fish-Little-pond effect: Generalizability of social comparison processes over two age cohorts from Western, Asian, and Middle Eastern Islamic countries. *Journal of Educational Psychology*, *107*(1), 258–271.

Marsh, H.W., Craven, R., & Debus, R. (1998). Structure, stability, and development of young children's self-concepts: A multicohort-multioccasion study. *Child Development*, *69*(4), 1030–1053.

Marsh, H.W., & Craven, R.G. (2006). Reciprocal effects of self-concept and performance from a multidimensional perspective: Beyond seductive pleasure and unidimensional perspectives. *Perspectives on Psychological Science*, *1*(2), 133–163.

Marsh, H.W., Craven, R.G., & Debus, R. (1991). Self-concepts of young children 5 to 8 years of age: Measurement and multidimensional structure. *Journal of Educational Psychology*, *83*(3), 377–392.

Marsh, H.W., & Hau, K.-T. (2003). Big-Fish-Little-Pond effect on academic self-concept: A cross-cultural (26-country) test of the negative effects of academically selective schools. *American Psychologist*, *58*(5), 364–376.
Marsh, H.W., & Hau, K.-T. (2004). Explaining paradoxical relations between academic self-concepts and achievements: Cross-cultural generalizability of the internal/external frame of reference predictions across 26 countries. *Journal of Educational Psychology*, *96*(1), 56–67.
Marsh, H.W., Hau, K.-T., & Kong, C.-K. (2002). Multilevel causal ordering of academic self-concept and achievement: Influence of language of instruction (English compared with Chinese) for Hong Kong students. *American Educational Research Journal*, *39*(3), 727–763.
Marsh, H.W., Hau, K.-T., & Wen, Z. (2004). In search of golden rules: Comment on hypothesis-testing Approaches to Setting Cutoff values for fit indexes and dangers in overgeneralizing Hu and Bentler's (1999) f#indings. *Structural Equation Modeling: A Multidisciplinary Journal*, *11*(3), 320–341.
Marsh, H.W., Köller, O., & Baumert, J. (2001). Reunification of East and West German school systems: Longitudinal multilevel modeling study of the big-fish-little-pond effect on academic self-concept. *American Educational Research Journal*, *38*(2), 321–350.
Marsh, H.W., & Parker, J.W. (1984). Determinants of student self-concept: Is it better to be a relatively large fish in a small pond even if you don't learn to swim as well? *Journal of Personality and Social Psychology*, *47*(1), 213–231.
Marsh, H.W., Richards, G.E., & Barnes, J. (1986). Multidimensional self-concepts: A long-term follow-up of the effect of participation in an outward bound program. *Personality and Social Psychology Bulletin*, *12*(4), 475–492.
Marsh, H.W., Seaton, M., Trautwein, U., Lüdtke, O., Hau, K.T., O'Mara, A.J., & Craven, R.G. (2008). The Big-fish–Little-pond-effect stands up to critical scrutiny: Implications for theory, methodology, and future research. *Educational Psychology Review*, *20*(3), 319–350.
Marsh, H.W., & Shavelson, R. (1985). Self-concept: Its multifaceted, hierarchical structure. *Educational Psychologist*, *20*(3), 107–123.
Marsh, H.W., Trautwein, U., Lüdtke, O., Baumert, J., & Köller, O. (2007). The big-fish-little-pond effect: Persistent negative effects of selective high schools on self-concept after graduation. *American Educational Research Journal*, *44*(3), 631–669.
Marsh, H.W., Trautwein, U., Lüdtke, O., Köller, O., & Baumert, J. (2005). Academic self-concept, interest, grades, and standardized test scores: Reciprocal effects models of causal ordering. *Child Development*, *76*(2), 397–416.
Marsh, H.W., & Yeung, A.S. (1997a). Causal effects of academic self-concept on academic achievement: Structural equation models of longitudinal data. *Journal of Educational Psychology*, *89*(1), 41–54.
Marsh, H.W., & Yeung, A.S. (1997b). Coursework selection: Relations to academic self-concept and achievement. *American Educational Research Journal*, *34*(4), 691–720.
McInerney, D.M., Cheng, R.W., Mok, M.M.C., & Lam, A.K.H. (2012). Academic self-concept and learning strategies: Direction of effect on student academic achievement. *Journal of Advanced Academics*, *23*(3), 249–269.
Möller, J., & Köller, O. (2001). Dimensional comparisons: An experimental approach to the internal/external frame of reference model. *Journal of Educational Psychology*, *93*(4), 826–835.
Möller, J., Pohlmann, B., Köller, O., & Marsh, H.W. (2009). A meta-analytic path analysis of the internal/external frame of reference model of academic achievement and academic self-concept. *Review of Educational Research*, *79*, 1129–1167.
Möller, J., Retelsdorf, J., Köller, O., & Marsh, H.W. (2011). The reciprocal internal/external frame of reference model: An integration of models of relations between academic achievement and self-concept. *American Educational Research Journal*, *48*(6), 1315–1346.
Möller, J., & Trautwein, U. (2015). Selbstkonzept. In E. Wild & J. Möller (Eds.), *Pädagogische Psychologie* (2nd ed., pp. 177–199). Berlin, Heidelberg: Springer.
OECD. (2006). *Assessing scientific, reading and mathematical literacy: A framework for PISA 2006*. Paris: OECD Publishing.
OECD. (2009). *PISA 2006 technical report*. Paris: OECD Publishing.

OECD. (2013). Students' drive and motivation. In OECD, *PISA 2012 results: Ready to learn* (Vol. 3, pp. 63–85). Paris: OECD Publishing.
Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at K-12 levels: A systematic review of 12 years of educational research. *Studies in Science Education*, *50*(1), 85–129.
Seaton, M., Marsh, H.W., & Craven, R.G. (2010). Big-fish-little-pond effect: Generalizability and moderation - two sides of the same coin. *American Educational Research Journal*, *47*(2), 390–433.
Shanahan, M. (2009). Identity in science learning: Exploring the attention given to agency and structure in studies of identity. *Studies in Science Education*, *45*(1), 43–64.
Shavelson, R.J., Hubner, J.J., & Stanton, G.C. (1976). Self-concept: Validation of construct interpretations. *Review of Educational Research*, *46*(3), 407–441.
Skaalvik, E.M., & Rankin, R.J. (1990). Math, verbal, and general academic self-concept: The internal/external frame of reference model and gender differences in self-concept structure. *Journal of Educational Psychology*, *82*(3), 546–554.
Taskinen, P.H., Schütte, K., & Prenzel, M. (2013). Adolescents' motivation to select an academic science-related career: The role of school factors, individual interest, and science self-concept. *Educational Research and Evaluation*, *19*(8), 717–733.
Triandis, H.C. (2001). Individualism-collectivism and personality. *Journal of Personality*, *69*(6), 907–924.
Valentine, J.C., DuBois, D.L., & Cooper, H. (2004). The relation between self-beliefs and academic achievement: A meta-analytic review. *Educational Psychologist*, *39*(2), 111–133.
van de Vijver, F.J.R., & Poortinga, Y.H. (2005). Conceptual and methodological issues in adapting tests. In C.D. Spielberger, P.F. Merenda, & R.K. Hambleton (Eds.), *Adapting educational and psychological tests for cross-cultural assessment* (pp. 39–63). Mahwah, NJ: Lawrence Erlbaum.
Wigfield, A., & Eccles, J.S. (1992). The development of achievement task values: A theoretical analysis. *Developmental Review*, *12*(3), 265–310.
Wigfield, A., Eccles, J.S., Yoon, K.S., Harold, R.D., Arbreton, A.J.A., Freedman-Doan, C., & Blumenfeld, P.C. (1997). Change in children's competence beliefs and subjective task values across the elementary school years: A 3-year study. *Journal of Educational Psychology*, *89*(3), 451–469.
Wünsche, P., & Schneewind, K.A. (1989). Entwicklung eines Fragebogens zur Erfassung von Selbst- und Kompetenzeinschätzungen bei Kindern (FSK-K). *Diagnostica*, *35*, 217–235.
Wylie, R.C. (1979). *The self-concept: Volume 2. Theory and research on selected topics* (Vols. 1–2). Lincoln: University of Nebraska Press.

APPENDIX

Appendix 1: List of the 74 selected articles

(1) Areepattamannil, S. (2012). First- and second-generation immigrant adolescents' multidimensional mathematics and science self-concepts and their achievement in mathematics and science. *International Journal of Science and Mathematics Education, 10*, 695–716. https://doi.org/10.1007/s10763-011-9319-7
(2) Areepattamannil, S., Freeman, J. G., & Klinger, D. A. (2011). Influence of motivation, self-beliefs, and instructional practices on science achievement of adolescents in Canada. *Social Psychology of Education, 14*, 233–259. https://doi.org/10.1007/s11218-010-9144-9
(3) Bøe, M. V., & Henriksen, E. K. (2013). Love it or leave it: Norwegian students' motivations and expectations for postcompulsory physics. *Science Education, 97*(4), 550–573. https://doi.org/10.1002/sce.21068
(4) Brown, S. L., & Ronau, R. R. (2012). Students' perceptions of single-gender science and mathematics classroom experiences: Students' perceptions of single-gender classrooms. *School Science and Mathematics, 112*(2), 66–87. https://doi.org/10.1111/j.1949-8594.2011.00121.x

(5) Capobianco, B. M., Yu, J. H., & French, B. F. (2015). Effects of engineering design-based science on elementary school science students' engineering identity development across gender and grade. *Research in Science Education, 45*(2), 275–292. https://doi.org/10.1007/s11165-014-9422-1

(6) Chandrasena, W., Craven, R. G., Tracey, D., & Dillon, A. (2014). Seeding science success: Psychometric properties of secondary science questionnaire on students' self-concept, motivation, and aspirations. *Australian Journal of Educational & Developmental Psychology, 14*, 186–201.

(7) Chang, M., Singh, K., & Mo, Y. (2007). Science engagement and science achievement: Longitudinal models using NELS data. *Educational Research and Evaluation, 13*(4), 349–371. https://doi.org/10.1080/13803610701702787

(8) Cheong, Y. F., Pajares, F., & Oberman, P. S. (2004). Motivation and academic help-seeking in high school computer science. *Computer Science Education, 14*(1), 3–19. https://doi.org/10.1076/csed.14.1.3.23501

(9) Chiu, M.-S. (2008). Achievements and self-concepts in a comparison of math and science: exploring the internal/external frame of reference model across 28 countries. *Educational Research and Evaluation, 14*(3), 235–254. https://doi.org/10.1080/13803610802048858

(10) DeWitt, J., Archer, L., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2011). High aspirations but low progression: The science aspirations-careers paradox amongst minority ethnic students. *International Journal of Science and Mathematics Education, 9*, 243–271. https://doi.org/10.1007/s10763-010-9245-0

(11) Eccles, J. S., & Wang, M.-T. (2016). What motivates females and males to pursue careers in mathematics and science? *International Journal of Behavioral Development, 40*(2), 100–106. https://doi.org/10.1177/0165025415616201

(12) Ehmke, T., Drechsel, B., & Carstensen, C. H. (2010). Effects of grade retention on achievement and self-concept in science and mathematics. *Studies in Educational Evaluation, 36*(1–2), 27–35. https://doi.org/10.1016/j.stueduc.2010.10.003

(13) George, R. (2006). A cross-domain analysis of change in students' attitudes toward science and attitudes about the utility of science. *International Journal of Science Education, 28*(6), 571–589. https://doi.org/10.1080/09500690500338755

(14) Gilmartin, S., Denson, N., Li, E., Bryant, A., & Aschbacher, P. (2007). Gender ratios in high school science departments: The effect of percent female faculty on multiple dimensions of students' science identities. *Journal of Research in Science Teaching, 44*(7), 980–1009. https://doi.org/10.1002/tea.20179

(15) Glowinski, I., & Bayrhuber, H. (2011). Student labs on a university campus as a type of out-of-school learning environment: Assessing the potential to promote students' interest in science. *International Journal of Environmental and Science Education, 6*, 371–392.

(16) Grabau, L. J., & Ma, X. (2017). Science engagement and science achievement in the context of science instruction: A multilevel analysis of U.S. students and schools. *International Journal of Science Education, 39*(8), 1045–1068. https://doi.org/10.1080/09500693.2017.1313468

(17) Hall, S. S., Kowalski, R., Paterson, K. B., Basran, J., Filik, R., & Maltby, J. (2015). Local text cohesion, reading ability and individual science aspirations: Key factors influencing comprehension in science classes. *British Educational Research Journal, 41*(1), 122–142. https://doi.org/10.1002/berj.3134

(18) Hänze, M., & Berger, R. (2007). Cooperative learning, motivational effects, and student characteristics: An experimental study comparing cooperative learning and direct instruction in 12th grade physics classes. *Learning and Instruction, 17*(1), 29–41. https://doi.org/10.1016/j.learninstruc.2006.11.004

(19) Hardy, G. (2014). Academic self-concept: Modeling and measuring for science. *Research in Science Education, 44*(4), 549–579. https://doi.org/10.1007/s11165-013-9393-7

(20) Häussler, P., Hoffman, L., Langeheine, R., Rost, J., & Sievers, K. (1998). A typology of students' interest in physics and the distribution of gender and age within each type. *International Journal of Science Education, 20*(2), 223–238. https://doi.org/10.1080/0950069980200207

(21) Jack, B. M., She, H.-C., & Lin, H. (2016). Effects of self-evaluated value and cognition on leisure science engagement. *International Journal of Science Education, Part B: Communication and Public Engagement, 6*(4), 341–354. https://doi.org/10.1080/21548455.2016.1222104
(22) Jayaratne, T. E., Thomas, N. G., & Trautmann, M. (2003). Intervention program to keep girls in the science pipeline: Outcome differences by ethnic status. *Journal of Research in Science Teaching, 40*(4), 393–414. https://doi.org/10.1002/tea.10082
(23) Jurik, V., Gröschner, A., & Seidel, T. (2013). How student characteristics affect girls' and boys' verbal engagement in physics instruction. *Learning and Instruction, 23*, 33–42. https://doi.org/10.1016/j.learninstruc.2012.09.002
(24) Kessels, U., & Hannover, B. (2008). When being a girl matters less: Accessibility of gender-related self-knowledge in single-sex and coeducational classes and its impact on students' physics-related self-concept of ability. *British Journal of Educational Psychology, 78*(2), 273–289. https://doi.org/10.1348/000709907X215938
(25) Khan, M. S. (2012). Serious science games, social selves and complex nature of possible selves. *Cultural Studies of Science Education, 7*(4), 993–1000. https://doi.org/10.1007/s11422-012-9467-2
(26) Kind, P., Jones, K., & Barmby, P. (2007). Developing attitudes towards science measures. *International Journal of Science Education, 29*(7), 871–893. https://doi.org/10.1080/09500690600909091
(27) Koul, R., Lerdpornkulrat, T., & Chantara, S. (2011). Relationship between career aspirations and measures of motivation toward biology and physics, and the influence of gender. *Journal of Science Education and Technology, 20*(6), 761–770. https://doi.org/10.1007/s10956-010-9269-9
(28) Koutsoulis, M. K., & Campbell, J. R. (2001). Family processes affect students' motivation, and science and math achievement in Cypriot high schools. *Structural Equation Modeling, 8*(1), 108–127.
(29) Krogh, L. B., & Andersen, H. M. (2013). Actually, I 'may' be clever enough to do it: Using identity as a lens to investigate students' trajectories towards science and university. *Research in Science Education, 43*(2), 711–731. https://doi.org/10.1207/S15328007SEM0801_6
(30) Lau, K. C. (2014). The science education of the East Asian regions: What we can learn from PISA. *Asia-Pacific Forum on Science Learning and Teaching, 15*(2).
(31) Lavonen, J., & Laaksonen, S. (2009). Context of teaching and learning school science in Finland: Reflections on PISA 2006 results. *Journal of Research in Science Teaching, 46*(8), 922–944. https://doi.org/10.1002/tea.20339
(32) Lay, Y. F., & Chandrasegaran, A. L. (2016). The predictive effects of motivation toward learning science on TIMSS grade 8 students' science achievement: A comparative study between Malaysia and Singapore. *EURASIA Journal of Mathematics, Science & Technology Education, 12*, 2949–2959. https://doi.org/10.12973/eurasia.2016.02315a
(33) Leibham, M. B., Alexander, J. M., & Johnson, K. E. (2013). Science interests in preschool boys and girls: Relations to later self-concept and science achievement: Early science interests and subsequent achievement. *Science Education, 97*(4), 574–593. https://doi.org/10.1002/sce.21066
(34) Leslie, L. L., McClure, G. T., & Oaxaca, R. L. (1998). Women and minorities in science and engineering: A life sequence analysis. *Journal of Higher Education, 69*, 239–276.
(35) Liou, P.-Y. (2014). Examining the Big-Fish-Little-Pond Effect on students' self-concept of learning science in Taiwan based on the TIMSS databases. *International Journal of Science Education, 36*(12), 2009–2028. https://doi.org/10.1080/09500693.2014.889331
(36) Liou, P.-Y., & Liu, E. Z.-F. (2015). An analysis of the relationships between Taiwanese eighth and fourth graders' motivational beliefs and science achievement in TIMSS 2011. *Asia Pacific Education Review, 16*(3), 433–445. https://doi.org/10.1007/s12564-015-9381-x
(37) Lu, Y.-Y., Chen, H.-T., Hong, Z.-R., & Yore, L. D. (2016). Students' awareness of science teachers' leadership, attitudes toward science, and positive thinking. *International Journal of Science Education, 38*(13), 2174–2196. https://doi.org/10.1080/09500693.2016.1230792
(38) Makwinya, N. M., & Hofman, R. H. (2015). Gender disparities in sciences: The question of parental influence on children's self-concept and utility-value. *Journal of Education and Practice, 6*(13), 70–75.

(39) Marsh, H. W., Abduljabbar, A. S., Abu-Hilal, M. M., Morin, A. J. S., Abdelfattah, F., Leung, K. C., … Parker, P. (2013). Factorial, convergent, and discriminant validity of TIMSS math and science motivation measures: A comparison of Arab and Anglo-Saxon countries. *Journal of Educational Psychology, 105*(1), 108–128. https://doi.org/10.1037/a0029907
(40) Mason, L., Boscolo, P., Tornatora, M. C., & Ronconi, L. (2013). Besides knowledge: a cross-sectional study on the relations between epistemic beliefs, achievement goals, self-beliefs, and achievement in science. *Instructional Science, 41*(1), 49–79. https://doi.org/10.1007/s11251-012-9210-0
(41) Mohammadpour, E. (2012). A multilevel study on trends in Malaysian secondary school students' science achievement and associated school and student predictors. *Science Education, 96*(6), 1013–1046. https://doi.org/10.1002/sce.21028
(42) Mubeen, S., & Reid, N. (2014). The measurement of motivation with science students. *European Journal of Educational Research, 3*(3), 129–144. https://doi.org/10.12973/eu-jer.3.3.129
(43) Mujtaba, T., & Reiss, M. J. (2014). A survey of psychological, motivational, family and perceptions of physics education factors that explain 15-year-old-students' aspirations to study physics in post-compulsory English schools. *International Journal of Science and Mathematics Education, 12*(2), 371–393. https://doi.org/10.1007/s10763-013-9404-1
(44) Mujtaba, T., & Reiss, M. J. (2016). 'I fall asleep in class … but physics is fascinating': The use of large-scale longitudinal data to explore the educational experiences of aspiring girls in mathematics and physics. *Canadian Journal of Science, Mathematics and Technology Education, 16*(4), 313–330. https://doi.org/10.1080/14926156.2016.1235743
(45) Nagengast, B., & Marsh, H. W. (2011). The negative effect of school-average ability on science self-concept in the UK, the UK countries and the world: The Big-Fish-Little-Pond-Effect for PISA 2006. *Educational Psychology, 31*(5), 629–656. https://doi.org/10.1080/01443410.2011.586416
(46) Nagengast, B., & Marsh, H. W. (2012). Big fish in little ponds aspire more: Mediation and cross-cultural generalizability of school-average ability effects on self-concept and career aspirations in science. *Journal of Educational Psychology, 104*(4), 1033–1053. https://doi.org/10.1037/a0027697
(47) Ng, K. T., Lay, Y. F., Areepattamannil, S., Treagust, D. F., & Chandrasegaran, A. L. (2012). Relationship between affect and achievement in science and mathematics in Malaysia and Singapore. *Research in Science & Technological Education, 30*(3), 225–237. https://doi.org/10.1080/02635143.2012.708655
(48) Patchen, A. K., Zhang, L., & Barnett, M. (2017). Growing plants and scientists: Fostering positive attitudes toward science among all participants in an afterschool hydroponics program. *Journal of Science Education and Technology, 26*(3), 279–294. https://doi.org/10.1007/s10956-016-9678-5
(49) Plieninger, H., & Dickhäuser, O. (2015). The female fish is more responsive: gender moderates the BFLPE in the domain of science. *Educational Psychology, 35*(2), 213–227. https://doi.org/10.1080/01443410.2013.814197
(50) Reis, S. M., & Park, S. (2001). Gender differences in high-achieving students in math and science. *Journal for the Education of the Gifted, 25*(1), 52–73.
(51) Riegle-Crumb, C., Moore, C., & Ramos-Wada, A. (2011). Who wants to have a career in science or math?: Exploring adolescents' future aspirations by gender and race/ethnicity. *Science Education, 95*(3), 458–476. https://doi.org/10.1002/sce.20431
(52) Sampson, P. M., Gresham, G., Leigh, M. M., & McCormick-Myers, D. (2014). Do you want single-gender science classrooms in your middle schools? *Teacher Education and Practice, 27*(1), 190–202.
(53) Schütte, K. (2015). Science self-concept and valuing science: A cross-cultural analysis of their relation among students from Western and East Asian countries. *Social Psychology of Education, 18*(4), 635–652. https://doi.org/10.1007/s11218-015-9311-0
(54) Şentürk, E., & Özdemir, Ö. F. (2014). The effect of science centres on students' attitudes towards science. *International Journal of Science Education, Part B, 4*(1), 1–24. https://doi.org/10.1080/21548455.2012.726754

(55) Shaw, A. J., Harrison, T. G., Medley, M. I., Sellou, L., Shallcross, K. L., Croker, S. J., … Shallcross, D. E. (2010). University-school partnerships: Polymer chemistry days run at a university for 14–15 year olds and their impact on attitudes to science. *Acta Didactica Napocensia, 3*(1), 19–26.
(56) Sheldrake, R. (2016). Students' intentions towards studying science at upper-secondary school: The differential effects of under-confidence and over-confidence. *International Journal of Science Education, 38*(8), 1256–1277. https://doi.org/10.1080/09500693.2016.1186854
(57) Sikora, J., & Pokropek, A. (2012). Gender segregation of adolescent science career plans in 50 countries. *Science Education, 96*(2), 234–264. https://doi.org/10.1002/sce.20479
(58) Simpkins, S. D., Price, C. D., & Garcia, K. (2015). Parental support and high school students' motivation in biology, chemistry, and physics: Understanding differences among latino and caucasian boys and girls: Parental support and high school students' motivation. *Journal of Research in Science Teaching, 52*(10), 1386–1407. https://doi.org/10.1002/tea.21246
(59) Simpson, A., Che, S. M., & Bridges, W. C. (2016). Girls' and boys' academic self-concept in science in single-sex and coeducational classes. *International Journal of Science and Mathematics Education, 14*(8), 1407–1418. https://doi.org/10.1007/s10763-015-9676-8
(60) Taskinen, P. H., Schütte, K., & Prenzel, M. (2013). Adolescents' motivation to select an academic science-related career: The role of school factors, individual interest, and science self-concept. *Educational Research and Evaluation, 19*(8), 717–733. https://doi.org/10.1080/13803611.2013.853620
(61) Thomas, A. E. (2016). Gender differences in students' physical science motivation: Are teachers' implicit cognitions another piece of the puzzle? *American Educational Research Journal*. https://doi.org/10.3102/0002831216682223
(62) Wan, Z. H., & Lee, J. C. K. (2017). Hong Kong secondary school students' attitudes towards science: A study of structural models and gender differences. *International Journal of Science Education, 39*(5), 507–527. https://doi.org/10.1080/09500693.2017.1292015
(63) Wang, C.-L., & Liou, P.-Y. (2017). Students' motivational beliefs in science learning, school motivational contexts, and science achievement in Taiwan. *International Journal of Science Education, 39*(7), 898–917. https://doi.org/10.1080/09500693.2017.1310410
(64) Wang, J. (2012). A comparative study of science achievement and self-concept during a historical transition. *International Education Studies, 5*(1), 137–146. https://doi.org/10.5539/ies.v5n1p137
(65) Wang, J., Oliver, J. S., & Staver, J. R. (2008). Self-concept and science achievement: Investigating a reciprocal relation model across the gender classification in a crosscultural context. *Journal of Research in Science Teaching, 45*(6), 711–725. https://doi.org/10.1002/tea.20182
(66) Wender, I. (2004). Relation of technology, science, self-concept, interest, and gender. *Journal of Technology Studies, 30*(3), 43–51. https://doi.org/10.21061/jots.v30i3.a.7
(67) Wilkins, J. L. M. (2004). Mathematics and science self-concept: An international investigation. *The Journal of Experimental Education, 72*(4), 331–346. https://doi.org/10.3200/JEXE.72.4.331-346
(68) Woods-McConney, A., Oliver, M. C., McConney, A., Maor, D., & Schibeci, R. (2013). Science engagement and literacy: A retrospective analysis for indigenous and non-indigenous students in Aotearoa New Zealand and Australia. *Research in Science Education, 43*(1), 233–252. https://doi.org/10.1007/s11165-011-9265-y
(69) Woods-McConney, A., Oliver, M. C., McConney, A., Schibeci, R., & Maor, D. (2014). Science engagement and literacy: A retrospective analysis for students in Canada and Australia. *International Journal of Science Education, 36*(10), 1588–1608. https://doi.org/10.1080/09500693.2013.871658
(70) Yeung, A. S., Kuppan, L., Foong, S. K., Wong, D. J. S., Kadir, M. S., Lee, P. C. K., & Yau, C. M. (2010). Domain-specificity of self-concept and parent expectation influences on short-term and long-term learning of physics. *New Horizons in Education, 58*(2), 54–72.
(71) Yip, D. Y., & Tsang, W. K. (2007). Evaluation of the effects of the medium of instruction on science learning of Hong Kong secondary students: Students' self-concept in science. *International Journal of Science and Mathematics Education, 5*(3), 393–413.

(72) Yu, C. H. (2012). Examining the relationships among academic self-concept, instrumental motivation, and TIMSS 2007 science scores: A cross-cultural comparison of five East Asian countries/regions and the United States. *Educational Research and Evaluation, 18*(8), 713–731. https://doi.org/10.1080/13803611.2012.718511
(73) Zain, A. N. M., Samsudin, M. A., Rohandi, R., & Jusoh, A. (2010). Using the Rasch model to measure students' attitudes toward science in 'low performing' secondary schools in Malaysia. *International Education Studies, 3*(2), 56–63.
(74) Ziegler, A., Finsterwald, M., & Grassinger, R. (2005). Predictors of learned helplessness among average and mildly gifted girls and boys attending initial high school physics instruction in Germany. *Gifted Child Quarterly, 49*(1), 7–18.

Appendix 2: Analysis Grid

A. General information

(1) Reference
(2) Category of article
  (a) Results of an empirical research
  (b) State of previous research (synthesis, meta-analysis)
  (c) Results of a documentary analysis
  (d) Critical stand
  (e) Intervention proposal
  (f) Training proposal
  (g) Other (specify)
(3) Sciences and technology fields taken into consideration
  (a) The study concerns sciences and technology in general
  (b) Biology
  (c) Physics
  (d) Chemistry
  (e) Geology
  (f) Technology
  (g) Astronomy
  (h) Mathematics
  (i) Other (specify)
(4) What is the purpose of the article?
  (a) Gaining insight into the functioning of science and technology self-concept, e.g. its connection to other variables
  (b) Using self-concept measures to evaluate an intervention
  (c) Testing a measurement instrument to investigate students' science self-concepts
(5) Specify the research questions or hypotheses.

B. Major themes of the article that are related to STSC research

(1) Distribution of STSC regarding sociocultural background variables
  (a) Gender
  (b) Culture
  (c) Age
  (d) Family background
(2) Relation of STSC to student variables
  (a) Beliefs system (e.g. locus of control, self-efficacy, epistemic beliefs)
  (b) Structure of STSC (e.g. Big-Fish-Little-Pond effect, relation to self-concepts in other domains)
  (c) Interest and motivation
  (d) Science identity
  (e) Actions (e.g. career choices, help-seeking, course choices, engagement)

(f) Achievement

(3) Relation between STSC and external factors
  (a) Teachers' influence
  (b) Influence of the greater educational structure
  (c) Influence of specific interventions

C. Self-concept model used

(1) How is self-concept defined (implicit/explicit)?
  (a) Explicitly
  (b) Not defined
(2) What self-concept model(s) do the authors refer to?
  (a) The Shavelson model
  (b) The Shavelson/Marsh model or the I/E model
  (c) Derivatives of Stavelson/Marsh
  (d) Hattie's rope model
  (e) without explicit reference to a model
(3) Personal comment

D. Methodological aspects

(1) Are there a methodology and results in the article?
  (a) Yes
  (b) No
(2) Describe the sample briefly
(3) Name the source of the data
  (a) Not specified
  (b) PISA data set
  (c) TIMSS data set
  (d) other secondary data
  (e) collected for the study
(4) What instrument is used to assess self-concept?
  (a) PISA questionnaire
  (b) TIMSS questionnaire
  (c) Fennema-Sherman scale
  (d) SDQ
  (e) other (specify)
(5) Measurement process
  (a) Questionnaire
  (b) Interview
  (c) Direct observation in class
  (d) Video recording
  (e) Audio recording
  (f) Analysis grid
  (g) Not specified
  (h) Other (specify)
(6) Data analysis
  (a) A qualitative analysis
  (b) A quantitative analysis
  (c) A mixed analysis
  (d) not specified by the authors
  (e) Other (specify)
(7) Personal comment on this section

Article 2

A mixed methods approach to culture-sensitive academic self-concept research

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education sciences

Article

A Mixed Methods Approach to Culture-Sensitive Academic Self-Concept Research

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Abstract: (1) Background: In self-concept research, Likert scales are still relied upon despite the fact that they pose methodological difficulties for research in culturally diverse societies. This calls the validity of the data into question. In the present study, we develop a mixed methods design for culture-sensitive academic self-concept research. We test it in a study about chemistry self-concept with secondary school students; (2) Methods: Interview (N = 43) and questionnaire (N = 116) data were collected; (3) Results: The mixed methods approach allowed connecting self-concept with culturally shaped narratives: in the quantitative data, we found the well-documented gender gap in favor of boys. However, among the students with a Turkish migration background, the girls showed stronger chemistry self-concepts. The interviews suggested that girls with Turkish migration background find it easier to connect their chemistry learning to their personal life than the boys with Turkish migration background; (4) Conclusion: Based on further literature, we hypothesize that these differences might be due to a less masculine conception of science in the Turkish society. The mixed methods approach allows detecting measurement bias, which increases the validity of science self-concept data in culturally diverse contexts.

Keywords: self-concept; gender; cultural background; mixed methods; chemistry

1. Introduction

Science self-concept research faces severe measurement difficulties when conducted in culturally diverse groups. A systematic literature review [1] showed that most research uses self-report data from Likert-type items. However, this produces difficulties in the measurement process because we do not know if the items have the same meaning in culturally different groups of students [2]. This problem persists in self-concept research since we still lack theoretical and methodological approaches for investigations of self-concept in culturally diverse societies [3].

In this article, we propose one possible solution to the prevailing methodological difficulties in academic self-concept research. We develop and test an approach for culture-sensitive academic self-concept research. Instead of relying exclusively on quantitative data, we suggest that a mixed methods approach might enhance the validity of the data. This is innovative in academic self-concept research since research in this area relies almost entirely on quantitative data [1] despite methodological difficulties. This approach can be employed in academic self-concept research irrespective of the subject that is studied. In this article, we will focus on chemistry since we dispose of expertise in this field. For assessing the use of the approach, we tested it in a study on chemistry self-concepts of secondary school students in the North of Germany. The investigation of chemistry self-concepts with the developed mixed methods approach serves to explore potentially fruitful paths for further research on self-concept in culturally diverse societies. In the present study, the mixed methods approach allows

(i) evaluating potential measurement bias and (ii) linking the self-concept-data to the associations of science with masculinity that might differ between cultures.

2. Theoretical Background

2.1. Methodological Difficulties in Self-Concept Research

Important measurement difficulties remain unresolved in self-concept research. When used in cross-cultural research or in culturally diverse societies, the established methods in self-concept research face methodological difficulties. This was shown by Barbara Byrne [3] who identified "a grave need for researchers to move beyond the paper-and-pencil approach to self-report measurement" (p. 904) because responses to self-concept questionnaires will be "influenced by a cultural bias that ultimately leads to differential perceptions of self" (p. 903). Byrne and colleagues [2] further categorize this error into two types: conceptual non-equivalence (self-concept means different things in different cultures) and measurement non-equivalence (bias caused by the instrument, e.g., because of culturally different response styles). Byrne [3] suggested using interviews alongside the established self-concept measures in order to control for this type of bias. However, the use of qualitative data in science self-concept research remains extremely rare, as we have pointed out in a systematic analysis of current self-concept research [1].

2.2. Development of an Approach to Culture-Sensitive Academic Self-Concept Research

Based on these considerations, the question remains how academic self-concept could be investigated in a more culture-sensitive way. A mixed methods design would be promising, following Byrne's [3] call for the combination of qualitative and quantitative data in self-concept research. Since investigations based on the prevailing theoretical models of self-concept are almost exclusively quantitative in nature [1], critical scrutiny of the theoretical foundations of science self-concept research is needed.

The prevailing models of self-concept allow assessing the strength of self-concepts. They therefore lay the foundation of quantitative assessments of science self-concept. The most prominent conception is the Shavelson model [4] which is, despite the fact that it was developed in the 1970s, still one of the key references in self-concept research. The authors define self-concept as "a person's perception of himself" (p. 411) and suggest that people have different self-concepts for different aspects of life that vary in strength. Science self-concepts belong to the academic domain and constitute a person's evaluation of his or her abilities in science. Building on this foundation, Herbert W. Marsh [5] developed the internal and external frame of reference model for research on academic self-concept which is still widely used.

However, for exploring qualitative differences in self-concept, the prevailing models provide little basis. A different approach is needed. For the purpose of this study, we use John Hattie's [6] model of the self for exploring qualitative dimensions of self-concept. The model focuses on psychological processes at the micro level. Hattie [6] emphasizes the active role of the self in the production of self-concepts. He does so by conceptualizing the self as a chooser. This allows investigating why a person adopts a specific self-concept. For example, a student's negative self-concept in science would be explained on the level of the following self-processes [6]:

1. *Protecting the self.* A student can choose a negative self-concept in science in order to protect his self, for example, because he does not achieve as well in science as his classmates. The acceptance of his weak abilities could lower the pressure to keep up with his classmates. This can protect the self.
2. *Preserving the self.* People seek long-term stability, i.e., the preservation of the self. If a student in the past achieved low in science and got good grades only recently, the student might still stick to a negative self-concept. Changing the self-concept could endanger the student's identity as a non-science person. Preserving his negative self-concept can, therefore, be a rational choice.

3. *Promoting the self.* If a student identifies as a language person and couples this with a distinction from the natural sciences, adopting a negative science self-concept can strengthen the student's identity as a language person. This can promote the self.

Hattie's model shifts the focus on processes. Self-concept can, therefore, be studied with a focus on the individual rationales underlying self-concept. According to Hattie [6], a wide range of psychological processes are involved in the construction of the self. They all serve to protect, to promote, or to preserve the self.

In the academic domain, learning goal orientations (LGO) and performance goal orientations (PGO) are of special importance [6]. For the purpose of the present study, we concentrate on these in order to gain first insights into the construction of students' science self-concepts. In the following, we will briefly describe learning and performance goal orientations, mainly based on the fundamental works of Dweck and colleagues which still constitute major building blocks in current literature on learning and performance goal orientations.

Learning and performance goal orientations can be thought of as two different mindsets. When people activate their learning goal orientation (LGO), they tend to interpret situations as opportunities to learn. This implies that they perceive themselves as capable to learn. This is called an incrementalist theory of intelligence [7] which relies on the belief that they can control the learning process [8]. In practice, these students tend to take more risks in academic situations (e.g., they give an answer in class even if they are not sure if it is correct) because these situations bear the potential for learning and personal growth. This chance appears to be of greater importance than the potential failure [9]. It makes it easier for them to accept failure because they tend to focus on the learning effort they made rather than on success [7]. This leads to persistence when confronted with difficult tasks [9].

In contrast, when people activate their performance goal orientation (PGO), they tend to interpret situations as contexts in which they need to demonstrate their abilities [10]. This leads to important differences. When students adopt a PGO, they tend to believe that people have certain abilities but they can only improve them to a minor extent. They perceive low personal control over the development of their competences. The locus of control [8] appears to be external because their abilities appear as predefined and fixed which is called an entity theory of intelligence [7]. This motivates students to present their abilities rather than to strive to develop them [11]. With a performance goal orientation mistakes are difficult to deal with because they can appear as a personal failure [12]. Students who are performance goal-oriented tend to give up more easily and to encounter feelings of helplessness because they assume their abilities to be fixed [9]. Failure tends to be explained with personal incompetence [12], which can lead to obtrusive thoughts disrupting the work process [11]. Social goals and the desire to belong to the group become more important and students are more likely to give up the task at hand [11].

Based on these considerations, academic self-concept research could become more culture-sensitive through the adoption of a mixed methods approach. The Shavelson, Hubner, and Stanton model [4] provides the basis for investigating the strength of self-concept. The qualitative dimension of self-concepts can be explored using Hattie's [6] model.

2.3. The Relationship between Science Self-Concept and Culture

The study presented in this article tests the mixed methods approach for more culture-sensitive academic self-concept research using a concrete example, namely chemistry self-concept. In the following, we will summarize some key findings about the relation between science self-concept and culture, as well as findings about chemistry self-concept.

Despite the prevailing methodological difficulties, cultural differences in science self-concept have received considerable attention in science education research. The gender relations in science self-concept are a well-researched area. Since gender is a cultural construct [13], the gender relations touch differences in science self-concept that are associated with cultural categories. In numerous studies, it has been shown that boys tend to have stronger science self-concepts in Western societies than girls. This has, for instance, been shown for the U.S. [14], Germany [15], and the U.K. [16]. However, this gender gap might depend on the cultural context since it was not found in a study conducted in Malaysia and Singapore [17] and in some other cases. One hypothesis could explain these findings: in some countries, science might not be associated as strongly with masculinity as it tends to be in Western countries (Figure 1, left). However, the present literature does not yet allow for a definite answer.

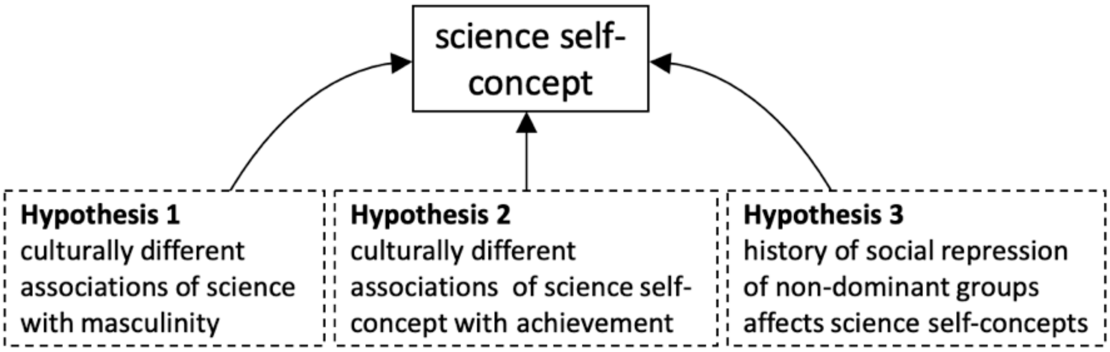

Figure 1. Hypotheses regarding possible influences of culture on science self-concept derived from literature by the authors.

In addition, the relation between science self-concept and achievement has been of central interest in investigations of the impact of culture on science self-concept. While the relation is positive in general [18], research indicates that it differs between cultures. In Asian and Eastern European countries, science self-concept levels are relatively low compared to the relatively high achievement levels in these regions [19]. This comes to a surprise because one would expect to find high levels of science self-concept in countries where the students achieve well. However, this finding suggests that self-concepts might play a different role for students in Asian and Eastern European countries than it does for students in Western countries (Figure 1, center). The reason for this difference seems to remain an open question.

Besides the differences in self-concept that seem to exist between countries, some studies identified effects of the cultural backgrounds of students living in the same country. In the U.S., students belonging to non-dominant ethnic groups tend to have lower self-concepts in science than students belonging to the dominant ethnic group [14]. This seems to be a pattern in some other Western countries as well: the same relation was found in Australia and New Zealand [20] and in the U.K. [21]. However, the study conducted in the U.K. [21] showed that students with an East Asian background are an exception. They show particularly strong self-concepts in science when living in Western countries.

The reasons for these differences between students with various cultural backgrounds living in the same country remain only partly understood. One factor explaining lower science self-concepts in students from a non-dominant ethnic group could be their socio-economic status which tends to be lower in many ethnic groups that have experienced or still experience repression, as Amanda Woods-McConney and colleagues [20] hypothesize (Figure 1, right). The students' socio-economic status is indeed strongly related to science self-concept [22]. Following this line of argumentation, it would be important to take a more holistic view in self-concept research, considering racial and social conflicts that existed in the past or that still exist. Australia, New Zealand, the U.K., and the U.S. all have a history shaped by colonialism and/or repressive policies that marginalized certain ethnic groups living in the country. The children from these groups now tend to show weaker science self-concepts. We believe that these phenomena can only be understood if the respective histories and present racial conflicts are considered.

These selected findings give an impression of the close intertwinement of science self-concept with culture. The associations of gender with science self-concept seem to differ between cultures, and likewise does the association with achievement. Further, the cultural backgrounds of students living in the same country seem to shape their science self-concepts. These findings suggest that students' thoughts about their abilities in science are embedded in the cultural context.

Chemistry self-concept tends to be less well understood than science self-concept. For research with secondary school students, no thoroughly tested and validated measurement instrument seems to be available. The existing well-tested instruments are designed for young adults in higher education, such as the Chemistry Self-Concept Inventory (CSCI) [23] and the Attitude toward the Subject of Chemistry Inventory (ASCI) [24] (revised version: [25]). These scales are based on Marsh's Self-Description Questionnaire III (SDQ) [26] which allows assessing the self-concepts of young adults. Studies tend to concentrate on chemistry self-concept in higher education, e.g., on the assessment of chemistry self-concept in a general chemistry course [27]. In addition, we are currently unaware of studies investigating the relation of chemistry self-concept with students' cultural backgrounds.

3. Research Goal and Questions

The goal of the present study is to explore the approach for a more culture-sensitive academic self-concept research developed in Section 2.2. We aim at developing an approach for culture-sensitive academic self-concept research for all subjects. In order to be culture-sensitive, a mixed methods design is needed [3]. We want to know:

TQ (theoretical question). To what extent can a mixed methods approach provide a basis for culture-sensitive academic self-concept research?

We intend to answer this question through the application to a concrete study. In this study, we concentrated on one concrete example of academic self-concept research, namely chemistry self-concept. We conducted an explorative study in which we investigated secondary school students' chemistry self-concepts. Special attention is turned towards the influences of gender and the students' cultural backgrounds on chemistry self-concept because these seem to influence science self-concepts (Figure 1). In this study, we want to assess both the strength of chemistry self-concept and its qualitative dimensions:

EQ1 (empirical question 1). How strong are the chemistry self-concepts of students with different cultural backgrounds and gender living in Germany?
EQ2 (empirical question 2). In what ways are the students' chemistry self-concepts associated with learning and performance goal orientations?

4. Materials and Methods

4.1. Type of Mixed Methods Design

We chose a concurrent triangulation mixed methods design [28] with questionnaires and interviews, based on both the perspective of the Shavelson, Hubner, and Stanton [4] model and the perspective of Hattie [6]. According to the criteria defined by John W. Creswell et al. [28], our design can be classified as a concurrent triangulation design: (i) the implementation was concurrent, i.e., the collection of qualitative and quantitative data took place at the same point in time. This design was chosen because we sought to compare the two data types in order to understand their interrelationships; (ii) Both data types were of equal priority; (iii) The integration of the two data types took place at data interpretation, i.e., data collection and data analysis were conducted separately for the data.

4.2. Instruments

Questionnaires. For assessing the students' chemistry self-concepts following the Shavelson model [4], we employed a chemistry self-concept scale developed by the authors (Table 1). The questionnaire was composed of nine Likert-type items covering both general aspects (items 1, 2, 3, 5) and more specific aspects such as the students' perception of their abilities in specific situations (items 3, 4, 6, 7), and life out of school (items 8, 9). The scale was piloted prior to the study and showed good reliability with values for Cronbach's α of 0.86. The students' cultural backgrounds were conceptualized with reference to the concept of migration background which accounts for the migration processes that took place in Germany after World War II. As defined in the official 2013 census [29], a person who was born in another country or whose parents have been born in another country has a migration background. The type of migration background was further specified by naming the respective countries.

Table 1. Mean values and standard deviations of the translated version of the chemistry self-concept scale (N = 116); the original in German language can be requested from the authors.

Item	*M* (*SD*)
1. Chemistry is one of my strengths.	3.48 (0.96)
2. In chemistry, I'm one of the better students.	3.35 (1.11)
3. I am good at doing experiments.	4.04 (0.78)
4. When I have done an experiment, I understand what the result means.	3.97 (0.83)
5. I usually get on well in chemistry classes.	3.98 (0.96)
6. I understand the texts we read in chemistry.	3.85 (0.87)
7. I'm good at solving mathematical problems in chemistry.	3.45 (1.27)
8. Sometimes my chemistry knowledge helps me understand things in everyday life.	3.38 (1.09)
9. I would be able to choose a profession in which chemistry knowledge is needed.	2.86 (1.23)

Interviews. In addition, we conducted semi-structured interviews with some of the students who completed the questionnaire. Here, we investigated the dynamics of chemistry self-concept through the lens of Hattie's model [6]. In line with Hattie [6], we focused on the students' learning and performance goal orientations as two important self-processes. The interviews were divided into three parts. (i) *Warm-up*. At the beginning of the interviews, we asked the students to share some of their experiences from chemistry class. In particular, we wanted to know what they like and what they dislike about it; (ii) *Handling success and failure*. We wanted to know how they deal with success and failure in chemistry class because this behavior is an indicator of learning goal orientation (LGO) and performance goal orientation (PGO) [12]. We asked them to describe a situation in which they had been satisfied with themselves and one situation in which they had been dissatisfied with themselves in chemistry. These attributions can indicate LGO and PGO; (iii) *Dealing with difficult tasks*. We asked them how they deal with difficult tasks. Here, we were interested in their attitude towards situations in which, on the one hand, they face obstacles but which, on the other hand, also open the opportunity to engage in deep learning processes. This can reflect LGO and PGO as well [9].

4.3. Sample

The study was conducted in accordance with the Declaration of Helsinki [30], and the protocol was approved by the Ethics Committee of the state of Bremen (local ministry). We informed the teachers, the parents, and the students in a letter about the aims of the study, the procedure, and the voluntary nature of the study, and obtained written consent. We emphasized that non-participation did not have any negative consequences and that students could withdraw their answers at any moment. These instructions were repeated orally before conducting the study in class. In order to protect the students' anonymity in the study, a non-traceable code was produced that allowed to match the interviews with the corresponding questionnaires.

Questionnaire data. We collected questionnaire data from 116 students in the course of three months. In the part of Germany where data collection took place, it depends largely on the individual schools and teachers when chemistry topics are introduced in class. We, therefore, asked the teachers prior to the data collection process, if they had already taught chemistry in the respective group. The students of our sample were aged 11–19 ($M = 15.2$, $SD = 1.4$) and attended six different public secondary schools. The large majority of students fell in the age range of 13–17 years which is typical for these grades. Those who are younger usually skipped a grade. The students who are older usually either had to repeat a school year because they did not achieve well, or they are immigrants who first attended a separate language class before entering the regular school system. With this age range and the different school contexts, we intended to gain insights into experiences with chemistry across different contexts. In total, 54.3% of the students who filled in the questionnaire were female, and the majority of the students reported to have a migration background (54.3%). The concept of migration background classifies students along national lines and does not put them into larger categories such as 'Asian' or 'Black' as the U.S. American concept of race does. Nevertheless, we tried to group the students. The largest group was composed of students with a Turkish and/or Kurdish background (Table 2, 23.3%; $N = 27$). We assembled the students with a Turkish and a Kurdish background in one group because all students with a Kurdish background also reported having a Turkish migration background. As a simplification, we will refer to these as students with a Turkish migration background.

Table 2. Migration backgrounds of the students in the sample.

	N	
	Questionnaire	**Interviews**
None	53 (45.7%)	19 (44.2%)
Turkish	27 (23.3%)	9 (20.9%)
Eastern European/Russian	9 (7.8%)	6 (14.0%)
South Asian	8 (6.9%)	3 (7.0%)
Sub-Saharan African	7 (6.0%)	3 (7.0%)
Others	12 (10.3%)	3 (7.0%)
Total	116 (100%)	43 (100%)

Interview data. Forty-three of the students from the quantitative study volunteered to be interviewed after filling in the questionnaire (Table 2). The students were interviewed in pairs because we intended to make them feel at ease during the interviews, thereby increasing the content validity of the data. We, therefore, asked them to pick a classmate who would like to be interviewed as well. However, some of the students were interviewed alone because they did not find a partner. The interviews lasted about 10–15 min. In the interview study, 60.5% ($N = 29$) of the participants were female. Students with a migration background made up for 55.8% ($N = 24$). The students with a Turkish background constituted the largest group with 20.9% ($N = 9$) among the students with a migration background. The interviews were conducted in German language. The extracts quoted in this article have been translated by the authors.

4.4. Data Analysis

Quantitative analyses. First, we calculated Cronbach's α as well as the mean values and standard deviations for each item of the questionnaire. In the next step, we carried out ANOVAs in order to investigate the effects of gender and cultural background on self-concept. In the first analysis, we compared students with any migration background to students without a migration background. In the second step, we limited the analysis to the two largest cultural groups: students with a Turkish background and students without a migration background. We conducted an ANOVA, investigating the effects of gender and cultural background. All analyses were carried out using R version 3.4.2 [31], in particular, the packages car [32] and psych [33].

Qualitative analysis. The interviews were analyzed using qualitative content analysis [34] with MAXQDA software. We opted for a content-based approach and coded each part of speech that contained a new content. These units were paraphrased. In this step, we focused on goal orientations, feelings, and evaluations of abilities in chemistry. Units with similar content were omitted. In the third step, we organized the content in four categories: (1) learning goal orientations, i.e., thinking patterns that show the desire to engage in learning processes; (2) performance goal orientations; (3) social goals, i.e., thoughts about the social relations in class, and (4) the students' evaluations of their abilities (self-concept). Categories 1, 2, and 4 were defined prior to the analysis. Category 3 was defined during the analysis because it appeared to be a relevant topic in the interviews. In the fourth and last step, we checked the appropriateness of the categories, going through the data once again.

5. Results

5.1. Questionnaire Data

Impact of migration background and gender on chemistry self-concept. We analyzed the effects of gender and migration background on self-concept. For this analysis, we used the complete sample. Reliability was tested using Cronbach's α which was with 0.86 very good. Levene's test was not significant at the 0.05 level for the main and interaction effects. The Q-Q plots indicated a normal distribution of the data and the Shapiro–Wilk tests were not significant at the 0.05 level. We therefore conducted an ANOVA with the four groups of boys ($N = 25$) and girls ($N = 28$) without a migration background, and boys ($N = 28$) and girls ($N = 35$) with a migration background (Table 3). The main effect of gender, $F(1, 112) = 4.09$, $p = 0.046$*, and the interaction effect were significant, $F(1, 112) = 6.38$, $p = 0.013$*. The effect of culture was not significant, $F(1, 112) = 1.60$, $p = 0.209$. This first analysis shows that boys have significantly stronger self-concepts than girls, *M(male)* = 3.71 > *M(female)* = 3.48. Also, the relationships between the gender groups seem not to be the same among students with and without a migration background: in the subsample of students without a migration background, boys scored higher than girls (*M(boys)* = 3.98 > *M(female)* = 3.40). In the subsample of students with a migration background, however, there seems to be little difference between the gender groups (*M(male)* = 3.50 > *M(female)* = 3.54).

Table 3. Results of the two-way ANOVAs comparing the self-concepts of girls and boys with different cultural backgrounds. (* = p < 0.05)

	F	***p***
Analysis 1. Boys and girls *without* migration background vs. *with* migration background		
effect of gender	4.09 (1, 112)	0.046 *
effect of migration background	1.60 (1, 112)	0.209
interaction effect	6.38 (1, 112)	0.013 *
Analysis 2. boys and girls *without* migration background vs. *with Turkish* migration background		
effect of gender	4.59 (1, 75)	0.035 *
effect of migration background	2.39 (1, 75)	0.127
interaction effect	5.04 (1, 75)	0.028 *

Impact of Turkish migration background and gender on chemistry self-concept. In the next step, we analyzed the effects of gender and having a Turkish background on chemistry self-concept. For this analysis, we used the subsamples of students without a migration background and with a Turkish migration background. Levene's test for the main and interaction effects was not significant at the 0.05 level for the main and interaction effects. The Q-Q plots indicated a normal distribution of the data and the Shapiro–Wilk tests were not significant at the 0.05 level. Just as in the previous ANOVA, the main effect of gender, $F(1, 75) = 4.59$, $p = 0.035$*, and the interaction effect of gender and culture, F(1,

75) = 5.04, $p = 0.028$*, were significant (Table 3). The effect of culture was not significant, $F(1, 75) = 2.39$, $p = 0.127$. This suggests that among students with a Turkish background, gender relations might be inversed. The boys with a Turkish background scored lower ($M = 3.32$) than the girls with a Turkish background ($M = 3.50$) while among the students without migration background, the boys scored higher than the girls ($M(boys) = 3.98 > M(female) = 3.40$). However, it is important to keep in mind that sample sizes for students with a Turkish background were small (13 boys, 14 girls). The discovered effects can, therefore, show tendencies in these groups but require further investigation.

5.2. Interview Data

With the interview data, we wanted to explore the dynamics of chemistry self-concept. More precisely, we wanted to investigate the relation of self-concept to learning and performance goal orientations (LGO and PGO) in chemistry class. We focused on the students without a migration background and those with a Turkish background because these were the largest cultural groups in the analysis. Table 4 provides an overview of the results of the analysis, showing patterns in the categories (1)–(4).

In the analyses, we link the students' self-concept scores from the questionnaires to the interview data. The overall chemistry self-concept mean value was $M = 2.41$. Scores higher than the mean indicate a positive self-concept. If the score is lower than 2.41, the student has a more negative chemistry self-concept than average. The scores are provided in brackets (SC = . . .).

5.2.1. Boys without Migration Background

(1) Learning goal orientation tended to be high (Table 4). The boys showed interest in chemistry content: "I find it interesting how substances combine to form a new substance, or how they change due to certain reactions" (interview 9b, SC = 3.56). Another student showed that he is proud of himself if he improves his skills in chemistry which is also a sign of an LGO: "[I am proud] when I manage to do something I haven't done before" (interview 10b, SC = 3.44).

Table 4. Overview of the results of the interview analysis.

	No Migration Background		**Turkish Migration Background**	
	Male	**Female**	**Male**	**Female**
N	**7**	**12**	**5**	**4**
(1) Learning goal orientation + strong . . . weak –	+	–	–	+
(2) Performance goal orientation + strong . . . weak –	– (exception: obtrusive thoughts in one case)	+	+	– (exception: in one case low persistence)
(3) Social context + relevant . . . irrelevant –	–	+	+	+
(4) Evaluation of chemistry abilities + positive . . . negative –	+	–	–	+/–

(2) Performance goal orientation seemed to be comparably unimportant (Table 4). Only in one case did obtrusive thoughts appear. These can be negative side effects of performance goal orientations [11]. The student explained:

> Once you have a problem you can't solve (. . .) you get stressed in that situation because then these thoughts come: what if I skip that one and keep on doing the other stuff? Will I later be able to do the one I've skipped? (. . .) that keeps stressing me (...). Then you got a bit of trouble understanding just anything. (interview 22a, SC = 3.22)

Despite these obtrusive thoughts, the student shows an above average chemistry self-concept (3.22). The thoughts, therefore, seem to have little impact on his overall belief in his abilities in chemistry.

(3) The social dimension of chemistry learning seemed to be of little relevance (Table 4). Social issues were almost not mentioned in the interviews when the students were asked to talk about their experiences in chemistry class. In contrast to all other groups, none of the boys without a migration background expressed social insecurity.

(4) The evaluation of abilities tended to be positive (Table 4). This was interpreted as a strong chemistry self-concept in the sense of the Shavelson model. One boy even expressed strong science aspirations: "I would like to try studying chemistry in college, to try at least, because it's interesting to me" (interview 21a, SC = 3.44). His self-concept score of 3.44 was far above the average. For this student, a strong chemistry self-concept seemed to be closely intertwined with chemistry-related career aspirations.

5.2.2. Girls without Migration Background

(1) Learning goal orientation tended to be low (Table 4). This showed, for instance, in a preference for easy tasks. One girl said that she feels "relieved" when she can do an easy task (interview 3a, SC = 1.89). Another girl seemed more learning goal oriented, but only slightly: she chooses to do easy tasks first "because that motivates me and then I do the difficult ones" (interview 2a, SC = 2.56). She needs a high motivation to work on difficult tasks which is a sign of rather weak learning goal orientation.

(2) Performance goal orientation seemed to be present (Table 4). This showed primarily through negative side-effects [35]. For instance, one girl showed an entity theory of intelligence [7], saying "I just feel stupid sometimes" (interview 5a, SC = 1.78). She did not talk about the things she needed to learn. Instead, her self-description as 'stupid' suggests that she sees herself as incapable of learning, which is an entity theory of intelligence.

(3) The social context seemed to be highly relevant (Table 4). This was in some cases coupled with ambiguous and rather negative feelings:

> I would say that [in contrast to other classes] there is maybe a bit more tolerance. There's no need to be so frightened to ask something that (. . .) you should know already. (interview 3b, SC = 1.78)

On one hand, this girl feels a lot of tolerance when someone makes a mistake. However, on the other hand, she feels that there are things she "should know already" which could reflect a feeling of pressure and insecurity. Although she thinks that there is no need to be frightened, this implies that she does not take it for granted to be accepted because she considers the possibility that she could feel frightened. Another girl showed a similar ambiguity. She said, "you just feel like you're one of them" (interview 3a, SC = 1.89). On the one hand, this girl wanted to express that she feels accepted in class. On the other hand, the fear of not being accepted appears to be very present to her and only banned for the moment. Another girl expressed her feeling of being an outsider in a drastic way: "you just feel as if you had no business there and that you're in the wrong place" (interview 5a, SC = 1.78).

(4) The evaluation of abilities tended to be negative (Table 4). Some girls said they had serious difficulties dealing with chemistry content.

> All these calculations and stuff, that's not my thing. I find it interesting but all this calculating with the ions switching from one side to the other, that's quite a bit confusing. (interview 3b, SC = 1.78)

Furthermore, the girls' self-concepts about their verbal and mathematical skills in chemistry seemed to be very mixed.

5.2.3. Boys with Turkish Migration Background

(1) Learning goal orientation seemed to be of little relevance (Table 4). Reflections on the learning process appeared very rarely in the interviews. One student liked easy tasks because in these situations, he "could help others, too" (interview 22b, SC = 1.67). This shows that content learning was not a high priority for this student.

(2) Performance goal orientation seemed to be rather strong (Table 4). Test performance seemed to be of high importance, as well as opportunities to show their abilities to the other students (interview 2b, SC = NA).

(3) The social context seemed to be relevant (Table 4). In one case, this was coupled with very difficult feelings. One of the boys (interview 22b, SC = 1.67) seemed to feel left behind. During the interview, he spoke a lot about feelings of uncertainty, nervousness, and being left alone. He described a situation when he prepared for a presentation with a group of students. However, his classmates abandoned the project, something he interpreted as "they let me down." This put him into a difficult situation because he is "rather nervous" when standing in front of the class. In such situations, the student tells himself that "nobody thinks bad of me" in order to "calm myself down". This reflects the student's preoccupation with his social position in the class. However, the positive side of this strong social focus showed in the fact that the student prefers working in groups.

(4) The evaluation of abilities was rather negative (Table 4). One of the students said, "we [him and the other interview partner who had a Turkish background as well] are not the smartest students in chemistry" (interview 6b, SC = 2.56). This tendency to describe the abilities as rather low was present in other interviews as well. One student said: "it [chemistry] is a bit difficult for me" (interview 22b, SC = 1.67), and it was the calculations in particular that put him to his limits. It is difficult for him to follow in class because he understands the content "only, like, partly" and sometimes gets really frustrated, angry, and sad about this.

5.2.4. Girls with Turkish Background

(1) Learning goal orientation seemed to be strong (Table 4). One student seemed to be engaged in deep learning processes in chemistry. She said, when "you get this mental representation, I like that part best." (interview 1b, SC = 2.56). She enjoys developing new ideas and representations of abstract entities which is a sign of a need for cognition. In addition, she likes understanding the theoretical background of experiments: "we see a change in the solution (. . .) and then we can maybe explain with a formula what happens" (interview 1b, 2.56). Another student expressed her desire to understand chemistry content this way: "well, I don't understand it *yet*. At some point, I'm gonna get it. It can't be that difficult" (interview 24a, SC = 3.11). Here, she shows an incremental theory of intelligence. She believes that she can improve her skills in chemistry.

(2) Performance goal orientation seemed to be of much less relevance compared to learning goal orientations (Table 4). Only one girl showed low task-persistence: "when I don't get it right from the start, then I try to see if . . . maybe I will understand it later, but when I, when I see I don't get it (. . .) I don't feel like making any more effort and it stays like that until the end of the lesson" (interview 1a, SC = 2.23). This can be interpreted as a sign of a performance goal orientation.

(3) The social context seemed to be very relevant (Table 4). For one student, her relationship with the teacher was important: "the classes are fun but I think it's more about the teacher than about the lessons as such" (interview 1a, SC = 2.23). She described her teacher as being very attentive and appreciated the teacher's efforts to actively work on the relationships with the students and to motivate them. Also, the two girls in this interview (1a, SC = 2.23 and 1b, SC = 2.56) referred to people outside school as being relevant for chemistry learning. They enjoyed sharing things they had worked on in class. For instance, two girls had produced a video during class about an experiment which they shared with people in their home environment. Chemistry learning, therefore, seemed to be easy to integrate into their social life.

(4) The evaluation of abilities was mixed (Table 4). Some students expressed a skeptical view on their abilities in chemistry, saying for example "I am not the best student in chemistry" (interview 23, SC = 2.44). One of these girls talked about her trouble to concentrate on the task when things get difficult. Others were rather positive.

6. Discussion and Conclusions

In this section, we will first discuss the two empirical research questions (EQ1 and EQ2) by summarizing the results of the study and interpreting them. Then, we will cover the theoretical question (TQ), discussing to what extent the approach can increase culture-sensitivity in academic self-concept research. In the last part, we will reflect on the study's limitations.

6.1. EQ1 and EQ2: Discussion of the Findings

In the analysis of the questionnaire data, we made three findings regarding EQ1 (How strong are the chemistry self-concepts of students with different cultural backgrounds and gender living in Germany?):

1. Gender had a significant impact on chemistry self-concept. We replicated the gender gap that had been reported on students in Germany [15]. The gender gap in favor of boys that exists in science self-concept in most regions has inspired a number of intervention studies. However, progress in this area still seems to be limited [1]. Perhaps different types of intervention studies could be interesting, focusing on aspects that are closely related to self-concept but that might be easier to change. For example, it has been shown that learning goal orientations are closely related to self-concepts [36]. It could be interesting to focus on these orientations in interventions because they influence task-choice and learning behavior directly.
2. The cultural background did not have a significant effect on chemistry self-concept. This is not in line with the finding that in most cases, the science self-concept of students who belong to a non-dominant cultural group is lower on average than that of students who belong to the dominant cultural group (e.g., [14]).
3. The interaction effect of gender and culture on chemistry self-concept was significant.

The analysis suggests that the students' cultural background has an impact on chemistry self-concept in interaction with gender. More precisely, gender relations seem to differ between the groups of students without a migration background and those with a Turkish migration background. In the sample of students without a migration background, we found the gender gap that had been reported on, with boys having stronger self-concepts [15]. However, in the subsample of students with a Turkish background, the girls tended to show stronger beliefs in their abilities in science: their mean self-concept score was higher than the boys'. This finding had not been documented in the literature and was, therefore, unexpected.

What could explain that gender relations seem to be inversed in the sample of the students with a Turkish background? We looked into the interview data for phenomena that could help to develop hypotheses, in order to answer EQ2 (In what ways are the students' chemistry self-concepts associated with learning and performance goal orientations?). In the four groups, it seemed that different patterns were active:

Pattern I: strong self-concept coupled with learning goal orientation. This appeared in the group of boys without migration background who seemed to be highly learning- and content-oriented. In comparison, the social context appeared almost irrelevant to them. This pattern was associated with high self-concept scores in the questionnaire.

Pattern II: strong self-concept coupled with learning and social goal orientation. This appeared in the group of girls with a Turkish migration background. These girls had high self-concept scores in the questionnaires, too, but showed a different pattern: in addition to a strong orientation towards chemistry content and learning, they had a strong social orientation. From their perspective, chemistry learning appeared as embedded in the social context.

Pattern III: weak self-concept with strong social focus and feelings of insecurity. This pattern appeared in the group of girls without migration background and boys with a Turkish background. It is characterized by concerns about social issues. This pattern was associated with low self-concept scores in the questionnaire and negative statements about their abilities in the interviews. This uncertainty about their abilities coupled with their social goal orientation leads many students to raise the question of social acceptance.

Knowing that chemistry self-concept can be associated differently with learning goal orientations and the feeling of social support could open new paths for application-focused self-concept research. It could be interesting regarding students who score very low on self-concept scales to explore the effects of cooperative learning and similar methods that try to enhance peer support. Also, task-choice behavior and other practical implications of learning goal orientations could be focused upon when trying to support the students' development of positive self-concepts. Insofar, the results of mixed methods design study could inspire more application-focused self-concept research which seems to be lacking [1].

6.2. TQ: The Culture-Sensitivity of the Approach

To what extent can the concurrent triangulation mixed methods approach provide a basis for culture-sensitive academic self-concept research? (TQ). In the present study, the approach helped to uncover a possible conceptual non-equivalence [2] in chemistry self-concept. Chemistry self-concept seemed to be related in different ways to (i) gender and to (ii) the salience of the social structure in chemistry class. In the subsample of students without a migration background, strong self-concepts seem to be possible only if the social structure is ignored. Speaking in stereotypes, one could conclude that in this subgroup, positive self-concepts are only possible for boys if they learn to focus on chemistry content while not considering the social structure. In contrast, in the Turkish subsample, gender seemed to be associated differently with chemistry self-concept. Chemistry appeared as slightly more accessible for the girls because they showed quite positive self-concepts and strong learning goal orientations. In addition, dissociating chemistry learning from the personal social context seemed not to be necessary for having a positive chemistry self-concept. The girls with a Turkish migration background who had high self-concept scores tended to show learning goal orientations with a focus on chemistry content and, at the same time, a strong focus on the social domain. It seemed to be possible for these girls to develop a personal connection with chemistry and to enjoy it as part of social life. Our hypothesis is, therefore, that chemistry might be perceived as more gender-neutral among the students with a Turkish migration background. In addition, it seemed to be perceived more strongly as part of social life. This shows that conceptual equivalence might not be given when analyzing chemistry self-concepts in these two cultural groups.

It is striking that the students' cultural background seems to play such an important role in their attitude towards chemistry. All students in our sample went to schools in the same country. They therefore experience chemistry in the same educational system. Most of the students with a Turkish migration background were born and raised in Germany and only their mother and/or father were born in Turkey.

We considered further literature in order to build a hypothesis of what might produce these differences. Our search made us aware of the fact that in Turkey, slightly more young women than men hold science degrees [37]. In addition, the girls achieved substantially better in science than the boys in the PISA 2015 [38] and TIMSS 2015 study [39]. This suggests that science might be perceived as more gender-neutral in Turkish society. Our hypothesis is that this different association of science with gender might influence the chemistry self-concepts of students with a Turkish background. This underlines the need for culture-sensitive science self-concept research.

Measurement non-equivalence seemed not to be present. Firstly, the students' oral descriptions of their abilities in chemistry seemed to correspond to their self-concept scores. The self-concept scores from the questionnaire, therefore, seem to be a good gauge for students' self-concepts in both cultural groups. Secondly, thinking about self-concept seemed to be equally salient in both cultural groups. This suggests that self-concept is of equal importance in both cultural groups. Measurement bias seems to be of minor importance in this study. This could possibly be due to the fact that all students live in Germany and most of them have probably been raised in the country. The students are, therefore, presumably equally familiar with Likert-type items.

The concurrent triangulation mixed methods design proposed in this study has several advantages compared to self-concept research that relies on Likert scale data only. (i) It can uncover conceptual non-equivalence as it did in this exploratory study; (ii) It can uncover measurement non-equivalence which seemed not to be present in our study; (iii) It pushes researchers to ask questions that go beyond the description of differences in self-concept. This can lead to more culturally embedded analyses. The present investigation constitutes an example of the attempt to embed self-concept data into the cultural context through trying to understand the culturally different associations of the chemistry with masculinity.

6.3. Limitations of the Study

The present study was exploratory in nature with the goal to assess the usefulness of a concurrent triangulation mixed methods design in self-concept research. Due to its exemplary nature, it faces several difficulties. One limitation of the study is the sample size, which poses difficulties, especially to the statistical analyses. However, the fact that we replicated the overall gender gap in favor of the boys encouraged us in our further analyses. It had been documented numerous times for Germany and, therefore, suggested that our sample represents some key trends. More importantly, the interviews support the assumption that the quantitative data are of good quality: many students talked about their abilities in the interviews. Their verbal statements corresponded to their self-concept scores in the questionnaire. Students who in the interviews talked about confidence in their abilities in chemistry showed self-concept scores above the mean. Students who were skeptical about their abilities in the interviews showed self-concept scores below the mean. This triangulation confirms the quality of the data. However, in order to be sure about the existence of the interaction effect between gender and cultural background, further investigations would be needed since this is the first time this has been documented.

Further, it is important to notice that the statement about the association of chemistry with masculinity that might differ between the two cultural groups is a hypothesis. At present, we cannot claim its validity because the interview study was explorative in nature. In order to claim validity for the hypothesis, a study aimed at hypothesis testing would be needed. The explorative approach was chosen because the primary goal of this study was to test a newly developed methodological and theoretical framework for more culture-sensitive academic self-concept research.

One strength of the approach is that it provides a framework for self-concept investigations in a mixed methods design with considerable explanatory power. This is due to the fact that the qualitative data are not used as illustrations but make substantive contributions to the whole analysis. In this study, the interviews served two purposes: (i) they allowed assessing the accuracy of the results from the quantitative part of the study. We saw that the students' statements about their abilities in the interviews corresponded to those in the questionnaire. In addition, it made us aware of conceptual non-equivalence. This is a triangulation assuring the validity of the data; (ii) The interview data allowed us to explore possible meanings of the findings from the questionnaire data. As stated above, in this study, we could derive hypotheses. However, we cannot claim their validity because this is the first time this approach was employed in a study. Despite this, the analysis of the interviews according to Hattie's process-oriented framework resulted in important insights. It made us aware of differences in gender conceptions that might play a role. We, therefore, believe that the approach to academic self-concept research explored in this article could lead to more culture-sensitive research and a deeper understanding of academic self-concept. Of course, the adoption of other models could be good alternatives, such as identity models which integrate self-concept in their conception. This could be fruitful because identity theories tend to focus on the processes of identity construction and sociocultural narratives whereas self-concept research provides quantitative information. Exploring the scope of joint approaches could advance self-concept research. We suggest that the presented approach could be used in other domains in order to further explore its explanatory power.

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References

1. Rüschenpöhler, L.; Markic, S. Self-concept research in science and technology education: Theoretical foundation, measurement instruments, and main findings. *Stud. Sci. Educ.* **2019**. [CrossRef]
2. Byrne, B.M.; Oakland, T.; Leong, F.T.L.; van de Vijver, F.J.R.; Hambleton, R.K.; Cheung, F.M.; Bartram, D. A critical analysis of cross-cultural research and testing practices. *Train. Educ. Prof. Psychol.* **2009**, *3*, 94–105. [CrossRef]
3. Byrne, B.M. Validating the measurement and structure of self-concept: Snapshots of past, present, and future research. *Am. Psychol.* **2002**, *57*, 897–909. [CrossRef] [PubMed]
4. Shavelson, R.J.; Hubner, J.J.; Stanton, G.C. Self-concept: Validation of construct interpretations. *Rev. Educ. Res.* **1976**, *46*, 407–441. [CrossRef]
5. Marsh, H.W. Verbal and math self-concepts: An internal/external frame of reference model. *Am. Educ. Res. J.* **1986**, *23*, 129–149. [CrossRef]
6. Hattie, J. Processes of integrating, developing and processing self information. In *Self-Processes, Learning, and Enabling Human Potential: Dynamic New Approaches*; McInerney, D.M., Marsh, H.W., Craven, R., Eds.; Information Age: Charlotte, NC, USA, 2008; pp. 51–85.
7. Dweck, C.S. Motivation. In *Foundations for a Psychology of Education*; Lesgold, A., Glaser, R., Eds.; Routledge: London, UK, 1989; pp. 87–136.
8. Anderson, A.; Hattie, J.; Hamilton, R.J. Locus of control, self-efficacy, and motivation in different schools: Is moderation the key to success? *Educ. Psychol.* **2005**, *25*, 517–535. [CrossRef]
9. Dweck, C.S. Motivational processes affecting learning. *Am. Psychol.* **1986**, *41*, 1040–1048. [CrossRef]
10. Dweck, C.S.; Leggett, E.L. A social cognitive approach to motivation and personality. *Psychol. Rev.* **1988**, *95*, 256–273. [CrossRef]
11. Button, S.B.; Mathieu, J.E.; Zajac, D.M. Goal orientation in organizational research. *Organ. Behav. Hum. Decis. Process.* **1996**, *67*, 26–48. [CrossRef]
12. Hole, J.L.; Crozier, W.R. Dispositional and situational learning goals and children's self-regulation. *Br. J. Educ. Psychol.* **2007**, *77*, 773–786. [CrossRef]
13. Rubin, G. The traffic in women: Notes on the 'political economy' of sex. In *Toward an Anthropology of Women*; Reiter, R., Ed.; Monthly Review Press: New York, NY, USA, 1975; pp. 157–210.
14. Riegle-Crumb, C.; Moore, C.; Ramos-Wada, A. Who wants to have a career in science or math? exploring adolescents' future aspirations by gender and race/ethnicity. *Sci. Educ.* **2011**, *95*, 458–476. [CrossRef]
15. Jurik, V.; Gröschner, A.; Seidel, T. How student characteristics affect girls' and boys' verbal engagement in physics instruction. *Learn. Instr.* **2013**, *23*, 33–42. [CrossRef]
16. Mujtaba, T.; Reiss, M.J. "I fall asleep in class ... but physics is fascinating": The use of large-scale longitudinal data to explore the educational experiences of aspiring girls in mathematics and physics. *Can. J. Sci. Math. Technol. Educ.* **2016**, *16*, 313–330. [CrossRef]

17. Ng, K.T.; Lay, Y.F.; Areepattamannil, S.; Treagust, D.F.; Chandrasegaran, A.L. Relationship between affect and achievement in science and mathematics in Malaysia and Singapore. *Res. Sci. Technol. Educ.* **2012**, *30*, 225–237. [CrossRef]
18. Marsh, H.W.; Craven, R.G. Reciprocal effects of self-concept and performance from a multidimensional perspective: Beyond seductive pleasure and unidimensional perspectives. *Perspect. Psychol. Sci.* **2006**, *1*, 133–163. [CrossRef] [PubMed]
19. Wilkins, J.L.M. Mathematics and science self-concept: An international investigation. *J. Exp. Educ.* **2004**, *72*, 331–346. [CrossRef]
20. Woods-McConney, A.; Oliver, M.C.; McConney, A.; Maor, D.; Schibeci, R. Science engagement and literacy: A retrospective analysis for indigenous and non-indigenous students in Aotearoa New Zealand and Australia. *Res. Sci. Educ.* **2013**, *43*, 233–252. [CrossRef]
21. DeWitt, J.; Archer, L.; Osborne, J.; Dillon, J.; Willis, B.; Wong, B. High aspirations but low progression: The science aspirations-careers paradox amongst minority ethnic students. *Int. J. Sci. Math. Educ.* **2011**, *9*, 243–271. [CrossRef]
22. Koutsoulis, M.K.; Campbell, J.R. Family processes affect students' motivation, and science and math achievement in Cypriot high schools. *Struct. Equ. Model.* **2001**, *8*, 108–127. [CrossRef]
23. Bauer, C.F. Beyond "student attitudes": Chemistry self-concept inventory for assessment of the affective component of student learning. *J. Chem. Educ.* **2005**, *82*, 1864–1870. [CrossRef]
24. Bauer, C.F. Attitude toward chemistry: A semantic differential instrument for assessing curriculum impacts. *J. Chem. Educ.* **2008**, *85*, 1440–1445. [CrossRef]
25. Xu, X.; Lewis, J.E. Refinement of a chemistry attitude measure for college students. *J. Chem. Educ.* **2011**, *88*, 561–568. [CrossRef]
26. Marsh, H.W. *Self Description Questionnaire (SDQ) III: A Theoretical and Empirical Basis for the Measurement of Multiple Dimensions of Latent Adolescent Self-Concept. An Interim Test Manual and Research Monograph*; University of Western Sydney, Faculty of Education: Macarthur, Australia, 1992.
27. Lewis, S.E.; Shaw, J.L.; Heitz, J.O.; Webster, G.H. Attitude counts: Self-concept and success in general chemistry. *J. Chem. Educ.* **2009**, *86*, 744–749. [CrossRef]
28. Creswell, J.W.; Plano Clark, V.L.; Gutmann, M.L.; Hanson, W.E. Advanced mixed methods research designs. In *Mixed Methods in Social & Behavioral Research*; Tashakkori, A., Teddlie, C., Eds.; Sage: Thousand Oaks, CA, USA, 1998; pp. 209–240.
29. Statistisches Bundesamt. *Bevölkerung und Erwerbstätigkeit Bevölkerung mit Migrationshintergrund: Ergebnisse des Mikrozensus 2013*; Destatis: Frankfurt am Main, Germany, 2013.
30. World Medical Association. World Medical Association declaration of Helsinki: Ethical principles for medical research involving human subjects. *JAMA* **2013**, *310*, 2191–2194. [CrossRef] [PubMed]
31. R Core Team. R: A Language and Environment for Statistical Computing. R Version 3.4.2. 2017. Available online: www.R-project.org/ (accessed on 7 May 2018).
32. Fox, J.; Weisberg, S. *An {R} Companion to Applied Regression*, 2nd ed. 2011. Available online: http://socserv.socsci.mcmaster.ca/jfox/Books/Companion (accessed on 5 May 2018).
33. Revelle, W. psych: Procedures for Psychological, Psychometric, and Personality Research: R Package Version 1.7.8. 2017. Available online: https://CRAN.R-project.org/package=psych (accessed on 7 May 2018).
34. Mayring, P. *Qualitative Content Analysis: Theoretical Foundation, Basic Procedures and Software Solution*; SSOAR: Klagenfurt, Austria, 2014; Available online: http://nbn-resolving.de/urn:nbn:de:0168-ssoar-395173 (accessed on 1 November 2018).
35. Roedel, T.D.; Schraw, G.; Plake, B.S. Validation of a measure of learning and performance goal orientations. *Educ. Psychol. Meas.* **1994**, *54*, 1013–1021. [CrossRef]
36. Rüschenpöhler, L.; Markic, S. Secondary school students' chemistry self-concepts: Gender, culture, and the impact on learning behaviour. *Chem. Educ. Res. Pract.* **2019**. [CrossRef]
37. OECD. *Chart A4.6 Tertiary Graduates in Science-Related Fields among 25–34 Year-Olds in Employment, by Gender*; OECD Publishing: Paris, France, 2009. [CrossRef]

38. Batyra, A. Gender Gaps in Student Achievement in Turkey: Evidence from the Programme for International Student Assessment (PISA). 2015. Available online: https://www.researchgate.net/publication/320560351_Gender_gaps_in_student_achievement_in_Turkey_Evidence_from_the_Programme_for_International_Student_Assessment_PISA_2015/link/59ede5c4aca27250fe79c7bf/download (accessed on 1 March 2019).
39. Batyra, A. Gender Gaps in Student Achievement in Turkey: Evidence from Trends in International Mathematics and Science Study (TIMSS). 2015. Available online: https://www.researchgate.net/publication/320562476_Gender_gaps_in_student_achievement_in_Turkey_Evidence_from_Trends_in_International_Mathematics_and_Science_Study_TIMSS_2015/link/59ede72e0f7e9bc36521f3b3/download (accessed on 1 March 2019).

Article 3

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

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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.

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 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 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 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.

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.

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 α. 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).

‡ 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.

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

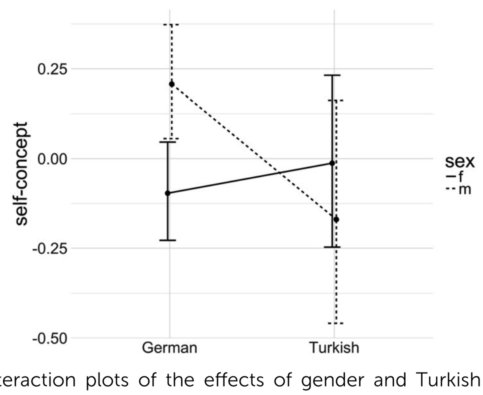

Fig. 1 Interaction plots of the effects of gender and Turkish migration background on chemistry self-concept with error bars.

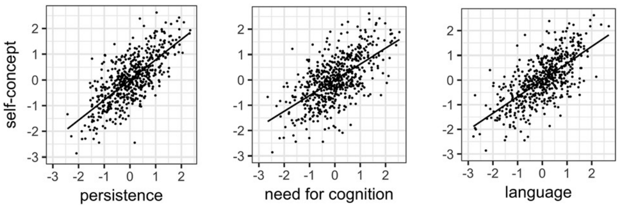

Fig. 2 Scatterplots with linear regression for the relationships of persistence, need for cognition, and language with self-concept.

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

	β	SE β	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 β values. Teacher support and Turkish migration background contributed significantly to the model but with lower β values. All the other variables had much smaller β 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 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.

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.

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)

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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References

Archer L., DeWitt J., Osborne J., Dillon J., Willis B. and Wong B., (2010), "Doing" science *versus* "being" a scientist: examining 10/11-year-old schoolchildren's constructions of science through the lens of identity, *Sci. Educ.*, **94**(4), 617–639, DOI: 10.1002/sce.20399.

Batyra A., (2017a), *Gender gaps in student achievement in Turkey: Evidence from the Programme for International Student Assessment (PISA) 2015*.

Batyra A., (2017b), *Gender gaps in student achievement in Turkey: Evidence from Trends in International Mathematics and Science Study (TIMSS) 2015*.

Bauer C. F., (2005), Beyond 'student attitudes': chemistry self-concept inventory for assessment of the affective component of student learning, *J. Chem. Educ.*, **82**(12), 1864–1870, DOI: 10.1021/ed082p1864.

Bauer C. F., (2008), Attitude toward chemistry: a semantic differential instrument for assessing curriculum impacts, *J. Chem. Educ.*, **85**(10), 1440–1445, DOI: 10.1021/ed085p1440.

Bless H., Wänke M., Bohner G., Fellhauer R. F. and Schwarz N., (1994), Need for cognition: Eine Skala zur Erfassung von Engagement und Freude bei Denkaufgaben, *Z. Sozpsychol.*, 147–154.

Broman K. and Simon S., (2015), Upper secondary school students' choice and their ideas on how to improve chemistry education, *Int. J. Sci. Math. Educ.*, **13**(6), 1255–1278, DOI: 10.1007/s10763-014-9550-0.

Bybee R. W., (1997), *Achieving scientific literacy: from purposes to practices*, Portsmouth, NH: Heinemann.

Cacioppo J. T. and Petty R. E., (1982), The need for cognition, *J. Pers. Soc. Psychol.*, **42**(1), 116–131, DOI: 10.1037/0022-3514.42.1.116.

Chan J. Y. K. and Bauer C. F., (2015), Effect of peer-led team learning (PLTL) on student achievement, attitude, and self-concept in college general chemistry in randomized and quasi experimental designs, *J. Res. Sci. Teach.*, **52**(3), 319–346, DOI: 10.1002/tea.21197.

Dahl D. B., (2016), *xtable: Export tables to LaTeX or HTML: R package version 1.8-2*, retrieved from https://CRAN.R-project.org/package=xtable.

Day E. A., Espejo J., Kowollik V., Boatman P. R. and McEntire L. E., (2007), Modeling the links between need for cognition and the acquisition of a complex skill, *Pers. Individ. Diff.*, **42**(2), 201–212, DOI: 10.1016/j.paid.2006.06.012.

DeWitt J., Archer L., Osborne J., Dillon J., Willis B. and Wong B., (2011), High aspirations but low progression: the science aspirations-careers paradox amongst minority ethnic students, *Int. J. Sci. Math. Educ.*, **9**(2), 243–271, DOI: 10.1007/s10763-010-9245-0.

Dickhäuser O. and Reinhard M.-A., (2006), Factors underlying expectancies of success and achievement: the influential roles of need for cognition and general or specific self-concepts, *J. Pers. Soc. Psychol.*, **90**(3), 490–500, DOI: 10.1037/0022-3514.90.3.490.

Dishon-Berkovits M., (2014), A study of motivational influences on academic achievement, *Soc. Psychol. Educ.*, **17**(2), 327–342, DOI: 10.1007/s11218-014-9257-7.

Dudovitz R. N., Chung P. J. and Wong M. D., (2017), Teachers and coaches in adolescent social networks are associated with healthier self-concept and decreased substance use, *J. Sch. Health*, **87**(1), 12–20, DOI: 10.1111/josh.12462.

Dweck C. S., (1986), Motivational processes affecting learning, *Am. Psychol.*, **41**(10), 1040–1048, DOI: 10.1037/0003-066X.41.10.1040.

Dweck C. S., (2000), *Self-theories: their role in motivation, personality, and development*, Philadelphia, PA: Psychology Press.

Dweck C. S. and Leggett E. L., (1988), A social cognitive approach to motivation and personality, *Psychol. Rev.*, **95**(2), 256–273, DOI: 10.1037/0033-295X.95.2.256.

Enders C. K. and Tofighi D., (2007), Centering predictor variables in cross-sectional multilevel models: a new look at an old issue, *Psychol. Methods*, **12**(2), 121–138, DOI: 10.1037/1082-989X.12.2.121.

Eren-Sisman E. N., Cigdemoglu C. and Geban O., (2018), The effect of peer-led team learning on undergraduate engineering students' conceptual understanding, state anxiety, and social anxiety, *Chem. Educ. Res. Pract.*, **19**(3), 694–710, DOI: 10.1039/C7RP00201G.

Ferla J., Valcke M. and Schuyten G., (2010), Judgments of self-perceived academic competence and their differential impact on students' achievement motivation, learning approach, and academic performance, *Eur. J. Psychol. Educ.*, **25**(4), 519–536, DOI: 10.1007/s10212-010-0030-9.

Fletcher T. D., (2012), *QuantPsyc: Quantitative Psychol. Tools: R package version 1.5*, retrieved from https://CRAN.R-project.org/package=QuantPsyc.

Fox J. and Weisberg S., (2011), *An {R} companion to applied regression*, 2nd edn, Thousand Oaks, CA: Sage, retrieved from http://socserv.socsci.mcmaster.ca/jfox/Books/Companion.

Grunert M. L. and Bodner G. M., (2011), Finding fulfillment: women's self-efficacy beliefs and career choices in chemistry, *Chem. Educ. Res. Pract.*, **12**(4), 420–426, DOI: 10.1039/C1RP90050A.

Hänze M. and Berger R., (2007), Cooperative learning, motivational effects, and student characteristics: an experimental study comparing cooperative learning and direct instruction in 12th grade physics classes, *Learn. Instruct.*, **17**(1), 29–41, DOI: 10.1016/j.learninstruc.2006.11.004.

Hardy G., (2014), Academic self-concept: modeling and measuring for science, *Res. Sci. Educ.*, **44**(4), 549–579, DOI: 10.1007/s11165-013-9393-7.

Henry L. and Wickham H., (2017), *purrr: Functional programming tools: R package version 0.2.4*, retrieved from https://CRAN.R-project.org/package=purrr.

Inchley J., Currie D., Young T., Samdal O., Torsheim T., Augustson L. … Barnekow V. (ed.), (2016), *Growing up unequal: gender and socioeconomic differences in young people's health and well-being: health behaviour in school-aged children (HBSC) study: international report from the 2013/2014 survey*, Copenhagen: World Health Organization.

Jacques P. H., Garger J., Thomas M. and Vracheva V., (2012), Effects of early leader–member exchange perceptions on academic outcomes, *Learn. Environ. Res.*, **15**(1), 1–15, DOI: 10.1007/s10984-012-9100-z.

Jansen M., Schroeders U. and Lüdtke O., (2014), Academic self-concept in science: multidimensionality, relations to achievement measures, and gender differences, *Learn. Individ. Diff.*, **30**(11), 11–21, DOI: 10.1016/j.lindif.2013.12.003.

Jenkins L. N. and Demaray M. K., (2015), Indirect effects in the peer victimization-academic achievement relation: the role of academic self-concept and gender, *Psychol. Sch.*, **52**(3), 235–247, DOI: 10.1002/pits.21824.

Kline P., (2000), *The handbook of psychological testing*, 2nd edn, London/New York: Routledge.

Koul R., Lerdpornkulrat T. and Poondej C., (2016), Gender compatibility, math-gender stereotypes, and self-concepts in math and physics, *Phys. Rev. Phys. Educ. Res.*, **12**(2), DOI: 10.1103/PhysRevPhysEducRes.12.020115.

Lau K. C., (2014), The science education of the East Asian regions: what we can learn from PISA, *Asia-Pacific Forum on Sci. Learn. Teach.*, **15**(2).

Leslie L. L., McClure G. T. and Oaxaca R. L., (1998), Women and minorities in science and engineering: a life sequence analysis, *J. High. Educ.*, **69**(3), 239–276, DOI: 10.1080/00221546.1998.11775134.

Lewis S. E., Shaw J. L., Heitz J. O. and Webster G. H., (2009), Attitude counts: self-concept and success in general chemistry, *J. Chem. Educ.*, **86**(6), 744–749, DOI: 10.1021/ed086p744.

Lin C.-J., Hung P.-H., Lin S.-W., Lin B.-H. and Lin F.-L., (2009), The power of learning goal orientation in predicting student mathematics achievement, *Int. J. Sci. Math. Educ.*, **7**(3), 551–573, DOI: 10.1007/s10763-008-9132-0.

Lüdecke D., (2018), *sjstats: Statistical functions for regression models: R package version 0.14.3*, retrieved from https://CRAN.R-project.org/package=sjstats.

Mair P., Schoenbrodt F. and Wilcox R., (2017), *WRS2: Wilcox robust estimation and testing: R package version 0.9.2*, retrieved from https://CRAN.R-project.org/package=WRS2.

Markic S. and Childs P. E., (2016), Language and the teaching and learning of chemistry, *Chem. Educ. Res. Pract.*, **17**(3), 434–438, DOI: 10.1039/C6RP90006B.

Marsh H. W., (1992), *Self description questionnaire (SDQ) III: a theoretical and empirical basis for the measurement of multiple dimensions of latent adolescent self-concept: an interim test manual and research monograph*, Macarthur: University of Western Sydney, Faculty of Education.

Marsh H. W. and Craven R. G., (2006), Reciprocal effects of self-concept and performance from a multidimensional perspective: beyond seductive pleasure and unidimensional perspectives, *Perspect. Psychol. Sci.*, **1**(2), 133–163, DOI: 10.1111/j.1745-6916.2006.00010.x.

Marsh H. W., Xu M. K. and Martin, A. J. (2012), Self-concept: a synergy of theory, method, and application, in Harris K. R., Graham S. and Urdan T. (ed.), *APA Educational Psychology Handbook, Volume 1, Theories, Constructs, and Critical Issues*, Washington, DC: American Psychological Association, pp. 427–458.

Nagengast B. and Marsh H. W., (2012), Big fish in little ponds aspire more: mediation and cross-cultural generalizability of school-average ability effects on self-concept and career aspirations in science, *J. Educ. Psychol.*, **104**(4), 1033–1053, DOI: 10.1037/a0027697.

Nagy G., Trautwein U., Baumert J., Köller O. and Garrett J., (2006), Gender and course selection in upper secondary education: effects of academic self-concept and intrinsic value, *Educ. Res. Eval.*, **12**(4), 323–345, DOI: 10.1080/13803610600765687.

Nielsen S. E. and Yezierski E. J., (2015), Exploring the structure and function of the chemistry self-concept inventory with high school chemistry students, *J. Chem. Educ.*, **92**(11), 1782–1789, DOI: 10.1021/acs.jchemed.5b00302.

Nielsen S. E. and Yezierski E. J., (2016), Beyond academic tracking: using cluster analysis and self-organizing maps to investigate secondary students' chemistry self-concept, *Chem. Educ. Res. Pract.*, **17**(4), 711–722, DOI: 10.1039/C6RP00058D.

OECD, (2005), *PISA 2003 Technical report*, Paris: OECD Publishing.

OECD, (2006), *Assessing scientific, reading and mathematical literacy: a framework for PISA 2006*, OECD Publishing.

OECD, (2009a), *Chart A4.6 Tertiary graduates in science-related fields among 25–34 year-olds in employment, by gender (2009)*, DOI: 10.1787/888932460192.

OECD, (2009b), *PISA 2006 Technical report*, OECD.

OECD, (2014a), *PISA 2012 Technical report*, OECD Publishing.

OECD, (2014b), *What students know and can do: student performance in mathematics, reading and science*, Rev. edn, Paris: OECD.

R Core Team, (2017), *R: a language and environment for statistical computing: R version 3.4.2.*, Vienna: R Foundation for Statistical Computing, retrieved from https://www.R-project.org/.

Raufelder D., Sahabandu D., Martínez G. S. and Escobar V., (2015), The mediating role of social relationships in the association of adolescents' individual school self-concept and their school engagement, belonging and helplessness in school, *Educ. Psychol.*, **35**(2), 137–157, DOI: 10.1080/01443410.2013.849327.

Revelle W., (2017), *psych: procedures for psychological, psychometric, and personality research: R package version 1.7.8.*, Evanston, IL, retrieved from https://CRAN.R-project.org/package=psych.

Riegle-Crumb C., Moore C. and Ramos-Wada A., (2011), Who wants to have a career in science or math? Exploring adolescents' future aspirations by gender and race/ethnicity, *Sci. Educ.*, **95**(3), 458–476, DOI: 10.1002/sce.20431.

Rüschenpöhler L. and Markic S., (2019), A mixed methods approach to culture-sensitive academic self-concept research, *Educ. Sci.*, **9**(3), 240, DOI: 10.3390/educsci9030240.

Shavelson R. J., Hubner J. J. and Stanton G. C., (1976), Self-concept: validation of construct interpretations, *Rev. Educ. Res.*, **46**(3), 407–441, DOI: 10.3102/00346543046003407.

Sikora J. and Pokropek A., (2012), Gender segregation of adolescent science career plans in 50 countries, *Sci. Educ.*, **96**(2), 234–264, DOI: 10.1002/sce.20479.

Simpkins S. D., Price C. D. and Garcia K., (2015), Parental support and high school students' motivation in biology, chemistry, and physics: understanding differences among latino and caucasian boys and girls, *J. Res. Sci. Teach.*, **52**(10), 1386–1407, DOI: 10.1002/tea.21246.

Simpson A., Che S. M. and Bridges W. C., (2016), Girls' and boys' academic self-concept in science in single-sex and coeducational classes, *Int. J. Sci. Math. Educ.*, **14**(8), 1407–1418, DOI: 10.1007/s10763-015-9676-8.

Spinath B., (1998), *Implizite Theorien über die Veränderbarkeit von Intelligenz und Begabung als Bedingungen von Motivation und Leistung*, Lengerich: Pabst Science Publishers.

Statistisches Bundesamt, (2013), *Bevölkerung und Erwerbstätigkeit Bevölkerung mit Migrationshintergrund: Ergebnisse des Mikrozensus 2013*, Statistisches Bundesamt.

Statistisches Bundesamt, (2017), *Bevölkerung und Erwerbstätigkeit: Bevölkerung mit Migrationshintergrund: Ergebnisse des Mikrozensus 2016*, Statistisches Bundesamt.

Taskinen P. H., Schütte K. and Prenzel M., (2013), Adolescents' motivation to select an academic science-related career: the role of school factors, individual interest, and science self-concept, *Educ. Res. Eval.*, **19**(8), 717–733, DOI: 10.1080/13803611.2013.853620.

Thomas A. E., (2017), Gender differences in students' physical science motivation: are teachers' implicit cognitions another piece of the puzzle? *Am. Educ. Res. J.*, **54**(1), 35–58, DOI: 10.3102/0002831216682223.

Wan Z. H. and Lee J. C. K., (2017), Hong Kong secondary school students' attitudes towards science: a study of structural models and gender differences, *Int. J. Sci. Educ.*, **39**(5), 507–527, DOI: 10.1080/09500693.2017.1292015.

Wentzel K. R., Battle A., Russell S. L. and Looney L. B., (2010), Social supports from teachers and peers as predictors of academic and social motivation, *Contemp. Educ. Psychol.*, **35**(3), 193–202, DOI: 10.1016/j.cedpsych.2010.03.002.

Wentzel K. R., Muenks K., McNeish D. and Russell S., (2017), Peer and teacher supports in relation to motivation and effort: a multi-level study, *Contemp. Educ. Psychol.*, **49**, 32–45, DOI: 10.1016/j.cedpsych.2016.11.002.

Wickham H., (2007), Reshaping data with the reshape package, *J. Stat. Softw.*, **21**(12), DOI: 10.18637/jss.v021.i12.

Wickham H., (2009), *ggplot2: Elegant graphics for data analysis: R package version 2.2.1.*, New York, NY: Springer.

Wickham H., (2011), The split-apply-combine strategy for data analysis, *J. Stat. Softw.*, **40**(1), DOI: 10.18637/jss.v040.i01.

Wickham H. and Henry L., (2018), *tidyr: easily tidy data with 'spread()' and 'gather()' functions: R package version 0.8.0.*, retrieved from https://CRAN.R-project.org/package=tidyr.

Wickham H., Francois R., Henry L. and Müller K., (2017), *dplyr: a grammar of data manipulation: R package version 0.7.4.*, retrieved from https://CRAN.R-project.org/package=dplyr.

Wood L. C., Ebenezer J. and Boone R., (2013), Effects of an intellectually caring model on urban African American alternative high school students' conceptual change and achievement in chemistry, *Chem. Educ. Res. Pract.*, **14**(4), 390–407, DOI: 10.1039/C3RP00021D.

Woods-McConney A., Oliver M. C., McConney A., Maor D. and Schibeci R., (2013), Science engagement and literacy: a retrospective analysis for indigenous and non-indigenous students in Aotearoa New Zealand and Australia, *Res. Sci. Educ.*, **43**(1), 233–252, DOI: 10.1007/s11165-011-9265-y.

Xu X. and Lewis J. E., (2011), Refinement of a chemistry attitude measure for college students, *J. Chem. Educ.*, **88**(5), 561–568, DOI: 10.1021/ed900071q.

Ziegler A. and Heller K. A., (2000), Conditions for self-confidence among boys and girls achieving highly in chemistry, *J. Second. Gifted Educ.*, **11**(3), 144–151, DOI: 10.4219/jsge-2000-627.

Article 4

Secondary school students' acquisition of science capital in the field of chemistry

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Secondary school students' acquisition of science capital in the field of chemistry

Lilith Rüschenpöhler * and Silvija Markic

Research has shown that students' science capital has a large impact on their science aspirations and their development of science identities. In this study, we apply the notion of science capital to chemistry education in order to investigate how students make use of science capital in the field of chemistry. We define chemistry capital as a person's resources that help him or her to succeed in the field of chemistry (*e.g.*, parents know chemistry content, sharing chemistry-related activities at home,...). We interviewed 48 secondary school students in Germany and conducted a thematic analysis. It reveals the following. (i) Chemistry capital in the home environment is unevenly distributed. Students who do not have family members who can connect with the mainstream conception of chemistry tend to be concentrated in schools with the lowest entry requirements (*Hauptschulen*, lower secondary education). Chemistry capital, therefore, tends to be reproduced. (ii) In most cases, families' chemistry capital translates into students' individual chemistry capital. This shows up in a multitude of links between families' chemistry capital and students' individual chemistry capital. (iii) The German school structures tend to aggravate the existing inequalities: this tends to deprive the students from *Hauptschulen* of qualified chemistry teachers. (iv) In some exceptional cases, students acquire chemistry capital independently from their families' capital. They do so either by following chemistry-related YouTube channels or by developing a chemistry identity as part of a general learner identity. In order to reduce the existing inequalities, there is an urgent need to provide *Hauptschulen* in Germany with qualified teaching staff for chemistry. If this precondition is met, teaching approaches that focus on identity building and engaging students and their parents in a dialogue about chemistry could potentially be fruitful.

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Introduction

Identifying with science is more difficult for girls and students from a working-class background than for middle-class boys (Archer *et al.*, 2010; DeWitt *et al.*, 2013). This has been shown in analyses of students' science capital. Science capital is a concept derived from the notion of capital developed by the French sociologist Pierre Bourdieu. It describes all resources a person can possess that have a value in the field of science. These resources can be scientific knowledge, personal contacts to scientists, engaging in science-related activities, *etc.* (Archer *et al.*, 2015a). The concept allows analysing the classed, gendered, and racialised nature of science identities (Archer *et al.*, 2014) as well as the reproduction of social inequalities (Archer *et al.*, 2015b).

Since the concept of science capital refers to science as a unitary entity, subject-specific knowledge about the reproduction of capital is not yet available. The aim of the present study is to gain an understanding of the reproduction of existing social inequalities in the field of chemistry education. This study investigates how students' social contexts translate into their individual perspectives on chemistry. In particular, we want to understand how secondary school students acquire chemistry-related resources in their families to gain access to the field of chemistry. We look at this in its interplay with institutional structures in school, *i.e.*, we are interested in knowing through which mechanisms social inequalities are reproduced and what role school plays. To conceptualise this, we use the concept of science capital by Archer *et al.* (2012b) as an analytical framework. It has proven to be a powerful tool in dismantling structures of social reproduction. Since we apply the notion to the field of chemistry, we speak of students' chemistry capital. Chemistry capital means all resources that have a value for students in the field of chemistry. Such a resource can, for instance, be a home environment in which talking about chemistry is appreciated and in which students are corrected in case they show misconceptions. A second example of chemistry capital is knowing a person who urges the student to join in chemistry-related activities. This can be a resource because sharing these experiences can help in developing a stronger personal attachment.

In the present study, we want to understand (i) the influence of families' chemistry capital on students' individual chemistry

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capital, (ii) the role of school structures, and (iii) students' individual strategies for acquiring chemistry capital. To do so, we look at students' perspectives. This helps us to understand what sources of chemistry capital they have access to and how this influences their acquisition of individual chemistry capital.

Theoretical background

In this study, we present findings about science capital. We show what science capital tries to explain: science identities are not equally distributed. They depend on gender, social class, and ethnicity. The concept of science capital provides an analytical framework for understanding these inequalities. We will present how it allows analysing processes of social reproduction in the field of science.

Science capital as an analytical framework

Science capital was introduced by Archer and colleagues in their analysis of the reasons why science aspirations and science identities differ between social groups (Archer *et al.*, 2015a). It provides a framework for understanding why engagement with science largely depends on gender, class, and ethnicity (Archer *et al.*, 2015a).

The concept describes three types of resources that contribute to a person's success in the field of science (Archer *et al.*, 2015a). (i) Science-related cultural capital comprises a person's science knowledge and attitudes towards science. Positive attitudes towards science contribute to success in the field of science (Potvin and Hasni, 2014). (ii) Science-related behaviours and practices constitute the second type of science capital. This type comprises, for example, science media consumption, visits to science museums or participation in science clubs. The integration of science-related activities in a person's personal life can contribute to knowledge acquisition and strong personal attachments to science (*e.g.*, Suter, 2014; Martin *et al.*, 2016). (iii) The third type of science capital is science-related social capital. It describes the science capital available through social relations, for example, knowing someone who works in science or possessing a supportive home environment (Thomas and Strunk, 2017).

The phenomenon: unequal distribution of science identities

While doing science is enjoyable for many students and they think science is important, only very few develop a science identity and concrete science aspirations (DeWitt and Archer, 2015). Science identity research has gained popularity over the last few years and has developed into a vivid, rich field of research. Shanahan (2009) provided an overview of the different trends in science identity research. In particular, she showed how science identity research tends to focus on the individual while neglecting the social structures in which identities are formed. In contrast, science capital research allows identifying how some of the structures influence individual identities. It, therefore, provides a conceptual tool for understanding the interrelations between individual science identities and the social contexts in which these identities are possible.

It has been shown that boys have a greater range of possible science identities than girls (DeWitt and Archer, 2015). However, not only gender characterises the phenomenon. It needs to be considered in conjunction with social class. Science identities that are intertwined with working-class culture tend to be negatively sanctioned in school. In contrast, science identities that are embedded in middle-class culture fit more easily into the school context (Archer *et al.*, 2014; Carlone *et al.*, 2015). This is the case for the 'geeky' scientist, an identity which is highly valued in the context of school science but which leaves very little room for girls, working-class students, and students of ethnic minorities (Archer *et al.*, 2014). The picture of the geeky science boy is thus not only gendered but also shaped by social class and ethnicity. Female science identities are possible but precarious because they need to be balanced against mainstream conceptions of femininity. This means girls who build a science identity risk their identity as a woman not being recognised. This is especially true for girls with a working-class background (Archer *et al.*, 2012a, 2013) because here science is perceived as ''not girly, not sexy, not glamorous'' (Archer *et al.*, 2013, p. 171). A science identity, therefore, does not conform with mainstream female identities which are especially powerful for young people.

Understanding social reproduction in the field of science

For understanding these inequalities in the field of science, science capital refers to the term of social reproduction (Archer *et al.*, 2015a). Families use their science capital for social reproduction. This means that parents who possess science capital tend to support their children's success in the field of science with the means they possess. For example, they can seek to promote their children's interest in science, consciously or unconsciously. This happens by establishing science-related activities in family life such as talking about science, watching documentaries, *etc.* In addition to intentional actions, science capital can be transmitted in more subtle, ''embodied'' ways (Archer *et al.*, 2015a). The family can express attitudes towards science not only verbally but in emotional and bodily reactions, or ways of performing particular science identities. This embodiment of attitudes can be conceptualised as habitus (Archer *et al.*, 2012b).

While achievement in science seems to be relatively independent of parental support (Ing, 2014; Tan, 2019), engagement in science depends heavily on parental support (Kurt and Taş, 2018). For example, it has been shown that students' science self-concepts are heavily influenced by parental attitudes towards the science subjects (Simpkins *et al.*, 2015). This is explained through a wide range of subject-specific support behaviours (*e.g.*, looking at science websites with the student) and subject-unspecific support behaviours (*e.g.*, general support during hard times at school) the parents show at home (Simpkins *et al.*, 2015).

Through these conscious actions and unconscious behaviours, the parents' science capital is transmitted to the younger generation. This means that the existing capital in the parent generation is used to generate further capital (Archer *et al.*, 2015a). This contributes to the reproduction of existing social structures. Science capital helps in understanding why science aspirations and science identities are concentrated in certain social groups and depend heavily on the family context (Archer *et al.*, 2012b).

The exchange value of capital

Not all types of science capital have the same value in the field of science. These differences can be understood using the notion of exchange value (Rios-Aguilar *et al.*, 2011). Referring to this concept, science capital can be thought of as a currency. This currency is exchanged between people in the field. For example, if parents successfully help students in doing their homework in science, this can contribute to the students' learning. The student develops science knowledge, *i.e.*, more cultural capital in the field of science. If the student shows this knowledge in chemistry class, it can be rewarded by the teacher. In addition, in the long run, this knowledge developed through ongoing support can be rewarded outside the field of education as well, for instance, if the student opts for a career in which science knowledge is needed. The parents' knowledge is transmitted to the student who can use it in the field of science to promote the student's success.

Certain types of science capital have high exchange value in the field of science. They are recognised as more valuable than others. This becomes clear, for instance when looking at different types of science-related activities. Participating in a science club at school is probably regarded as more valuable than watching science-related YouTube channels. If a student mentions his participation in a science club in an application to a science-related job, this would probably be recognised as a science-related extracurricular activity. In contrast, if a student has been following science-related YouTube channels, it is less clear if this would be recognised as a science-related extracurricular activity. The activities differ in status, *i.e.*, in currency value. However, a generation conflict might be present here. While science clubs are probably currently more appreciated among employers, YouTube seems to be more recognised as a valuable source among younger people. In future, the currency value of following YouTubers might undergo changes when the younger generation gets hold of the more powerful positions.

Families that are highly engaged in the field of mainstream science would tend to suggest activities to their children that are highly valued in the field of science. They have knowledge about what counts as valuable in the field. In contrast, parents who are not involved in mainstream science tend to transmit science capital with less exchange value. They might not know what types of capital are recognised in the field of mainstream science. They, therefore, encounter more difficulties when trying to refine their children's interest in science in a way that is valued in the field of science (Archer *et al.*, 2012b).

Chemistry capital

To date, the concept of science capital has been employed only in one study in the field of chemistry which showed that science capital is positively associated with students' aspirations to study post-compulsory chemistry (Mujtaba *et al.*, 2018). However, the authors of this study used a science capital scale for their questionnaire and not a chemistry-specific instrument. Further knowledge about chemistry capital has not been produced yet. In particular, the processes of social reproduction in the field of chemistry have not received attention. We, therefore, lack knowledge about chemistry capital.

The purpose of the present study is to apply the concept of science capital to the field of chemistry in order to investigate processes of social reproduction in chemistry education. For this, we employ the term 'chemistry capital' in analogy to the notion of science capital. 'Chemistry capital' describes the cultural and social capital as well as the behaviours and practices that are used in the field of chemistry. This application of the Bourdieusian notion of capital to a specific field does not constitute an entirely new concept. Rather, chemistry capital can be defined as the part of science capital that is valued in the specific field of chemistry. We therefore adopt Archer *et al.*'s (2014) argumentation:

"'science capital' is not a separate 'type' of capital but rather a conceptual device for collating various types of economic, social and cultural capital that specifically relate to science—notably those which have the potential to generate use or exchange value for individuals or groups to support and enhance their attainment, engagement and/or participation in science." (p. 5)

Following this rationale, chemistry capital is not a separate type of capital. Rather, it describes all types of capital in the Bourdieusian sense that relate to chemistry and that are, therefore, resources in the field.

Research questions

In order to gain insights into these processes of reproduction in the field of chemistry, we focus on the capital flows from students' environments into their personal chemistry capital. In particular, we look at the capital in the home environment (support from parents, *etc.*), in school (teacher support), and students' individual capital (chemistry knowledge, practices, and attitudes). All these three aspects of chemistry capital are part of students' personal chemistry capital. The tripartition, however, serves to trace the flows of students' chemistry capital and the sources they have access to.

In particular, we want to know:

(i) How does school contribute to students' acquisition of chemistry capital?

(ii) How does chemistry capital in the home environment contribute to students' individual chemistry capital?

(iii) What individual strategies do students employ for acquiring chemistry capital?

Our conceptualization of chemistry capital focuses on the types of capital that have high exchange value in the field of chemistry, *i.e.*, that are valued in the context of school chemistry.

Methods

Sample

We interviewed 48 students from 14 classes in 6 different secondary schools. The research project was conducted with students from grades 8–10 because, in these grades, chemistry is compulsory in Germany. Thus, these students already had experience with chemistry without having opted for or against specialisation in chemistry. We included the three most common secondary school types in Germany. 15 students (31%) went to *Gymnasium* (grammar school), 21 students (44%) went to *Realschule* (track for students in the middle ability group), and 12 students (25%) went to *Hauptschule* (school with the lowest entry requirements).

Students from *Gymnasium* are slightly underrepresented in the sample, while students from the other school types are slightly overrepresented when compared to the official enrolment data (Statistisches Landesamt Baden-Württemberg, 2017). This was intended because students from *Hauptschule* tend to be included less frequently in educational research. Their perspectives, therefore, tend to be less well understood. In the present study, we were particularly interested in these students' perspectives because they tend to have an educationally and economically disadvantaged family background (Anger *et al.*, 2007). We wanted to know what resources these students possess for building a personal connection with chemistry. The students in the sample were aged 13–18† (M = 15), and 48% (23 students) were female. The majority (40 students, 83%) had a migration background which reflects the social structure of the urban setting in the Stuttgart metropolitan region in which data were collected.

The students were selected on a voluntary basis. This study is part of a larger research project. For the main study, the students filled in a questionnaire, after which interviews were conducted with those students who volunteered. When asking the students to participate in the interviews, we emphasised that we were interested in their individual perspectives on chemistry, irrespective of their identification as a 'good' or a 'bad' student in chemistry. Through this, we tried to make clear that we were interested in the full diversity of perspectives on chemistry.

Instrument

The interviews were semi-structured (Qu and Dumay, 2011) using an interview guide focusing on the role that chemistry plays in the students' life in school and at home. The interview guide was composed of introducing questions (see Qu and Dumay, 2011) designed to guide the interviews through all thematic sections. Further, it suggested that probing and specifying questions with which we tried to follow the interviewees in their unique perceptions of the situation and to keep the conversation going. We also used interpreting questions in which we rephrased the interviewees' answers in order to make sure that we had understood the content correctly. The interview guide was piloted in a sample of four students from two classes in grades 8 and 9 from one school. These four interviews are not part of the sample described above.

In its final version, the interview guide comprised three sections. (i) *Chemistry in school*. In order to start the conversation, we asked the students to describe what comes to their mind when they think about chemistry. Following this, we asked them to describe a situation in which they had been satisfied and one situation in which they had been dissatisfied with themselves in chemistry class. In addition, we wanted to know what they like and dislike about chemistry. (ii) *Chemistry at home*. In this section, we wanted to investigate the role that chemistry plays in the students' private life and in particular at home. We wanted to know in which places chemistry appears in their private life. Then, we asked them if they had talked about chemistry at home, and if yes, we asked them to describe one of these situations and how they perceived it. In addition, we wanted to know which person in their private life has the deepest chemistry knowledge and we tried to explore their social relationship. Finally, we asked them about their experiences with chemistry-related content on television or on video-sharing platforms such as YouTube. (iii) *Future engagement in chemistry*. In the last section, we wanted to find out what role the students imagine chemistry to play in their future lives.

All interviews were conducted in German. The extracts from the interviews we present here have been translated into English by the authors.

Ethics

Participation in the study was based on informed consent. Prior to conducting the study, we obtained the local governments' and school permissions. Since most of the students were underage, we also obtained the teachers', the students', and their parents' permissions. We did this in a letter 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 teachers, students, and parents could withdraw their permission at any moment, in which case the student's 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.

All interviews were conducted by the first author. A code allowed the authors to match the questionnaires with the interviews, while keeping the data anonymous. The questionnaire data are presented elsewhere (Rüschenpöhler and Markic, n.d.). In this study, we used only the interviews and some personal background data (gender, age, migration background). The interviews were recorded and the audio files were transcribed by two research assistants. After the interviewer had controlled for the accuracy of the transcripts, the audio files were deleted. Any personal data appearing in the transcripts that could have allowed tracing back the students' identity were deleted from the transcripts.

Analysis

We conducted a thematic analysis by Braun and Clarke (2006) (see also Vaismoradi *et al.*, 2013) based on an *a priori* coding

† We interviewed students in grades 8–10 for which the typical age range is 13–16 years. 90% of the students fell into this range. The 0.5% who were younger were probably students who had skipped a grade. The remaining students who exceeded the age range are probably students who had to repeat a school year due to low achievement, or they are immigrants who first attended a separate class for German as a foreign language before entering the regular school system.

scheme. This scheme was adapted from the literature on the different facets of science capital (cultural, social, economic) to the concept of chemistry capital. We used structural coding (Saldaña, 2016) to analyse the chemistry capital that the students reported having in their families. Here, we differentiated between chemistry-specific and subject-unspecific family capital that the students could use in the field of chemistry. The students' individual chemistry capital was coded using structural coding as well. To analyse causal links between the families' chemistry capital and the students' individual chemistry capital, we used process coding (Saldaña, 2016). In several analytical steps, the final coding scheme was produced. In order to ensure argumentative validation, the analytical work was discussed in regular meetings in a team consisting of one senior researcher, two early career researchers, and one chemistry teacher. An overview of the main categories of the final coding scheme as well as an example for one main category can be found in the Appendix.

In order to reveal the final themes, we took another analytic step for analysing the patterns of causal links for every single case (see the Appendix for an example). We drew causal networks (Miles *et al.*, 2014) for all interviews, resulting in 48 networks. In these networks, we visualised the causal links between the families' chemistry capital and the students' individual chemistry capital, as well as links between different aspects of chemistry capital. Causality was conceptualised in the sense of Maxwell (2012), drawing upon the concept of *local* causation. This term describes causal chains that are contextualised, for instance, the causality between emotional states, thoughts and the social structure (*e.g.*, 'I feel good in chemistry class because my teacher is really nice'). Since in the present study, we were interested in exactly this type of local, socially embedded causal relationship, we adopted this notion of causation. We drew causal links only if the students explicitly reported a causal connection. The causal networks were accompanied by short case reports (Miles *et al.*, 2014) that summarised the respective pattern of causal chains for each student. An example of a causal network with a case report can be found in the Appendix.

In the final step, we organised the individual patterns into groups of cases that shared similarities using pattern coding (Saldaña, 2016). For this purpose, we first divided the sample into groups according to the type of chemistry capital in the families: (a) cases with family backgrounds with chemistry capital, (b) cases with subject-unspecific capital at home that has exchange value in chemistry, (c) cases in which scarcely any capital with exchange value in chemistry was visible, and (d) cases in which the family context seemed to provide no chemistry capital with exchange value. Then, we analysed the contributions of science capital at home to the individual chemistry-related science capital in the respective groups in order to reveal typical patterns and deviations from these patterns.

Results

In the following, we will present the results from the thematic analysis of the interview data from 48 students. It was possible to identify four groups of cases. Each of these groups will be presented in a scheme showing the interactions between the different aspects of students' science capital. The schemes will be described in four sections (a–d), each describing a group of cases that seem to have similar types of chemistry capital at home as described above. We will describe the contributions that chemistry capital with exchange value makes to the students' individual chemistry capital. At the end of each section, we summarise the findings. For each group of cases, we will propose a conceptualisation using schemes. The schemes contain the type of capital that the students find in their home environment. Here, we limit our analysis to the capital with exchange value in the field of chemistry education, as described earlier (see 'Theoretical background').

We map the influence of the home environment on students' individual chemistry capital. Individual capital is divided into three sections:

(i) The first aspect is the emotional attachment to chemistry. With this term we refer to the affective part of attitudes towards chemistry. Attitudes towards chemistry are usually defined as composed of cognitive, affective, and behavioural aspects (Xu and Lewis, 2011; Potvin and Hasni, 2014). The emotional attachment to chemistry describes not only the students' emotions towards chemistry, for instance, boredom and excitement but also certain aspects of their attitudes towards chemistry such as their self-concept and the like.

(ii) As the second aspect of the students' individual capital, we conceptualised chemistry knowledge. Under this, we subsumed aspects in the interviews which suggested that the student had gained access to chemistry knowledge. This showed up, for instance, when students expressed thoughts about chemical content.

(iii) The third aspect we focused on regarding the students' individual chemistry capital is chemistry-related activities in leisure time. These activities were, for instance, participating in chemistry clubs, reading books about chemistry, watching YouTube videos about chemistry, *etc.*

The influences are symbolised by arrows, following the structure of causal networks developed for each individual student (see the Appendix for an example). If a factor appeared to be causally (Maxwell, 2012) linked to another factor, we drew an arrow. Straight arrows symbolise a reinforcement. If an arrow is dashed, this means that the relationship appears to be rather weak or unstable (*e.g.*, in Fig. 2). In some cases, we drew arrows as red zigzag lines symbolizing conflictual relationships (Fig. 3 and 4). In one group (Fig. 4), we found individual processes of the acquisition of chemistry capital which we represent using green arrows. This will be described in more detail in Section d.

(a) Family background with chemistry capital

A very small number of students (6; 12.5%) mentioned aspects in their life suggesting that their families have the type of chemistry capital that has a high exchange value in science. Most of these students (5) were from *Gymnasium* (grammar school), while only one was from *Realschule* (track for students in the middle ability group).

Cultivating social relationships through chemistry. Chemistry knowledge can enrich social relationships at home, a pattern that became apparent in several cases.

"I can talk to my parents about it, about chemistry, something my sister doesn't understand at all. When you know more you have more things to talk about. You just have new possibilities in conversations, instead of asking 'how's the weather today?' (...) you can just talk about things like, how do you get on with chemistry? What didn't you understand?" (S-NG-81V_CA-20-11)

In three interviews we found signs for a contribution of family chemistry capital to the students' emotional connection with chemistry. One student dislikes chemistry. However, because her mother is interested, she reconsiders her attitude. Her mother is, in this regard, a role model (Fig. 1, left).

"I don't know, I just think if my mother was that interested in it, then I think that it would be interesting to me, too, because (...) sometimes I just hate the subject, sometimes I don't. But I am okay with it and so I think at some point I will be interested in it." (S-NG-81V_BA-19-04)

Another student explained how his brother's excitement about chemistry inspired positive feelings toward chemistry in him. These feelings are maintained even when chemistry class is boring because he reminds himself of the aspects that both he and his brother enjoy about chemistry. This case shows how the emotional attachment can be inspired by the home environment.

In one case, we found a hint that family chemistry capital can help in developing a sense for the relevance of chemistry. This student perceives chemistry as important because she understands the impact of her mother's job in waste treatment on the environment, and the chemistry knowledge her mother needs.

Intergenerational transmission of chemistry knowledge. In all interviews, the students reported that their families' chemistry capital helps them to develop chemistry knowledge (Fig. 1, centre). Their family members explain chemistry content to them, they correct students' mistakes in case of misunderstandings, and they can act as 'translators' of scientific texts from chemistry class. One case showed especially well how chemistry knowledge is transmitted from elder generations to the younger ones: from the students' great-grandfather to his grandfather and then to the student.

"S: My grandpa could *of course* (...) explain it to me. (...) My great-grandfather taught my grandpa a lot, and my grandpa...

Y: Ah okay, your great-grandfather taught your grandpa...?

S: Exactly." (LB-GD-81H_LI-05-03)

Nurturing chemistry-related activities. All students reported talking about chemistry at home. In two cases, chemistry capital at home led to chemistry-related activities out of school (doing experiments at home; Fig. 1, right). One student explained:

"We have a garden in XX (...) there we have a big shed and there he had chemicals, he had stuff with which you can do experiments. Once for example, we did some kind of foam volcano or something like that. The foam squirted all over the place." (LB-GD-81H_LI-05-03)

Summary. Chemistry capital in the family seems to support the students' acquisition of chemistry capital in important ways (Fig. 1). First, the parents are a resource of chemistry knowledge and can, therefore, explain chemistry content. In addition, they nurture positive attitudes towards chemistry because they can act as role models and build an atmosphere in which talking about chemistry is a natural part of family life. This, in turn, contributes to the development of an understanding of chemistry content. The same is true for chemistry-related activities which, for some students, are an important part of family life. These activities can help in anchoring chemistry knowledge.

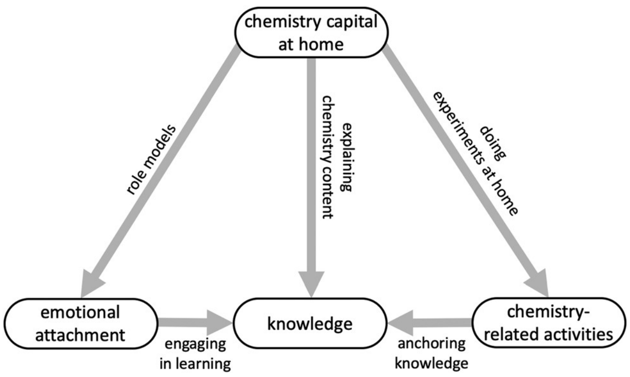


Fig. 1 Interactions between home environments in which chemistry capital is present and the students' acquisition of chemistry capital. The arrows symbolise contributions.

(b) General educational capital at home

A small number of students (4; 8.3%) showed considerable amounts of capital at home which is not chemistry-specific. Still, it has exchange value in the field of chemistry because it supports learning in general. One of these students was from a *Realschule* (school for the middle ability group), and the remaining students went to a grammar school (*Gymnasium*).

A subject-unspecific learner-friendly atmosphere. The students in this group described atmospheres in which learning and sharing knowledge are important parts of their family life. We assume that this can inspire an emotional attachment to chemistry (Fig. 2, left). In general, learning academic content helps in building social relationships at home because new insights are welcomed. However, chemistry does not get particular attention as was the case in group (a). Here, the focus seems to be on learning in general and not on particular subjects. In most of these family contexts, the acquisition of knowledge is supported in general. The emerging emotional and motivational attachments to chemistry (enjoyment, learning goal orientations, need for cognition, *etc.*) contribute to the learning process (Fig. 2, bottom left). This social embeddedness of chemistry learning becomes visible in the following extract.

"They [my family] always want to know what I am learning and they want to understand it. That's why it's more fun to explain it to them and that's also why I want to know all these things. So that I can *really* explain it to them." (S-NG-83V_AN-23-12)

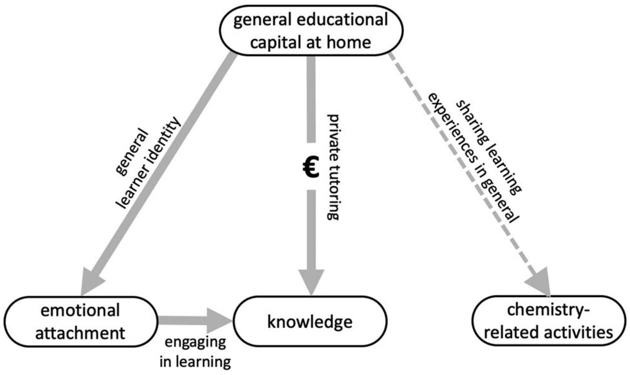


Fig. 2 Interactions between home environments in which general educational capital is present and the students' acquisition of chemistry capital. The dashed line symbolises a rather weak relation.

Because the family is interested in chemistry content, the student engages in deep learning processes in order to be able to answer the parents' questions. In contrast to this, one student explained that he does not speak about chemistry at home because his parents have very pronounced interest and seem not to be interested in chemistry. However, this student also experiences an atmosphere at home that supports learning and the acquisition of knowledge.

Making investments to support chemistry learning. Some families use their economic capital to support their children's chemistry learning: two students in this group had a private tutor their parents paid for. This way, the parents contribute to their children's conceptual understanding by means of money (Fig. 2, centre). Another student described how her grandfather engages in personal research every time he cannot answer a question from his granddaughter. This way, he supports her learning by investing his personal time in his granddaughter's chemistry learning. It seems like these types of investments are made because the families want to support their children's learning progress also in the subject areas in which they do not have sufficient knowledge.

In contrast to the first group, the students in this group tend to know more about chemistry than their parents:

"If I explained it slowly, they would understand it I think, if I did it like in a school lesson. Because I think it is not entirely new to them, but a long time ago." (S-JK-103DU_DE-29-01)

For this student, learning chemistry requires work at home and the willingness to engage in conceptual changes. She develops a different view of the material world than her parents. Support in the acquisition of chemistry knowledge needs to be mediated by means such as money (Fig. 2, arrow in the centre)

Sharing chemistry learning experiences at home. Chemistry-related activities at home tend to be part of the general learning culture in the family (dashed line in Fig. 2, right). One student watches documentary films with her father and spends time with him acquiring knowledge and sharing a passion for learning and discovering. Another student copies his parents' learning behaviour:

"When he's interested in something, a specific topic, he gets really into that, just like I do. I have seen him sitting two days in a row in front of his computer, doing research about something." (S-PR-91B_AD-11-09)

In this group, we did not find evidence for a link between these students' emotional attachment and their acquisition of chemistry knowledge as shown in Fig. 4. However, this might be due to the small number of students in this group.

Summary. Subject-unspecific capital at home can support the students' acquisition of chemistry capital in many ways (Fig. 2). The students in this group experience a very learner-friendly atmosphere which stimulates positive attitudes towards learning regarding any subject. The students, therefore, show rather positive emotions towards chemistry because it is a subject where they can learn. This emotional attachment helps in engaging in deep learning processes and the acquisition of chemistry knowledge. The conceptual understanding is supported in some cases indirectly, for instance, by paying for private tutoring. The parents use their economic capital in order to compensate for what they perceive as a lack of chemistry capital. Chemistry-related activities are rare in this environment. The families seem to share learning experiences in general but chemistry is not focused on.

(c) Capital with exchange value scarcely present

In nine cases (18.8%), capital with exchange value in the field of chemistry seemed to be scarcely existent at home. Five of these students went to *Realschule* (track for the middle ability group), three to *Gymnasium* (grammar school), and one student to *Hauptschule* (school with the lowest entry requirements).

The students as 'chemistry experts'. In this group, a particular situation occurred: the parents or other family members tended to show interest in the students' learning at school or in chemistry. Chemistry knowledge in the home environment seemed to be limited, just as was the case in group (b). However, in contrast to group (b), there seemed to be little knowledge about how to *acquire* chemistry knowledge. While one student in group (b) had explained how her grandfather learns chemistry in order to help his granddaughter, this seemed not to be an option in this group. The students in this group tended to be the chemistry experts at home. One student described how this expertise can turn into a responsibility when speaking about chemistry at home:

"S: Of course, I have to explain it correctly. If I say something wrong, then...

Y: What happens then?

S: Well, then the wrong things get spread." (S-JK-103DU_RA-06-10)

Since there is no other person who could correct her misconceptions, she is responsible for the accuracy of the chemistry content discussed at home. There seems to be no other source of knowledge the parents have access to. In this context, the students seem to be the only source that can introduce chemistry content at home. This can create tensions (Fig. 3, red arrow in the centre).

The discrepancy between students' and parents' world views. The introduction of chemical concepts at home can cause conflicts with the family (Fig. 3, centre).

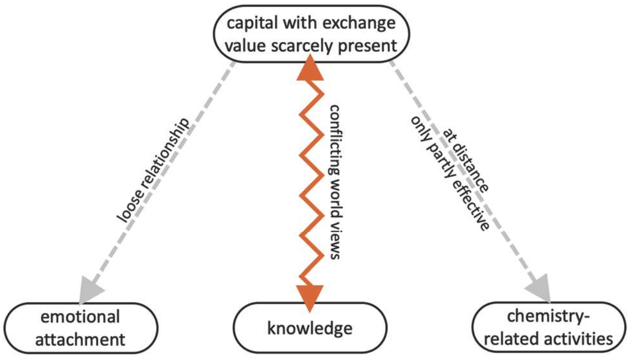


Fig. 3 Interactions between home environments in which capital with exchange value in the field of chemistry is scarcely present and the students' acquisition of chemistry capital. The dashed lines symbolise weak relationships, and the red zigzag line indicates a conflict.

"Y: Have you ever talked about your chemistry class at home?

S: Yes, for example about the atom model. I talked about that at home. But apart from that, I don't do that very often.

Y: How did they react at home?

S: Well sometimes, when my parents don't understand it, they want to explain to me that it's wrong." (S-NG-82V_CH-09-02)

This kind of conflict seems to be tied to the particular context the students are in: the parents do not have much chemistry knowledge and they do not have access to sources of chemistry knowledge. However, they tend to be interested in their children's learning processes. This creates a particular situation: the parents cannot check if the students' conceptions are supported by the scientific community. Because the students appear as the only source of chemistry knowledge, discrepancies between world views of parents and children can persist. This situation can be considered to be emblematic for this group.

Stimulation of chemistry-related activities is partly effective. Some of the students' families tried to support the students in their chemistry learning. In one case, these attempts appeared to help the student.

"S: She [her mother] asked me what it exactly was about and then I explained it to her, and then, well, it's always like: I learn something, I explain it to her and then she takes the book and corrects me (...).

Y: And how was it for you to work like this with your mother?

S: It was good. We do that quite often. Also, when I have to give a presentation, I read it to her, well, I present it to her and she tells me what I can do better or (...) what I am doing good. It's good because she's someone I trust in." (S-PR-101G_ZU-01-06)

Her mother actively supports her daughter's learning process in chemistry. Her support is process-focused and subject-unspecific and it seems to be effective: later in the interview, the student reported that she used to read the chemistry school book in her free time. This interest in school books might have been stimulated by the learning experiences she shared with her mother which she enjoyed a lot. However, the mother seems to possess very limited content knowledge and little general educational capital except for her positive attitude towards her daughter's progress in school. In this case, strong aspirations regarding educational success become apparent as well as attempts to actively embedding learning in the family culture. However, in contrast to the cases in group (b), in this case, the resources are more limited (*e.g.*, little discussions about content possibly due to the lack of knowledge, the school book is the resource of knowledge, not a family member) and most striking are the aspirations for a good education.

In many other cases in this group, the provided support is probably less effective (Fig. 3, right). One student received a notebook from his godmother with which she intended to support his chemistry learning. However, the notebook is empty and only has the periodic system of elements printed on the cover. Neither the student nor his godmother understands what it stands for. All they know is that it is related to chemistry. The gift is well-intentioned but it does not provide the student with actual capital. It does not provide access to chemistry knowledge or give the student concrete advice about how to organise his learning process. For this student, chemistry learning seems to remain a solitary enterprise.

Another factor that makes the support only partly effective is physical distance (Fig. 3, right). One student has a cousin who studies chemistry, which inspires the student's interest. The cousin seems to be a role model for the student.

"S: I was interested partly because of her because she was like: it's really cool. And she produces some stuff [chemical substances], and I was like: I want that, too.

Y: What did she tell you?

S: Eh, that they deal with medicine, that they produce medicine and sometimes also things like make-up and lotions. (...) She just told me that she does these things and I asked her: eeh, but that's really boring, because I knew chemistry class in school, like: ugh, what would you do there?, and she was like: no, it's actually not like chemistry in school. Well, it is, but not like I knew it, but *exciting*." (S-RS-91S_KH-01-0)

However, the girls live at a distance which complicates their exchange. Her identification with this cousin, therefore, remains limited and the student does not develop serious chemistry-related aspirations. Here, too, the support she can provide is limited in scope. In a second case, a student had a friend whose mother works in the field of pharmacy. The student used to do chemical experiments in her friend's private laboratory at home. However, the student moved from Croatia to Germany. The contact between the girls is, therefore, less frequent and the student cannot do chemical experiments at home anymore. In addition, in Croatia, her chemistry teacher had motivated her to join his chemistry club which she enjoyed very much. In Germany, she does not have this support anymore. Because chemistry-specific capital is not situated in their home zones, these two girls lose their link to chemistry.

Summary. Home environments in which capital with exchange value in the field of chemistry is scarcely visible can support the students' acquisition of chemistry capital only partly (Fig. 3). Some students engage in chemistry learning as it is taught in school, while, at the same time, some parents reject this world view. Talking about chemistry at home can, therefore, lead to conflicts. In contrast, in some cases, people in the home environment try to support the students' acquisition of chemistry capital. However, this support is effective only to a limited extent. Some students know people with chemistry capital who do not live in the same town and are therefore only occasionally accessible. This complicates the students' acquisition of chemistry capital: chemistry-related activities take place sporadically. The emotional attachment to chemistry remains unstable or superficial. In addition, attempts to support the students' acquisition of chemistry capital remain ineffective. This is due to the lack of knowledge about what constitutes chemistry capital with exchange value.

(d) Absence of capital with exchange value at home

Almost two-thirds of the students in our sample (29 students; 60.4%) seemed to have at home no capital with exchange value in the field of chemistry. The majority of these students were from non-academic track schools: 14 of them from *Realschule* (track for the middle ability group) and 11 from *Hauptschule* (school with the lowest entry requirements). Four students were from *Gymnasium* (grammar school). This suggests that there might be an association between the students' chemistry capital at home and the school type. 11 out of the 12 (91.7%) students from *Hauptschule* fell into this group, while this was the case for only 4 out of the 15 (26.7%) students from *Gymnasium*. *Realschule* seems to have an intermediate position: 14 out of the 21 (66.7%) students fell into this group. The students from *Hauptschule* are, therefore, overrepresented in this group, while the students from *Gymnasium* are underrepresented. However, this possible association describes a tendency only because a considerable number of students from *Gymnasium* were classified in this group.

Chemistry appears as irrelevant at home. In this group, chemistry appeared to be something that is not talked about at home (Fig. 4, "absence of capital with exchange value"). This means for example that little interest is shown when the student talks about chemistry. Chemistry is excluded from the home environment.

"Y: Are there other places where you can find chemistry, outside school?

S: No.

Y: When you think about your free time, do you have contact with chemistry somewhere? (...)

S: No, never.

Y: Pardon?

S: I don't think so." (S-RS-91S_BE-06-10)

When chemistry is not embedded in the students' social contexts outside school, the question of the relevance of chemistry arises (Fig. 4, dashed arrow on the left). In one case, this causal link became very clear:

"I think, somehow, chemistry doesn't make sense to me. I just think to myself, what do I need that for, where do I need all this stuff about atoms and ionic crystals, because from the people around me I don't hear anything about ions and then I think, I don't need chemistry. On the one hand, I do because

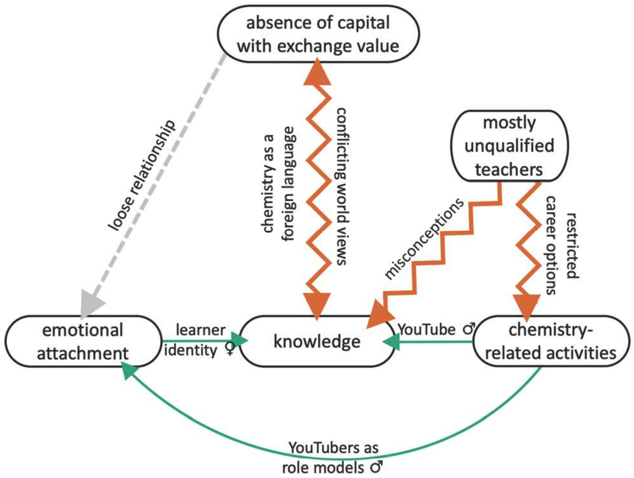


Fig. 4 Interactions between home environments in which capital with exchange value in chemistry is absent and the students' acquisition of chemistry capital. The green arrows constitute mechanisms of chemistry capital acquisition that the students deploy independent of external sources. The influence of unqualified chemistry teachers is added in this scheme because in this group the absence of this source of chemistry capital was reflected on.

of things like putting salt on the streets against black ice. That you shouldn't do that in winter. There I understand it. But other than that, I don't understand these things about the periodic table of elements. I don't think that this is something important for my future." (S-NR-92D_MA-25-05)

No one in this student's private life seems to touch subjects related to chemistry. She perceives chemistry as personally irrelevant because it is limited to the school context. Many students in this group shared the feeling that chemistry is not relevant.

Chemistry as a foreign language. Chemistry language was perceived as difficult by many students (Fig. 4, centre). The language seems to complicate chemistry learning for many students. One student described this in terms of a foreign language:

"In all classes, you have to develop a mental representation of things in order to understand. But [in chemistry] I always think (...): do they speak a different language than me?" (S-PR-92B_GI-23-10)

For some students, the teacher acts as a translator of the language of chemistry. He or she helps the students access chemistry capital.

Nevertheless, the language of chemistry can be a barrier to talking about chemistry at home. One student explained:

"Because my mum and dad don't speak German so well. And explaining in Turkish would be even more difficult because of all these technical terms and so on." (S-RS-10P_FA-01-06)

For this student, learning chemistry in the German language means that he cannot share it with his parents because they speak Turkish and seem not to have a lot of chemistry capital. Another student made similar experiences:

"S: They just asked about everything: what *this* is and what *that* is.

Y: What for example?

S: For example, eh, I told them about the thing with, eh, copper sulfide. I had to explain first, eh, for example when we put copper powder into a flame, then I had to explain first what copper *powder* is and so on.

Y: Like, the word?

S: Yes, the word. They couldn't understand it.'' (S-PR-93B_CR-29-06)

Because of the scientific language, these students cannot share the chemistry knowledge they acquire in school. If a student in this group develops interest in a topic in chemistry, sharing it with the family seems to be almost impossible.

Conflicting world views and misconceptions. Many students in this group said that they have difficulties understanding chemistry content. In other interviews, we noticed that they had serious difficulties understanding the particle structure of matter or they reported general difficulties of imagining chemical processes.

In some cases, there seemed to be misconceptions about the field of chemistry. Some of them confused it with what they had learned in biology class about fossils. In addition, one student seemed either not to know or to reject sources of reliable science knowledge. She had watched a YouTube video of an eight-year-old boy who said that he had been living on Mars in a former life. The student believed in his report on aliens who live under the surface of Mars and who breathe carbon dioxide.

However, some students did develop an understanding of chemistry. This seemed to be a true conceptual change:

''S: It was shocking.

Y: What do you mean?

S: I didn't know that everything, the, the whole world has something to do with chemistry. (...) Also in school when we write. The ink we use or the ink eraser, that has something to do with chemistry.'' (S-PR-92B_GI-23-10)

Three students experienced their science knowledge as incompatible with religious beliefs (Fig. 4, red arrow in the centre). One of them rejected the world view supported in science education in general. The other two did not want to choose between the two. One of them is very passionate about science in general and chemistry in particular. In his family, this causes conflicts because his parents and siblings believe in God and Genesis:

''My parents and my siblings, they know that God created them. I am on *that* side, too, (...) because I am Christian and orthodox and it's *also* important. Regarding the big bang, I am not so sure. There are facts and that's why I'm sometimes undecided.'' (S-PR-92B_KO-20-03)

Structural inequalities restrict options to acquire chemistry capital. In one interview, it became clear that structural inequalities can restrict students' options to acquire chemistry capital. Some students in this group perceived chemistry as highly relevant to them because they wanted a career for which chemistry knowledge is required.

''S: Ah, another problem is that I wanted to start an apprenticeship. (...) Somewhere it said that you need biology, chemistry, and maths. And then you ask yourself, you are really interested but then you ask yourself if you're capable of doing that or if you need the things we had in chemistry class or what exactly is important. Yeah, it is a problem because you feel limited.

Y: Limited because of what?

S: When there are these requirements: chemistry would be good to know, maths, biology and you don't know if you are prepared for that.

Y: What apprenticeship is that?

S: Pharmaceutical technician.'' (S-JK-103DU_FA-29-03)

For this student, chemistry is of high personal relevance but this is problematic: she believes that she lacks essential chemistry knowledge which is a prerequisite for her preferred career path. A similar situation was found in a second case. The student reported similar difficulties to those described above: career choices were restricted because she had the impression that she has insufficient chemistry knowledge for her preferred career as a nurse.

For these students, not even their teacher is a resource of chemistry capital. He did not study chemistry (Fig. 4, top right). Nevertheless, he is supposed to teach the subject. One of these students expressed her impression that chemistry is covered rather superficially.

''We cover things only superficially. And as far as I know, our teacher is not really a science teacher.'' (S-RS-10P_NA-19-12)

Before interviewing the students of his class, we had talked to the teacher, as well as to his colleagues. None of them had studied chemistry at the university level. Still, they taught the subject and reported serious difficulties understanding and teaching the chemistry content in the curriculum (Fig. 4, red arrow ''misconceptions'' on the top right).

And this seems not to be an exception: in our sample, not a single student from *Hauptschule* had a teacher who had studied chemistry at university. In contrast, all teachers at *Realschule* and *Gymnasium* in our sample were certified chemistry teachers. This seems to reflect a structural inequality: a very low proportion of teachers at *Gymnasium* teach chemistry without being certified for the subject. In contrast, this proportion is much higher at *Hauptschule* (Richter *et al.*, 2013).

The interview data suggest that the lack of certified chemistry teachers can have severe consequences for the students' lives. The student who would like to become a nurse doubts if she will be able to meet the entry requirements because her chemistry class is not a good source of chemistry capital (Fig. 4, red arrow ''restricted career options'' on the right). There seems to be a double disadvantage: all students from *Hauptschule* in our sample did not have a certified chemistry teacher (Fig. 4, right). In addition, 11 out of the 12 students from *Hauptschule* – more than 90% – had no chemistry capital at home. This means that students with little chemistry capital tend to be concentrated in schools where they are not provided with adequate opportunities to acquire chemistry capital. The students at *Hauptschule*, therefore, face the double disadvantage of having neither family support nor adequate school support in their chemistry learning. In contrast, the students who did possess chemistry capital were concentrated in *Gymnasium* and *Realschule* (see Section a). Here, they were provided with real chances to acquire further chemistry capital because their teachers hold a degree in chemistry.

Emotional detachment from chemistry. In general, the students in this group tended to report on very weak or negative emotional attachments to chemistry (Fig. 4, left). The data suggest that one reason for this is the presence of unqualified chemistry teachers coupled with a home environment that is detached from chemistry. Many students perceived chemistry as boring. They appeared to be emotionally detached from chemistry. If a student reported positive feelings towards chemistry, these feelings remain rather superficial. This reflects a very weak personal attachment to chemistry.

"Well, I am not *personally* as interested in it that I could think about it 24 hours, but I mean, if there are interesting things...I am interested in interesting things. (...) But there's not much I find interesting." (S-PR-92B_MB-01-01)

This detachment could be a sign of a rejection of chemistry. The student described how he shows his disinterest in chemistry class:

"S: I don't even write things down, I just sit there. So yes, it's boring.

Y: Okay and what do you do then?

S: Where? When?

Y: When you're sitting there.

S: Nothing. I sit there, I turn myself around I look to the back of the room. I do everything but participate in class.

Y: Why?

S: Loss of concentration I would say, but it's not like that. It's rather that I don't feel like. I just don't want to." (S-PR-92B_MB-01-01)

This student insists that it is his choice not to participate and not because he lacks the ability to concentrate. This reflects stronger feelings than boredom.

A second case supports the hypothesis that strong feelings might be one reason for rejecting chemistry. When asked at the beginning of the interview what she associates with chemistry, this student said:

"S: Chaos. (laughing)

Y: Chaos? Okay, what do you mean?

S: I can't understand these things with all these ... the ions and so on.

Y: (...) How does it feel when you don't understand it?

S: Confusing because then I'm sitting there and I think to myself, ugh, chemistry again, and I don't understand all these things she's talking about. Lately, I've been trying to use my brains and I work at home but it doesn't change much." (S-NR-92D_MA-25-05)

Instead of rejecting chemistry as something boring, she gets involved emotionally and experiences difficult thoughts and feelings about the fact that she does not understand chemistry. Rejecting chemistry could, therefore, be interpreted as a strategy to protect self-esteem if students do not have chemistry capital at home. Another student feels useless because she cannot take part in the discussions in chemistry. Another student feels desperate because she cannot meet the expectations in chemistry class.

All of these students who reported difficult feelings towards chemistry were female. This reaction could be interpreted in terms of the concept of laddishness (Jackson, 2002). Being a lad implies a rejection of the educational context because education is perceived as a female domain. Boys can, therefore, reject chemistry more easily than girls. Following this interpretation, the girls are more prone to experience difficult feelings if they don't meet the expectations in chemistry.

Using YouTube to acquire chemistry capital. In contrast to the first three groups of students (Sections a–c), in this group, we identified patterns of independent acquisition of chemistry capital (Fig. 4, represented by green arrows). Two male students developed a particularly strong emotional connection with chemistry through the consumption of documentaries on T.V. and YouTube videos (Fig. 4, bottom, green arrow from chemistry-related activities to emotional attachment). The two boys both follow the YouTuber Techtastisch, who describes his channel as being "full of dangerous and exciting experiments" (Techtastisch, n.d.).

They build a strong emotional bond with chemistry. One of the students said: 'I am just really excited about chemistry', when explaining his relation to chemistry as presented in the YouTube videos. The other student has a 'favourite element' that he discovered through the YouTuber and he described the physical properties he finds interesting. This suggests that chemistry knowledge might be acquired independently through the videos (Fig. 4, green arrow from activities to knowledge). Also, the definition of a personal 'favourite element' reflects a high degree of identification with chemistry. He adds laughingly that you can do "all kinds of funny stuff" with this element. He visibly enjoys chemistry and thinks of it as fun. This emotional link, in turn, opens for him the perspective of choosing a career in chemistry.

"S: What I was thinking about was becoming a chemical production technician or a chemist. For that I would have to go to university but...maybe even a chemistry teacher because I just love it so much." (S-PR-91B_JU-11-04)

This student is proud when others call him a nerd which shows his adoption of a nerdy chemistry identity.

"S: Most times, they just say: oh, nerd.

Y: Okay and how does it feel for you to be called a nerd?

S: Somehow, it's almost a kind of recognition because indirectly they say, you are smarter than us and that's why we try to put you down." (S-PR-91B_JU-11-04)

Although the sample size is too small to allow for definite conclusions, we suppose that it might be easier for boys than for girls to identify with chemistry through YouTube (Fig. 4, green arrows). The two boys in our sample related to a particularly masculine conception of chemistry in which emphasis was put on the dangers of chemistry. In contrast to these two cases, many students in this group do not develop a chemistry identity although they watch popular T.V. series such as The Big Bang Theory and the like. Some students mistake the series as a true story about science. Some even develop career aspirations inspired by fictional characters. These career aspirations tend to remain in the range of popular career aspirations such as forensic science, a field that has grown in popularity due to these types of series.

Drawing on inner strengths to acquire chemistry capital. Apart from the two boys who developed a strong bond with chemistry through following a YouTuber, one girl took a different path for developing a connection with chemistry independently. She showed a remarkable need for cognition (Cacioppo and Petty, 1982) and persistence (Bandura, 1989) and seemed to draw on these inner strengths for developing a connection with chemistry (Fig. 4, green arrow "learner identity" on the left).

"I brood over things until I understand them. Especially in chemistry because (...) then I get this inner positive feedback when I have done a difficult task." (S-PR-101G_OL-14-11)

Brooding seems to describe an important part of her identity. She repeated the word numerous times in the interview. Brooding is part of her identity as a learner which is not limited to chemistry.

"I am the type of person who broods over things until I really understand them. Because I cannot do otherwise. I can't just say, okay, I take a short break, and then, a few minutes later, I retry doing it." (S-PR-101G_OL-14-11)

In contrast to the two boys who followed the YouTuber, she does not have a role model. The social aspect of identification processes, *i.e.*, the identification with someone or with a group, does not play a role in her chemistry experience. Thinking about chemistry is a solitary enterprise for her and it is limited to her private room at home. She does not share her experiences.

"Y: Have you shown that to your family? Or...

S: Not really. They aren't really interested in that. That's why I have done it for myself because I thought it was really cool. (both laughing)

Y: Have you told someone about it?

S: No, (quietly) nobody actually." (S-PR-101G_OL-14-11)

Some other students showed a need for cognition that allowed them to build a certain connection with chemistry although they remained weaker. Here, too, the students identified themselves rather as learners and not subject-specifically as chemistry learners.

Summary. In this group, the students mainly develop chemistry capital with exchange value either through the use of social media or through a strong desire to learn (Fig. 4). These are exceptional cases. Many students in this group do not attempt to acquire chemistry capital because it appears to be irrelevant in their social environment. Some experience conflicts between the world view that is shared at home and the view they get to know in chemistry class. Many students, therefore, develop negative attitudes towards chemistry and reject the subject as boring or irrelevant. To many, chemistry language is perceived as a foreign language. This weak emotional attachment to chemistry experienced by most students seemed to have no impact on the acquisition of chemistry knowledge. But the students also experience structural inequalities. Most of them are taught chemistry by teachers who did not study chemistry. These teachers' potential to support them in the acquisition of chemistry capital independently of the home environment is, therefore, limited. Chemistry-related activities are limited to the consumption of videos on YouTube.

Discussion and conclusions

In the present study, we analysed secondary school students' chemistry capital. To our knowledge, this constitutes the first investigation of the transmission processes of science capital in chemistry. The analysis of 48 interviews with secondary school students in Germany allows exploring contributions of the home environment and school structures to students' chemistry capital and revealed some individual strategies with which students acquire it.

The transmission of chemistry capital from the home environment

Our data suggest that two types of existing capital in a home environment translate into chemistry capital with exchange value for the students: (i) a family background with chemistry capital and (ii) general educational capital at home. Only a small number of students possess these two types of capital. The first type is chemistry capital, *i.e.*, chemistry-related cultural and social capital and chemistry-related practices in the home environment. This type of capital is used by the parents and other relatives to support the students' acquisition of chemistry capital. Students who have chemistry capital in their home environment experience chemistry as part of their private life as well. Talking about chemical content and experiencing the excitement of a parent regarding chemistry inspires students to develop positive attitudes towards chemistry and to engage in chemistry learning. Engaging in chemistry learning means that students can participate in family life. In addition, the students in this type of environment always have a person at hand who will help them to overcome their misconceptions and who will explain chemistry content to them. This results in a transmission of chemistry knowledge and chemistry-related practices from one generation to another. This finding that chemistry capital tends to be transmitted between the generations is in line with the transmission processes of science capital as described in the literature (Archer *et al.*, 2012b).

Other than chemistry capital, there is a second type of capital in the home environment that can be used by students to acquire chemistry capital. It is a general educational capital, *i.e.*, a capital with exchange value in the whole field of education. This capital is subject-unspecific and, therefore, does not translate as directly into students' chemistry capital as the first type. However, it can have an important impact on the acquisition of students' chemistry capital. The students in this type of home environment experience a general learner-friendly atmosphere. Formal learning constitutes an essential part of family life and school work is highly valued. This inspires students to engage in chemistry learning because it means that they can participate in family life and it enriches their relationships. In some cases, family members use economic capital to help the students to acquire chemistry capital (*e.g.*, paying for private tutoring) or they use their learning skills to acquire chemistry capital themselves that they can transmit to the students.

This shows the central role families play in the acquisition of chemistry capital. Families try to transmit their chemistry capital to their children. This helps the students develop emotional bonds with chemistry, and chemistry knowledge, and to engage in chemistry-related activities. They are processes of the reproduction of chemistry capital. However, this study looked at the perspectives of the students only. Direct observations of these processes of reproduction would be important to gain a deeper understanding of the concrete processes in the field of chemistry.

Habitus conflicts

In contrast to the patterns described above, a great number of students described chemistry as being only loosely related to their home environment. Many of these students perceive chemistry as irrelevant because it does not play a role in their out-of-school environment. These students keep chemistry at distance. The data suggest that an important reason for this inner distance is the potential conflicts that can arise if a student engages in chemistry although chemistry is not part of family life. In several cases, serious conflicts occurred when students talked about chemistry at home. This can be due either to the incompatibility of certain religious beliefs with the world view of mainstream chemistry or to an incompatibility which is more diffuse in nature.

These patterns of compatibility and incompatibility can be understood using the concept of habitus that is deeply anchored in Bourdieusian theory (Archer *et al.*, 2012b). The habitus students need to adopt if they want to succeed in chemistry education is compatible only with certain family contexts. These contexts are family contexts with chemistry capital or with general educational capital. Here, the habitus acquired in chemistry education is very close to that of the family and therefore welcomed. In contrast, for students who live in a context where capital with exchange value in the field of chemistry is rare, the adoption of habitus from school chemistry can cause conflicts with parents and significant others. The habitus cultivated in mainstream chemistry can be rejected because it proposes a different world view. Adopting this habitus can, therefore, be risky and many students reject chemistry as irrelevant or boring.

We believe that it would be important to introduce the presented sociological perspective of chemistry capital in teacher training. This could contribute to an understanding of the fact that the expressions of boredom and disinterest might be not only individual in nature but also shaped by habitus conflicts students experience. The sociological lens of chemistry capital can help in opening up the teachers' perspectives. It suggests considering reasons beyond the individual that might contribute to students' expressions of feelings. It is important to acknowledge that knowledge about the students and their family backgrounds is always limited. In Germany, chemistry takes up around two or three lessons per week, starting in adolescence. If a teacher gives only chemistry lessons in a class, the teacher will share only a very limited amount of time with the students. Creating personal connections with the students and learning about their backgrounds can be difficult in this situation. However, it is important to acknowledge that feelings of boredom can be caused by social structures that might be unknown to the teacher. Introducing this sociological perspective in teacher training could help the teachers to better understand their students' emotional reactions.

In addition, research is needed about how to deal with habitus conflicts. Practical interventions need to be developed and assessed. Involving parents in the students' chemistry learning could provide a fruitful path. This has, for instance, been explored in the KEMIE project (Sommer *et al.*, 2013) and by the second author (Markic *et al.*, 2016). In this type of intervention, parents are an active part of doing chemistry with their children. For example, students are supposed to do experiments as homework. Here, it could be interesting to explore in what ways these experiments can be used to engage parents in a dialogue with their children about what is happening. This could contribute to reducing implicit habitus conflicts by making existing differences explicit and engaging in shared activities concerned with chemistry content.

Strategies for the individual acquisition of chemistry capital

Some students manage to develop chemistry capital although chemistry appears to be incompatible with their family habitus. Two strategies seem to be successful: some students developed a strong bond with chemistry through following a YouTuber. Chemistry-related YouTube channels not only allow acquiring chemistry knowledge but can present role models. The students managed to develop a chemistry identity and one of them developed concrete career aspirations in the field of chemistry. Following YouTubers can, therefore, constitute important support for the development of chemistry identities for students who do not possess chemistry capital. However, this strategy is not open to all students. Chemistry-related YouTube channels tend to present the chemistry nerd, with its emphasis on the dangers of chemistry, *etc.* (*e.g.*, Techtastisch, n.d.). This identity rarely appeals to girls (Archer *et al.*, 2012a, 2013) and working-class boys (Carlone *et al.*, 2015).

One strategy for some girls to connect with chemistry could be to adopt a general learner identity and to draw on inner strengths such as a need for cognition (Cacioppo and Petty, 1982). This connection with chemistry is less subject-specific because it could be applied to any subject and is, therefore, less pronounced. In addition, it is probably more fragile because there is no role model available that could provide social support for performing a female chemistry identity. The girl in our study who adopted this strategy left the impression of connecting with chemistry in solitude. Everything took place in her private room without any human exchange, be it real or through social media. She cultivated a habitus on her own while keeping her social context apart. This might save students from conflicts. Developing a chemistry identity by watching YouTube videos partly takes the students out of isolation because they experience potential role models.

These findings emphasise the need for teaching methods that provide role models especially for girls and for all students who have in their home environments little capital with exchange value in the field of chemistry. Working on diversification of chemistry-related YouTube channels could be one path. It would be important to provide role models to a wider range of students, not only to those for whom a nerdy science identity (DeWitt *et al.*, 2013) is thinkable. Also, it would be important to emphasise the use of chemistry for students, especially regarding their career paths, as has been pointed out by Archer and colleagues (Archer *et al.*, 2015b).

Structural discriminations in the school system

Students with chemistry capital and general educational capital in the family context seem to be concentrated in *Gymnasium* (grammar school) and *Realschule* (track for the middle ability group). This reflects the strong social stratification that is present in the German school system: although some improvements have been made (Agasisti *et al.*, 2018), the school system disadvantages immigrant students and those with a working-class background (Carey, 2008), a fact that has been known for decades. Students from a working-class background are overrepresented in *Hauptschulen* (schools with the lowest entry requirements) and underrepresented in *Gymnasien* (grammar schools). Likewise, middle-class students are overrepresented in *Gymnasien* (grammar schools) (Carey, 2008).

The present study points out one mechanism through which this stratification is perpetuated: all the students in our sample who went to *Hauptschule* were taught by teachers who did not hold a degree in chemistry. In contrast, all the students from *Realschule* and *Gymnasien* were taught by certified chemistry teachers. Although the sample is not representative, this illustrates structural discrimination that is present all over Germany. In the schools with the lowest entry requirements (*Hauptschulen*), considerable proportions of science teachers do not hold a degree in the subject they teach (Richter *et al.*, 2013). In contrast, almost all teachers in grammar schools (*Gymnasien*) are qualified for their subjects (Richter *et al.*, 2013).

This has severe consequences for the students' chemistry capital: it remains closely intertwined with the students' home environment. Students who do not possess chemistry capital or general educational capital at home tend to acquire scarcely any individual chemistry capital. School seems to compensate for the unequal distribution of chemistry capital only to a minor extent. Most teachers who do not hold a degree in chemistry probably have less chemistry capital than those who studied chemistry at the university level. The students at *Hauptschule* are, therefore, deprived of a valuable source of chemistry capital. This aggravates the existing social inequalities.

In particular, in *Hauptschulen*, where the proportion of working-class students is disproportionally high (Carey, 2008), teachers who are qualified for their subjects are indispensable. The fact that YouTubers and students' inner strengths appear as more important sources of chemistry capital than their teachers is unacceptable. Also, students can be limited in their career plans because of the low quality of chemistry education: two girls seriously doubted if they could follow their career aspirations because they had the impression not to learn chemistry in school sufficiently due to their teachers' lack of qualifications in chemistry.

If we want equality of chances in chemistry education, all students, irrespective of their ethnicity and social background, need to be taught by qualified chemistry teachers. Without this structural precondition, the stratification will remain largely unaltered, even if new educational approaches are adopted. In Germany, we know of one rationale that leads to the present situation: in *Hauptschulen*, many students come from an unstable social environment (Trautwein *et al.*, 2007). The assumption is that these students need a stable social environment in school. Therefore, in many schools, teachers are supposed to teach as many lessons per week as possible in one class so that deep teacher–student relationships can develop. However, it implies that many teachers teach subjects they have not studied at the university level. The students are deprived of important sources of chemistry capital.

In order to change this, it will be necessary to increase the number of, for instance, social workers or school psychologists in those school contexts in which social tensions impede content learning. These people could take care of social support. This way, teachers could again focus on the subjects they are competent in. Without a policy change, social stratification in chemistry education will not decrease.

Limitations

This study constitutes the first investigation of chemistry capital. It, therefore, faces several limitations. One limitation is the concentration on students only. We conducted interviews with the students but we did not ask the parents or observe interactions between students and their families. Interviews with parents would allow understanding the chemistry capital at home. Observations of interactions between parents and students would allow observing the actual interactions. They would, therefore, constitute a source of primary data, compared to the student reports on interactions. However, these data only show details of the interactions. The student interviews used in this study, in contrast, provide a broader picture. In particular, they allow focusing on the students' interpretations of the interactions and their meanings in the students' lives.

Further, it would be interesting to assess chemistry capital quantitatively using a questionnaire as has been done with science capital in the past (*e.g.*, DeWitt *et al.*, 2013). This would help in assessing the chemistry capital in the home environment with greater precision. The knowledge about chemistry capital produced in the present study constitutes a basis for the construction of an appropriate instrument.

Conflicts of interest

There are no conflicts to declare.

Appendix

Overview of the main categories of the final coding scheme

(i) *Structural preconditions* (gender, school type, teacher qualification,. . .)

(ii) *Cultural capital at home*
  (a) General educational cultural capital
  (b) Chemistry capital
(iii) *Individual connections with chemistry*
  (a) Chemistry-related activities
  (b) Emotional attachment to chemistry
  (c) Perception of the language of chemistry
  (d) Access to chemistry knowledge
  (e) Sense of relevance
  (f) Perception of the social context in chemistry class

Example of one main category: chemistry capital at home

Chemistry capital at home is defined as all chemistry-specific resources a student has access to in the home environment. Resources can be economic in nature (*e.g.*, parents pay for private tutoring), they can be cultural capital such as chemistry knowledge (*e.g.*, a family member can help in case the student is struggling with chemistry content), and they can be emotional resources (*e.g.*, family members are interested in or excited about chemistry, they welcome talk about the subject at home). For all indicators of the presence or absence of chemistry capital, coded examples are provided in the code book in order to guide the coding process.

Indicators of strong chemistry capital are:

(a) the student speaks about chemistry at home (*i.e.*, talking about chemistry at home is possible),

(b) significant others such as parents have a positive attitude towards chemistry,

(c) talking about chemistry content has a positive influence on social relations (*e.g.*, a family member is excited when the student starts talking about chemistry),

(d) family members support the student's chemistry learning (*e.g.*, explaining chemistry content, correcting mistakes) and

(e) economic capital is used for chemistry-specific support (*e.g.*, buying a chemistry set for the student).

Indicators of weak chemistry capital are:

(a) chemistry is not talked about at home,

(b) significant others such as parents do not have a positive attitude or even a negative attitude towards chemistry,

(c) talking about chemistry content has a negative influence on social relations (*e.g.*, conflicts emerge such as between religious and scientific worldviews) and

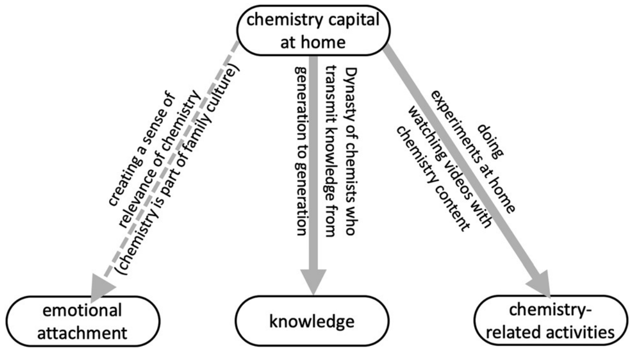
(d) significant others possess little chemistry knowledge.

In cases in which indicators for strong and weak chemistry capital appear, coding decisions were made based on the following principles:

– Economic and content-based support of chemistry learning was assumed to be more important than parents' attitudes towards chemistry. We assumed that having a person who can explain chemistry content and correct misconceptions supports the students' success in the field of chemistry more than only sharing positive emotions towards chemistry because the content-based support can have a direct impact on achievement.

– The impact of chemistry on the social relations was evaluated separately because it concerned only certain cases. If talking about chemistry caused serious conflicts (*e.g.*, between religious and scientific worldviews), this was classified as weak chemistry capital.

Example of a causal network with a case report for one student



Case report. In this case, many causal relationships (local causation, Maxwell, 2012) between the student's capital at home and his individual chemistry capital become apparent. The student seems to have capital with exchange value at home: his grandfather and his great-grandfather were both chemists. His great-grandfather explained chemistry content to his grandfather who now teaches his grandchild chemistry. In addition, the two do chemistry experiments together in a garden house. His grandfather, therefore, suggests chemistry-related activities. In addition, the boy watches videos with chemistry content. However, regarding this activity, no direct suggestion from the part of the family was reported. We suppose that the family's general closeness to chemistry might have triggered this activity but this cannot be shown in the data. Also, the boy shows a strong emotional attachment to chemistry. He enjoys the subject and aspires to a career in chemistry since he was a small child. The arrow is dashed because direct causal links were not reported in the interviews (*e.g.*, he did not say, 'I want to become a chemist because my grandfather is a chemist', but 'I would like to be a chemist'). However, we suppose that this choice largely depends on the family context because, in his family, chemistry plays an essential role in family life.

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Notes and references

Agasisti T., Avvisati F., Borgonovi F. and Longobardi S., (2018), *Academic resilience: What schools and countries do to help disadvantaged students succeed in PISA* (OECD Education Working Papers No. 167), DOI: 10.1787/e22490ac-en.

Anger C., Plünnecke A. and Seyda S., (2007), *Bildungsarmut: Auswirkungen, Ursachen, Maußnahmen*, in Trautwein U., Baumert J. and Maaz K. (ed.), Hauptschule, pp. 39–45.

Archer L., DeWitt J., Osborne J., Dillon J., Willis B. and Wong B., (2010), ''Doing'' science *versus* ''being'' a scientist: examining 10/11-year-old schoolchildren's constructions of science through the lens of identity, *Sci. Educ.*, **94**(4), 617–639, DOI: 10.1002/sce.20399.

Archer L., DeWitt J., Osborne J., Dillon J., Willis B. and Wong B., (2012a), ''Balancing acts'': elementary school girls' negotiations of femininity, achievement, and science, *Sci. Educ.*, **96**(6), 967–989, DOI: 10.1002/sce.21031.

Archer L., DeWitt J., Osborne J., Dillon J., Willis B. and Wong B., (2012b), Science aspirations, capital, and family habitus: how families shape children's engagement and identification with science, *Am. Educ. Res. J.*, **49**(5), 881–908, DOI: 10.3102/0002831211433290.

Archer L., DeWitt J., Osborne J., Dillon J., Willis B. and Wong B., (2013), 'Not girly, not sexy, not glamorous': primary school girls' and parents' constructions of science aspirations, *Pedag., Cult. Soc.*, **21**(1), 171–194, DOI: 10.1080/14681366.2012.748676.

Archer L., DeWitt J. and Willis B., (2014), Adolescent boys' science aspirations: masculinity, capital, and power, *J. Res. Sci. Teach.*, **51**(1), 1–30, DOI: 10.1002/tea.21122.

Archer L., Dawson E., DeWitt J., Seakins A. and Wong B., (2015a), ''Science capital'': a conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts, *J. Res. Sci. Teach.*, **52**(7), 922–948, DOI: 10.1002/tea.21227.

Archer L., Dewitt J. and Osborne J., (2015b), Is science for us? Black students' and parents' views of science and science careers, *Sci. Educ.*, **99**(2), 199–237, DOI: 10.1002/sce.21146.

Bandura A., (1989), Human agency in social cognitive theory, *Am. Psychol.*, **44**(9), 1175–1184.

Braun V. and Clarke V., (2006), Using thematic analysis in psychology, *Qual. Res. Psychol.*, **3**(2), 77–101, DOI: 10.1191/1478088706qp063oa.

Cacioppo J. T. and Petty R. E., (1982), The need for cognition, *J. Pers. Soc. Psychol.*, **42**(1), 116–131, DOI: 10.1037/0022-3514.42.1.116.

Carey D., (2008), *Improving Education Outcomes in Germany* (OECD Economics Department Working Papers No. 611), DOI: 10.1787/241675712618.

Carlone H. B., Webb A. W. Archer L. and Taylor M., (2015), What kind of boy does science? A critical perspective on the science trajectories of four scientifically talented boys, *Sci. Educ.*, **99**(3), 438–464, DOI: 10.1002/sce.21155.

DeWitt J. and Archer L., (2015), Who aspires to a science career? A comparison of survey responses from primary and secondary school students, *Int. J. Sci. Educ.*, **37**(13), 2170–2192, DOI: 10.1080/09500693.2015.1071899.

DeWitt J., Osborne J., Archer L., Dillon J., Willis B. and Wong B., (2013), Young children's aspirations in science: the unequivocal, the uncertain and the unthinkable, *Int. J. Sci. Educ.*, **35**(6), 1037–1063, DOI: 10.1080/09500693.2011.608197.

Ing M., (2014), Gender differences in the influence of early perceived parental support on student mathematics and science achievement and STEM career attainment, *Int. J. Sci. Math. Educ.*, **12**, 1221–1239.

Jackson C., (2002), 'Laddishness' as a self-worth protection strategy, *Gender Educ.*, **14**(1), 37–50, DOI: 10.1080/09540250120098870.

Kurt U. and Taş Y., (2018), The relationships between parental involvement, students' basic psychological needs and students' engagement in science: a path analysis, *J. Educ. Sci. Environ. Health*, 183–192, DOI: 10.21891/jeseh.436730.

Markic S., Schneider K. and Wessels A., (2016), Parents and students cooperatively experience chemistry, in Eilks I., Markic S. and Ralle B. (ed.), *Science education research and practical work*, Aachen: Shaker, pp. 279–284.

Martin A. J., Durksen T. L., Williamson D., Kiss J. and Ginns P., (2016), The role of a museum-based science education program in promoting content knowledge and science motivation, *J. Res. Sci. Teach.*, **53**(9), 1364–1384, DOI: 10.1002/tea.21332.

Maxwell J. A., (2012), The importance of qualitative research for causal explanation in education, *Qual. Inq.*, **18**(8), 655–661, DOI: 10.1177/1077800412452856.

Miles M. B., Huberman A. M. and Saldaña J., (2014), *Qualitative data analysis: a methods sourcebook*, 3rd edn, Thousand Oaks, CA: SAGE Publications, Inc.

Mujtaba T., Sheldrake R., Reiss M. J. and Simon S., (2018), Students' science attitudes, beliefs, and context: associations with science and chemistry aspirations, *Int. J. Sci. Educ.*, **40**(6), 644–667, DOI: 10.1080/09500693.2018.1433896.

Potvin P. and Hasni A., (2014), Interest, motivation and attitude towards science and technology at K-12 levels: a systematic review of 12 years of educational research, *Stud. Sci. Educ.*, **50**(1), 85–129, DOI: 10.1080/03057267.2014.881626.

Qu S. Q. and Dumay J., (2011), The qualitative research interview, *Qual. Res. Acc. Man.*, **8**(3), 238–264, DOI: 10.1108/11766091111162070.

Richter D., Kuhl P., Haag N. and Pant H. A., (2013), Aspekte der Aus- und Fortbildung von Mathematik- und Naturwissenschaftslehrkräften im Ländervergleich, in Pant H. A., Stanat P., Schroeders U., Roppelt A., Siegle T. and Pöhlmann C. (ed.), *IQB-Ländervergleich 2012: Mathematische und naturwissenschaftliche Kompetenzen am Ende der Sekundarstufe I*, Münster/New York/München/Berlin: Waxmann.

Rios-Aguilar C., Kiyama J. M., Gravitt M. and Moll L. C., (2011), Funds of knowledge for the poor and forms of capital for the rich? A capital approach to examining funds of knowledge, *Sch. Field*, **9**(2), 163–184, DOI: 10.1177/1477878511409776.

Rüschenpöhler L. and Markic S., (n.d.), Secondary school students' chemistry self-concepts: gender, culture and the impact on learning behaviour, DOI: 10.1039/c9rp00120d.

Saldaña J., (2016), *The coding manual for qualitative researchers*, 3rd edn, Los Angeles, London: SAGE.

Shanahan M., (2009), Identity in science learning: exploring the attention given to agency and structure in studies of identity, *Stud. Sci. Educ.*, **45**(1), 43–64, DOI: 10.1080/03057260802681847.

Simpkins S. D., Price C. D. and Garcia K., (2015), Parental support and high school students' motivation in biology, chemistry, and physics: understanding differences among latino and caucasian boys and girls, *J. Res. Sci. Teach.*, **52**(10), 1386–1407, DOI: 10.1002/tea.21246.

Sommer K., Russek A., Kleinhorst H., Kakoschke A. and Efing N., (2013), KEMIE: Kinder erleben mit ihren Eltern Chemie [special issue], *Chemkon*, **20**(5), 211–248.

Statistisches Landesamt Baden-Württemberg, (2017), *Allgemeinbildende Schulen in Baden-Württemberg im Gesamtüberblick Schuljahr 2016/17)*, retrieved from https://www.statistik-bw.de/BildungKultur/SchulenAllgem/abschulen.jsp.

Suter L. E., (2014), Visiting science museums during middle and high school: a longitudinal analysis of student performance in science, *Sci. Educ.*, **98**(5), 815–839, DOI: 10.1002/sce.21116.

Tan C. Y., (2019), Involvement practices, socioeconomic status, and student science achievement: insights from a typology of home and school involvement patterns, *Am. Educ. Res. J.*, **56**(3), 899–924, DOI: 10.3102/0002831218807146.

Techtastisch, (n.d.), *Techtastischer Kanaltrailer*, retrieved from https://youtu.be/akalsyYH9Dw.

Thomas J. A. and Strunk K. K., (2017), Expectancy-value and children's science achievement: parents matter, *J. Res. Sci. Teach.*, **54**(6), 693–712, DOI: 10.1002/tea.21382.

Trautwein U., Baumert J. and Maaz K., (2007), Hauptschule, *Aus Politik Und Zeitgeschichte*, **28**, 3–9.

Vaismoradi M., Turunen H. and Bondas T., (2013), Content analysis and thematic analysis: implications for conducting a qualitative descriptive study, *Nurs. Health Sci.*, **15**(3), 398–405, DOI: 10.1111/nhs.12048.

Article 5

How the home environment shapes students' perceptions of their abilities: The relation between chemistry capital at home and students' chemistry self-concept

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How the home environment shapes students' perceptions of their abilities: the relation between chemistry capital at home and students' chemistry self-concept

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ABSTRACT
Participation in science is unevenly distributed among secondary school students, depending on gender, social class, and ethnicity. In the present study, the influence of the home environment on students' chemistry self-concept is investigated as a factor for explaining participation in science. For this, the sociological lens of chemistry capital is employed. A mixed methods study (N=48) was conducted using quantitative data about self-concept and related variables (need for cognition, incremental theory, perception of language) and qualitative interview data on chemistry capital. The data suggest that chemistry self-concept is not related to chemistry capital in quantitative terms. However, the investigation of the qualitative dimensions suggests that chemistry capital in the home environment might change the frame of reference against the backdrop of which students interpret their abilities. We propose the interpretation that students compare their abilities in chemistry with significant others at home. If parents possess chemistry capital, this might lead to more negative evaluations of their abilities which can be counterbalanced by comparisons with classmates. If parents do not possess chemistry capital, the students might perceive themselves as more competent. Further investigations are needed to test this hypothesis. The results and the integrative mixed method approach will be discussed.

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Chemistry capital; science capital; chemistry education; self-concept; learning goal orientations; language; secondary school; Bourdieu; frame of reference

Introduction

The underrepresentation of women and ethnic minorities in science occupations (OECD, 2008, 2009a) is an issue of international concern. Many science fields are dominated by men, by people from the middle class and the ethnic majority (e.g. Archer et al., 2014). The potential workforce is reduced not only in quantity but also in the diversity of social backgrounds and thereby deprived of valuable perspectives.

Chemistry plays a special role in the pursuit of career goals in science: it can act as a gate-keeper for persistence of young people in careers in science and technology (Cohen & Kelly, 2019). A lack of chemistry knowledge can, therefore, severely limit

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young people in their career choices in science. One crucial factor that impacts achievement and career aspirations in science is science self-concept (Marsh & Craven, 2006; Taskinen et al., 2013). Chemistry self-concepts are, therefore, important factors in the pursuit of science careers. However, chemistry self-concepts have attracted less attention than the self-concepts in the other science domains (see Rüschenpöhler & Markic, 2020b). We know that chemistry self-concept varies considerably by social background, for instance, by ethnicity and gender (Rüschenpöhler & Markic, 2020b). There is evidence that the home environment plays a key role in the formation of the chemistry self-concepts of secondary school students (e.g. Makwinya & Hofman, 2015) which could thereby affect achievement in chemistry and the persistence in science careers. Understanding the influence of the home environment on chemistry self-concept could, therefore, provide valuable knowledge for the design of interventions aiming at widening the participation in science.

In this article, the role of the home environment regarding chemistry self-concept is investigated using the perspective of chemistry capital (Rüschenpöhler & Markic, 2020a). Chemistry capital does not only *describe* factors that might influence self-concept but it seeks to *explain* how this influence is wielded. This paper presents an analysis of the relation of chemistry capital in the home environment with chemistry self-concept focusing on secondary school students. Based on findings from science capital research (Archer et al., 2015) and a previous investigation on chemistry capital (Rüschenpöhler & Markic, 2020a), we expected to find a positive relation, i.e. that the chemistry capital in the home environment has a positive influence on chemistry self-concept.

Theoretical background

This section first provides an overview of important findings on chemistry self-concept. Based on this knowledge, chemistry capital is introduced as a tool for understanding the role of the home environment in the formation of chemistry self-concept.

Chemistry self-concept

Self-concept is multidimensional in nature (Marsh & Yeung, 1998; Shavelson et al., 1976), which means that every person has a multitude of self-concepts for the different aspects of life, e.g. the social and the academic domain. In the academic domain, a multitude of subject-specific academic self-concepts exist. Chemistry is one such academic self-concept and it describes a person's perception of his or her abilities in chemistry (Rüschenpöhler & Markic, 2020b).

One factor explaining the great interest in science self-concept research is the strong positive correlation between science self-concept and achievement that has been documented in a multitude of studies (e.g. Areepattamannil, 2012; Wang & Liou, 2017). Correlations with other important outcomes have contributed to the interest in science self-concept as well, i.e. with career choices in science (e.g. Eccles & Wang, 2016; Taskinen et al., 2013) and science aspirations (DeWitt et al., 2011; Riegle-Crumb et al., 2011).

Chemistry self-concept has received considerably less attention than physics, mathematics or general science self-concept (Rüschenpöhler & Markic, 2020b). The existing research concentrates on young adults in post-secondary education (e.g. Bauer, 2005;

Xu & Lewis, 2011). We initiated a research project investigating the chemistry self-concepts of secondary school students and, in particular, the influence of gender and the students' sociocultural backgrounds on chemistry self-concept. We found that the influence of gender differs between students of different cultural backgrounds (Rüschenpöhler & Markic, 2019a, 2020b): in Germany, where the study was conducted, boys belonging to the ethnic majority showed stronger chemistry self-concepts than girls. In contrast, among students with a Turkish migration background, the girls were more confident in their abilities in chemistry. This seems to be a cultural pattern: in Turkey, more women than men work in science (OECD, 2009a) and girls achieve substantially better in science in secondary school (Batyra, 2017a, 2017b) while the inverse is true for Germany (OECD, 2009a). We assume that influences from the home environment, e.g. through parents or another principal carer, could be one factor that could potentially explain the observed differences.

Further, we showed that chemistry self-concept is positively correlated with learning goal orientations and the perception of language (Rüschenpöhler & Markic, 2020b). A learning goal orientation is a specific way of interpreting situations, i.e. as opportunities to improve one's abilities (and not e.g. as an opportunity to show one's abilities, or to engage in social relationships) (Dweck, 1986). Closely associated with learning goal orientations are a need for cognition (i.e. the engagement in and enjoyment of deep thinking, Dickhäuser & Reinhard, 2006) and an incremental theory of intelligence (i.e. the belief that abilities can be changed and improved, Dweck & Leggett, 1988). Besides learning goal orientations, we could show that the students' perceptions of their understanding of and participation in the scientific language of chemistry is positively correlated with chemistry self-concept (Rüschenpöhler & Markic, 2020b). These variables could mediate the relation between chemistry self-concept and achievement as it has been suggested previously in the case of learning goal orientations (Dishon-Berkovits, 2014; Lin et al., 2009) because learning goal orientations are positively correlated with achievement (Lin et al., 2009).

The formation of academic self-concepts

Research about the formation of self-concepts traditionally focuses on psychological and social processes in class. This is conceptualised in Marsh's internal/external frame of reference model (1986). The model states that two comparison processes are central to the formation of students' academic self-concepts: (i) students employ an external frame of reference, comparing their abilities with their classmates. (ii) Students compare their abilities in different subjects, which constitutes the internal frame of reference.

The influence of the home environment on chemistry self-concept lacks conceptual clarity. There are some studies investigating the relationships between the students' home environments and their science self-concepts (e.g. Makwinya & Hofman, 2015; Simpkins et al., 2015). These studies show that the home environment might play a role in the formation of science self-concepts. Students' science self-concepts seem to be positively correlated with their parents' science self-concepts (Makwinya & Hofman, 2015). Further, the parents' and the students' beliefs about the utility-value of science tend to be positively correlated (Makwinya & Hofman, 2015). Further, students who report that they receive high parental support in science tend to show stronger science self-concepts than those who receive little parental support (Simpkins et al., 2015). It, therefore, seems reasonable to assume that the home environment plays a role in the students' formation of chemistry self-concepts. The existing studies identify correlations but are not based on a model that would conceptualise the role the home environment plays in the formation of self-concepts. This kind of model seems to be absent in the literature to date.

Chemistry capital as an analytical lens for investigating the impact of the home environment

In an earlier work, we developed the notion of chemistry capital (Rüschenpöhler & Markic, 2020a) for modelling the exchange processes of resources in the field of chemistry. It is defined as 'a person's resources that help him or her to succeed in the field of chemistry' (Rüschenpöhler & Markic, 2020a) which follows the definition of science capital by Archer and colleagues (Archer et al., 2014). These resources can be a wide range of things, ranging from chemistry knowledge and positive attitudes towards chemistry to chemistry-related activities and contacts to people who are excited about chemistry. Chemistry capital thus provides a sociological perspective on chemistry learning. For instance, it can be employed as an analytical lens for investigating the impact of the home environment on students' chemistry learning. We identified several processes through which secondary school students acquire chemistry capital (Rüschenpöhler & Markic, 2020a). The study showed that the students' home environments play a central role in the transmission of chemistry capital, regarding chemistry knowledge, attitudes towards chemistry, and chemistry-related activities.

The notion of chemistry capital is rooted in science capital research (e.g. Archer et al., 2015) which uses the Bourdieusian concept of capital. Bourdieu sought to understand how particular social classes dominate others and how this power is maintained over generations. He argued that social distinction does not only depend on money but on a broad range of social practices:

> It is in fact impossible to account for the structure and functioning of the social world unless one reintroduces capital in all its forms and not solely in the one form recognised by economic theory. (Bourdieu, 1986, p. 46)

He conceptualised money and economic capital as only one type of capital explaining social distinctions. Other forms of capital exist, i.e. cultural, social, and symbolic capital. Economic capital can be used to acquire cultural, social, and symbolic capital 'but only at the cost of a more or less great effort of transformation' (Bourdieu, 1986, p. 287). This is the case because the non-economic types of capital can be very subtle in nature – they consist in differences in taste, habitus, etc. (Bourdieu, 1979) which cannot be simply bought. When Bourdieu developed his theory in the late 1970s in France, he focused on the distinctions of social classes that take place in the field of humanities and fine arts. However, Prieur and Savage (2013) argue that today, social distinctions have shifted towards the field of science and technology. Archer and colleagues (2015) follow this argumentation and propose the notion of science capital for analysing social inequalities in the field of science (Archer et al., 2014). The assumption is that science and technology are fields in which important social distinctions nowadays take place (Prieur & Savage, 2013).

We introduced the resource-oriented notion of chemistry capital based on the notion of science capital. What counts as a resource depends on the 'logic' of the respective field, as Bourdieu (1979) points out:

> The logic of every field determines those [types of capital] that are accepted as valid on the market, which are pertinent and *efficient* in the game at hand, which, *in relation with the field*, function as specific capital (p. 127, emphasis in the original, translated by the authors)

Analogously, chemistry capital maps the specific types of capital that have value in the specific field of chemistry. In the first study about chemistry capital, we classified students according to the capital they possess in the home environment (Rüschenpöhler & Markic, 2020a). Chemistry capital in the home environment falls mostly into the category of social chemistry capital which means that it is bound to social relationships in which chemistry is embraced. For instance, it can consist in parents' positive attitudes towards chemistry, their chemistry knowledge, their interest in discussing chemistry at home or conducting experiments together. This chemistry capital can also be present in the students' home environments if chemistry plays a role in relationships with some other principal carer, a sibling or some other relative. Even a relationship with a close friend can constitute chemistry capital in the home environment if (a) chemistry plays an important role in strengthening this relationship and (b) the chemistry-related exchanges take place in a very private setting. The analysis showed several mechanisms through which chemistry capital in the home environment plays a role in the development of students' individual chemistry capital.

Research questions

Based on the findings that certain factors in the home environment such as parental support influence science self-concepts, the goal of the present investigation was to conceptualise this influence for the field of chemistry. In particular, we wanted to understand the relation of students' chemistry self-concepts with chemistry capital in the home environment. Chemistry capital was used to conceptualise the chemistry-related resources in the home environment. Thus, we want to answer two research questions:

(1) What relation exists between chemistry capital in the home environment and the students' chemistry self-concepts?

Archer and colleagues (2015) had shown that science capital is positively correlated with self-efficacy. Based on this result, we expected that chemistry capital in the home environment plays a role in the formation of students' chemistry self-concepts because self-concept and self-efficacy are highly correlated (Huang, 2012).

Besides, we had found that chemistry self-concept is closely related to learning goal orientations and the students' perception of their linguistic abilities in chemistry (Rüschenpöhler & Markic, 2020b). We, therefore, expected these variables to be positively related to chemistry capital, too. Thus, we want to evaluate:

(2) What relation exists between chemistry capital in the home environment and the students' learning goal orientations and the perception of their linguistic abilities in chemistry?

Methods

Type of research

Academic self-concept research is confronted with methodological difficulties which is also true for the field of science self-concept research. Likert scales dominate the field (Rüschenpöhler & Markic, 2019b) despite the concern that this might produce biased data when employed in culturally diverse contexts (Byrne, 2002; Byrne et al., 2009; van de Vijver & Poortinga, 2005). Thus, the use of mixed methods designs in self-concept research has been recommended (Byrne, 2002) which is still widely ignored in science self-concept research. In a preliminary study, a mixed methods approach to academic self-concept research was developed and tested (Rüschenpöhler & Markic, 2019a). It showed that using a mixed methods approach allows evaluating the validity of the self-concept data and can inspire culturally embedded interpretations of self-concept. In the present study, a mixed methods approach is employed as well.

In the past, an abundance of typologies for mixed methods designs have been produced which still do not capture the complexity of mixed methods research (Guest, 2013). It has been proposed not to describe the specific type of *study design* but the *procedures of interaction* (Creswell, 2009). The present mixed methods study can thus be described using Guest's (2013) perspective concentrating on the points of interface between data sets, focusing on their time and purpose. It has one point of interface in which qualitative interview data and quantitative data from a survey are connected (figure 1). Data collection was concurrent (see figure 1, left). In analysis phase I (figure 1, centre), the qualitative and quantitative data sets were first analysed separately to understand the distribution of chemistry self-concepts and to conceptualise chemistry capital. In phase II, the data sets are connected. The purpose of mixing the data at this point is to investigate the relations between chemistry self-concept and chemistry capital which was the ultimate goal in the overarching research project. The qualitative interview analyses which preceded the present mixed methods study, served to conceptualise chemistry capital. Without this prior analysis, the present mixed methods analysis of qualitative chemistry capital and quantitative chemistry self-concept data would not have been possible.

In the following section, we will first describe the sample and the instruments used in this study. Then, we will provide a brief overview of the analyses that were conducted in phase I. Finally, the analyses of phase II, which are the subject of the present article, will be described.

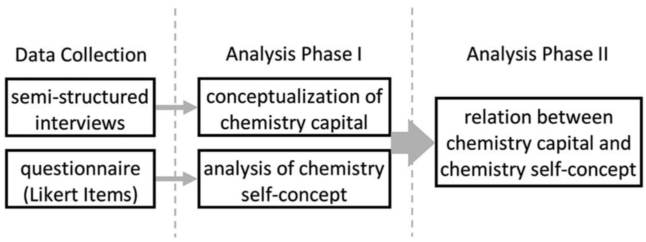

Figure 1. Overview of the research process. The point of interface of the quantitative and qualitative data described in the present article takes place in analysis phase II.

Sample

We designed the sample using a purposeful sampling strategy with the goal to create a sample of great variety. The reason for this is that the present study constitutes a first approach to a new field: we try to explore mechanisms between chemistry capital and established variables such as self-concept. In this first exploration, it was a crucial concern for us to look at the picture as holistically as possible. Therefore, we decided to design a sample of students who had already had contact with school chemistry but in different school types because the German school system is traditionally based on separating school children in different schools according to their achievement at a very early age (about 10/11 years). Including students from different school types allows to look at the relations between the variables with a wide focus in order to develop an understanding of how the relationships could be conceptualised and inform hypotheses.

48 students from 14 different classes from 6 different schools in Germany participated in the mixed methods study. To match the interview and questionnaire data, a code for each student was created which was written on the questionnaires and repeated orally in the interviews. The study was conducted in grades 8–10 in classes in which chemistry had already been taught. This range of grades was chosen because, in Germany, it depends on the local policy and the school type in which grade chemistry is introduced. The students were 13–18 years old[1] (M=15.4) and went to *Gymnasium* (grammar schools, N=15, 31%), *Realschule* (schools for the middle ability group, N=21, 44%), or *Hauptschule* (schools with lowest entry requirements, N=12, 25%), the three traditional school types in Germany. Boys and girls were almost equally represented (23 female students, 48%) and most of the students had a migration background[2] (40 students, 83%) which is typical for the urban region in which the study was conducted.

We followed the ethical principles defined in the declaration of Helsinki (World Medical Association, 2013). The research project and the procedure of data collection and processing were approved by both the local Ministry of Education in Baden-Württemberg and the university as required by law. Participation was based on informed consent. Since most participants were underage, we also informed the parents about the project and obtained their consent in written form. Further, the concerned school principals and teachers were informed and gave their permissions. All parties, including the students, were informed about the goals and the purpose of the study, its voluntary nature and that non-participation would not have any negative consequences. The interview and questionnaire data were anonymised using a code for each student. The interview data were transcribed, and the transcripts anonymised in case personal information was revealed. The audio files were deleted after this. Encryption software was used to protect the data of illegal access as required by the official regulations in Germany.

Instruments

In a questionnaire with Likert items, data were collected about the students' chemistry self-concepts and variables closely related to chemistry self-concept. Chemistry self-concept was measured with the PISA 2006 science self-concept scale (Q37; OECD, 2009b) in which the word 'science' was replaced with 'chemistry'. Two indicators of learning goal orientations were considered, namely need for cognition (items 1, 4, 18, 23, 40; and 41 from Cacioppo & Petty, 1982; 'in chemistry' added to the sentences) and theory of intelligence (entity and incremental beliefs subscales of Dweck, 2000; 'for chemistry' added to the sentences). These scales are quite established in their respective fields. Further, the students' perception of their linguistic abilities in chemistry was measured using a scale constructed by the authors (2020a) because no research instrument was available. Items: (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. These variables were chosen because they could mediate the relation between chemistry self-concept and achievement (Rüschenpöhler & Markic, 2020b). Details about the reliability are published elsewhere (Rüschenpöhler & Markic, 2020a).

Chemistry capital was investigated in semi-structured qualitative interviews using an interview guide (Qu & Dumay, 2011) with an average duration of about 20–25 min. The purpose of these interviews was to gain first insights into the functioning of chemistry capital and to understand the mechanisms through which it is transmitted from the home environment to the students. This qualitative investigation was necessary because chemistry capital is a new concept for which an instrument for quantitative assessments does not yet exist. All interviews were conducted by the first author directly after the students had filled in the questionnaires (for more detail see Rüschenpöhler & Markic, 2020a).

Analysis phase I

The scales used in the questionnaires yielded data of good quality (for more details on factor structure and internal consistency see Rüschenpöhler & Markic, 2020b) and were analysed using inferential statistics (ANOVAs and multiple linear regression; Rüschenpöhler & Markic, 2020b). The qualitative data from the interviews were analysed in a thematic analysis comprising several steps of analysis (Rüschenpöhler & Markic, 2020a), in the course of which four groups of students were characterised according to the chemistry capital they possess in the home environment. The qualitative analyses revealed that the home environment is an important source of chemistry capital for a small number of students. A far larger number of students possess little chemistry capital in the home environment (see Table. 1; Rüschenpöhler & Markic, 2020a).

Analysis phase II

In phase II, the qualitative and quantitative data were mixed because we were interested in the relation between chemistry self-concept and chemistry capital. We analysed the roles chemistry self-concept and some related variables play in the four groups of students who possess different types of chemistry capital in the home environment (Table. 1).

Conducting inferential statistics was not possible for two reasons. (i) The requirements for many methods in inferential statistics were not met. The chemistry capital data are scaled at nominal level because they consist in the assignment of students to a group of students who share similar characteristics regarding chemistry capital in the home environment. Further, the sample sizes in the four chemistry capital groups vary

Table 1. Characterisation of the four groups of students according to the capital they have access to in the home environment.

Group 1. Chemistry capital in the home environment
- chemistry is part of family life: talking about chemistry, conducting experiments, etc.
- close relatives explain chemistry content and correct misconceptions
- role-models in the home environment facilitate the development of positive attitudes towards chemistry

Group 2. General educational capital in the home environment
- general educational capital available: very learner-friendly atmosphere; learning and knowledge are highly valued and parents try to transmit their enthusiasm; chemistry knowledge is limited
- some use economic resources to help students acquire chemistry capital
- supporting students by showing subject-unspecific learning strategies

Group 3. Scarcely any chemistry capital in the home environment
- chemistry and general educational capital are both very limited
- knowledge about chemistry and how to acquire chemistry knowledge is limited
- some attempts to support students' chemistry learning succeed, but this often fails because it is not clear how to support students in chemistry effectively

Group 4. Home environment shaped by the absence of chemistry capital
- talking about chemistry can create conflicts in the home environment: the world view supported in chemistry appears as incompatible with the world views in the home environment
- students tend to struggle with chemistry learning or reject it as 'boring'
- exceptional cases: some students develop chemistry capital either through very strong learning goal orientations or using a YouTuber as a role model

For more information, see Rüschenpöhler and Markic (2020a).

($N_{group1} = 6$, $N_{group2} = 4$, $N_{group3} = 9$, $N_{group4} = 29$) and are too small for most analyses. Although Bayesian statistics could handle the issue of sample size, it would not yield insightful results because the empirical basis for the definition of an informative prior is lacking. (ii) Knowledge for formulating sound hypotheses about the relationship between chemistry self-concept and chemistry capital is lacking. With chemistry capital, we explore a research field in which little knowledge exists. In this context, hypotheses testing would be based on speculation.

For these reasons, descriptive statistics were used. Boxplot diagrams with scatter plots were created separately for each variable from the questionnaire. Each diagram displays the distribution of the quantitative data in the four chemistry capital groups (Rüschenpöhler & Markic, 2020a). Information from the qualitative interviews was added to understand the relation between chemistry capital and the concerned variable. In this process, hypotheses are developed about how the variables could be related.

Results

RQ1. The relation between chemistry capital in the home environment and chemistry self-concepts

As displayed in figure 2, there seems to be no linear trend in the relation between chemistry capital and chemistry self-concept. To better understand the relation, cases with very positive and very negative chemistry self-concepts are investigated across all four groups. The purpose is to understand what positive and negative chemistry self-concepts can mean to the students in the four different groups.

Students with positive chemistry self-concepts

In all four groups of students with different types of capital in the home environment, some students had very positive chemistry self-concepts. Some of the students who have exceptionally high self-concepts (a, c and f, see figure 2) share similarities. These three students have a very positive attitude towards chemistry despite their differences in chemistry capital in the home environment. For instance, student (a) said: 'I am always really excited about chemistry classes and I look forward to them so much. And then, zap!, poof!, it's over' and student (f) 'like[s] chemistry *in itself*.' These students aspire to a chemistry-related occupation and identify strongly with the subject. Student (a) said 'maybe I'll become a chemist', student (c) 'definitely' wants to have a chemistry-related job. Student (f) wants to become a chemical lab technician, chemist or chemistry teacher. Moreover, these students all engage in chemistry-related activities. In all chemistry capital groups, some students develop positive chemistry self-concepts and show similar patterns of career aspirations, attitudes towards chemistry, and chemistry-related activities.

The interview data suggest that there are qualitative differences, depending on the students' chemistry capital in the home environment: the chemistry-related activities differ. Student (a) who possesses chemistry capital in the home environment, conducts experiments with a family member at home. The activity is part of a social interaction and transmits chemistry-specific skills from the elder to the younger generation. The student and his relative are unequal partners. Student (c), who does not possess chemistry-specific capital but general educational capital, watches science documentaries on T.V. with a family member. This activity is less interactive and intergenerational transmission of chemistry-specific is replaced by a mutual acquisition of chemistry capital. The student's relative does not have more knowledge about chemistry than the student so they are equal partners. Student (f) follows videos with chemistry content of a YouTuber who embraces a nerdy chemistry/science identity. This student does not have a real-life partner with which

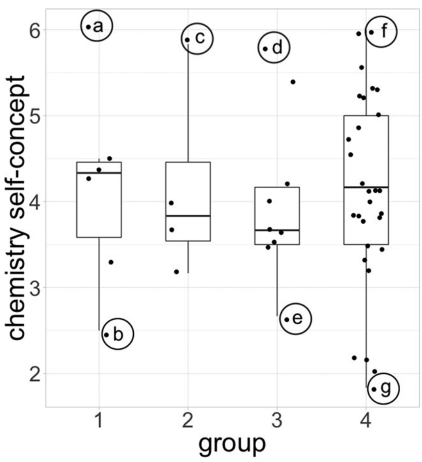

Figure 2. The distribution of chemistry self-concepts in the four chemistry capital groups. The groups differ in the chemistry capital available in the home environment: in group 1, strong chemistry capital is present, in group 2, general educational capital is available, in group 3, very little educational capital is available, and in group 4, educational capital seems to be absent from the home environment.

he could share the acquisition of chemistry capital. These differences in chemistry-related activities could play a role in the development of chemistry self-concepts: these three students can compare with people at home who possess different levels of chemistry capital. Their frames of reference in the home environment differ.

However, it is not clear if the home environment constitutes a frame of reference relevant to the formation of chemistry self-concepts. Student (d) does not develop a connection with chemistry in the home environment and, therefore, perceives only the frame of reference of school chemistry as relevant. His classmates are his frame of reference: 'well, I am often the only one in class who understands it, and I know the stuff already and the others don't get it. And I just think, ok, I'm good' (case d). In contrast to students (a), (c), and (f), neither a real-life nor a fictional partner is available for the acquisition of chemistry capital in the home environment. He possesses little chemistry capital in the home environment, has a very positive chemistry self-concept but only a superficial connection with chemistry. He neither aspires to jobs in the field, nor engages in chemistry-related activities nor shows positive attitudes towards chemistry content. Chemistry does not play a role in his life outside school.

Students with negative chemistry self-concepts

The students with negative chemistry self-concepts did not form a homogenous group either. Student (b), who possesses chemistry capital in the home environment, experiences mixed feelings towards chemistry. This girl hates chemistry but still, she finds it fascinating and perceives a personal relevance of the subject. This is inspired by her mother who works in a chemistry-related field and seems to support an emotional resilience in her daughter. Although the girl has a negative self-concept and negative feelings towards chemistry, she is convinced that one day, she will like chemistry. Student (g) (figure 2) seems not to have a personal connection with chemistry and the subject bores this boy. Student (e) is very interested in specific topics in chemistry, such as the radionuclides. Regarding these students, the role of the frame of reference and chemistry capital in the home environment is unclear.

Summary

Our initial assumption was that chemistry capital in the home environment would be positively related to self-concept, based on findings on science capital (Archer et al., 2015). We thought that having chemistry capital in the home environment would support the development of positive self-concepts because acquiring and dealing with chemistry knowledge is a natural part of life in the home environment.

To our surprise, this assumption was not supported by the data. It seems like no clear relation exists between chemistry capital in the home environment and the students' chemistry self-concepts. The data show that equally strong chemistry self-concepts appear in all four groups, i.e. among students with very different levels of chemistry capital in the home environment. However, it is important to keep in mind that this study was conducted using a sample of medium size. The four different chemistry capital groups range from small (group 2, N=4) to medium (group 4, N=29). To better understand the relation, analyses of data from a larger sample using a chemistry capital questionnaire would be desirable.

RQ2. The relation between chemistry capital in the home environment and variables closely associated with chemistry self-concept

For answering research question 2, we investigated the relationships between chemistry capital and several variables that are closely connected with chemistry self-concept: learning goal orientations (measured via need for cognition and incremental theory of intelligence) and the perception of chemistry language.

Learning goal orientations

First, we looked at the students' learning goal orientations. We measured the students' need for cognition in chemistry as one indicator of a learning goal orientation. The mean values for this variable are almost identical in groups 1, 3 and 4 (figure 3). Only in group 2, this value is slightly higher. This could be explained with the strong emphasis that is put on learning and knowledge acquisition in these students' home environments.

As a second indicator for a learning goal orientation, we looked at the students' incremental theory of intelligence in chemistry. This seems to be related to chemistry capital (figure 4). The mean values decrease from group 1 to group 4. This could indicate that a linear trend might describe the data accurately. Learning goal orientations might, therefore, be associated with the students' chemistry capital in the home environment.

The perception of language

Regarding the perception of chemistry language, a clear trend was not visible (figure 5). Only a small positive relation might be present.

Rather, the interview data suggest that there are important qualitative differences between the groups regarding the definition of difficulties with chemistry language. Student (b) scored very low on the language scale (figure 5) and the self-concept scale (figure 2). This is a girl whose mother works in a chemistry-related field. The girl stated that she hates chemistry but will grow to like chemistry one day, a belief that is inspired by her mother's passion for chemistry. She reports difficulties with chemistry language but that she can always ask her mother for help: 'we just had a text about absorption (…) and I

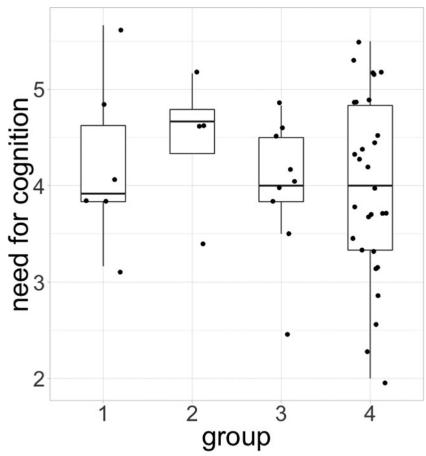

Figure 3. The distribution of need for cognition in the four chemistry capital groups.

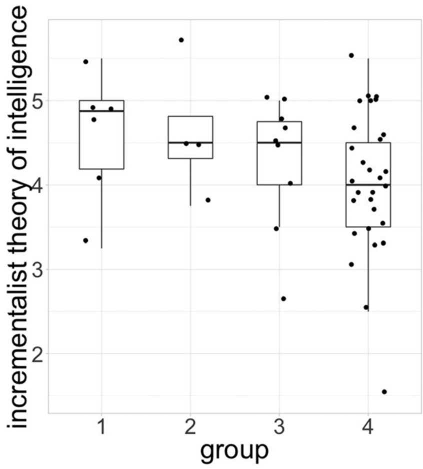

Figure 4. The distribution of incremental theory of intelligence in the four chemistry capital groups.

had to read it again at home and let my mother explain it to me because I didn't know what that was.' These difficulties differ from those reported in group 4. Student (h) (figure 5) has very little chemistry capital in the home environment. The girl's parents are non-native speakers. In the interview, she said, 'I always think, (…) on the worksheet, do they speak a different language than me?'. Both girls experience linguistic difficulties in chemistry but of very different kinds. The student in group 4 who scored even lower on the language scale than student (h) (figure 5) felt completely alienated in chemistry class. Serious difficulties with the language in chemistry were reported in the interviews only in group 3 and 4. Here, some students experience the language of chemistry class as alien to the home environment. This kind of drastic linguistic barrier seems not to exist in groups 1 and 2. Chemistry capital seems to be associated with the *type* of linguistic problems the students face.

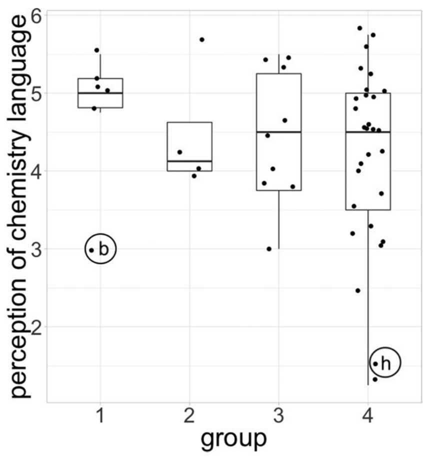

Figure 5. The distribution of the perception of chemistry language in the four chemistry capital groups.

Summary

Our initial assumption was that chemistry capital in the home environment would be positively related to learning goal orientations because we assumed that chemistry capital in the home environment would draw the students closer to chemistry and, thereby making it appear 'learnable'. This is confirmed regarding incremental theory of intelligence. Need for cognition seems to be influenced rather by general educational capital. However, the sample size in group 2 was very small and this result needs to be taken with precaution.

Further, we supposed that chemistry capital would have a positive impact on the students' perception of their linguistic abilities in chemistry. We believed that if students are immersed in a surrounding in which chemical terms are part of the family language, this would contribute to a positive evaluation of their linguistic abilities in chemistry. The present investigation supports the assumption of a quantitative relation only partly. Much clearer was the fact that students with chemistry capital in the home environment use different frames of reference when defining linguistic difficulties than students with low levels of chemistry capital. These experience situations in which basic concepts and terms are unknown while students with higher levels of chemistry capital define linguistic problems regarding complex linguistic entities.

Discussion

The study's results came partly to a surprise. Based on literature (Archer et al., 2015), we expected chemistry self-concept to be stronger among students who have chemistry capital in the home environment because they experience chemistry as part of their family life. We supposed that living with and/or spending time with people who can connect with chemistry would positively influence the students' beliefs that chemistry is something they could be good at. However, this seems not to be the case. In the following, we would like to propose three possible explanations for this finding.

Explanation I. No relation exists between chemistry capital in the home environment and chemistry self-concept

No relation may exist between chemistry self-concept and chemistry capital. This would mean that either (i) factors in school, (ii) other factors in the home environment or (iii) individual factors are more important in the formation of self-concept.

The assumption (i) that school factors are crucial in self-concept formation guides research about the Big-Fish-Little-Pond-Effect (Marsh, 1987). It has been shown extensively that the ability level of the class and the school shape students' academic self-concepts (e.g. Liou, 2014; Lüdtke et al., 2007). This means that students with the same ability level tend to have more negative self-concepts if they are surrounded by high-achievers while their self-concepts tend to be more positive when surrounded by low-achievers. It could be assumed that social comparisons in school are crucial in the formation of self-concept while chemistry capital only plays a minor role.

The assumption that (ii) other factors in the home environment play a central role would require further conceptualisation. What factors could play a role? Only certain variables which are part of chemistry capital in the home environment may be important, such as parental support or their education level (Simpkins et al., 2015), social status (Bodovski, 2014) or parental control (Silinskas & Kikas, 2019). A conceptualisation of the impact of these family-related factors on self-concept seems to be lacking.

The assumption (iii) that individual factors are more important in the formation of chemistry self-concept implies that chemistry self-concept can best be explained by students' psychological dispositions, not by the sociocultural context. However, it has been shown numerous times that self-concepts depend on sociocultural factors such as gender and the social status of ethnic groups (see Rüschenpöhler & Markic, 2019b). If chemistry capital is not the central explanatory variable for these sociocultural influences, a good conceptualisation is still lacking. Sociocultural narratives that define the chemistry-related prestige of certain social groups could be important. This prestige could be conceptualised using the Bourdieusian term of symbolic capital (Bourdieu, 1994) which has not yet been analysed in terms of science or chemistry capital. This could be an interesting path for future research.

Explanation II. Chemistry capital in the home environment changes the frame of reference for chemistry self-concept

Frames of reference play a central role regarding academic self-concepts. This is the case for social (the Big-Fish-Little-Pond-Effect; Marsh, 1987) and internal comparisons (the internal/external frame of reference model; Marsh, 1986). The social context of the family could constitute a frame of reference and influence students' chemistry self-concepts. For students with chemistry capital in the home environment, this could lead to the following situation: if close relatives are good at chemistry, the students might compare their abilities with them and conclude that they are not very competent in chemistry. However, this negative effect could be balanced in comparison with classmates because chemistry capital in the home environment tends to support chemistry learning and the acquisition of chemistry knowledge. Compared to close relatives, these students could feel less competent while they could feel more competent than their classmates. In group 4, some students who do not have chemistry capital in the home environment scored very high on the chemistry self-concept scale. They had no connection with chemistry in the home environment and, therefore, a very different frame of reference. Compared to their parents, these students could feel competent in chemistry. This could explain the extreme cases in which students seem to have very little intellectual connection with chemistry but still perceive themselves as competent in chemistry. This interference of the frames of reference in the home environment and school could explain why no relation between chemistry capital and self-concept was found.

Explanation III. The study is limited in explanatory power

The third explanation is that the present study's limitations mask an existing effect of chemistry capital in the home environment on chemistry self-concept. Chemistry capital was investigated based on qualitative data because this field is very new. In the mixed methods analysis presented in this article, only a small sample could be used. Inferential statistics based on quantitative data would be needed to better understand the relation. To gain this kind of data, a chemistry capital scale is needed.

The relation between chemistry self-concept and learning goal orientations and the perception of abilities regarding chemistry language

The data suggest that incremental theory of intelligence in chemistry is related to chemistry capital. Students with higher levels of chemistry capital in the home environment tend to perceive chemistry as something that can be learned incrementally. Need for cognition is rather related to general educational capital although this finding would require further investigations.

Regarding the perception of chemistry language, we expected to find a linear relation with chemistry capital because in home environments with chemistry capital, chemistry language forms a natural part. However, a linear trend was not found. The qualitative data suggest that the students define difficulties with chemistry language in very different ways. Students who do not have chemistry capital in the home environment can encounter very drastic difficulties with the language in chemistry while students with chemistry capital in the home environment experience difficulties at a different level. For these students, a problem with chemistry language is situated at the level of complex structures such as difficulties with particular texts in chemistry. Possessing chemistry capital, therefore, seems to change the frame of reference against the backdrop of which problems are defined.

Conclusion

The present study provides valuable insights into research on the influence of the home environment of chemistry self-concept. Three conclusions can be drawn:

(1) Chemistry capital might not be related in quantitative terms with chemistry self-concept. The extreme cases discussed in this study suggest that chemistry self-concepts of the same intensity can be associated with very different considerations and concrete contexts. Chemistry self-concept research could benefit from a focus on the concrete thoughts associated with self-concepts. This could inspire practical interventions, a type of study that is needed in science self-concept research (Rüschenpöhler & Markic, 2019b).
(2) The home environment could constitute a frame of reference relevant to the formation of chemistry self-concepts and related variables. This could be interesting in interpreting responses to Likert scale data. For instance, regarding the language scale in this study, the students' definitions of problems with chemistry language differed greatly, depending on the chemistry capital in their home environments. This way, chemistry capital might not explain differences in the scores of certain scales but in the frame of reference that is employed in the interpretation of the items.
(3) Symbolic capital has not been analysed in terms of science capital but could be interesting for conceptualising the role of prestige in science self-concept. This could also advance research on gender differences.

To gain more clarity, quantitative analyses of the relation between chemistry capital and chemistry self-concept would be desirable. This would require the development of a chemistry capital scale. Further, investigations of the role of the home environment as a frame of reference would be needed.

Further, the perspective of chemistry capital can allow identifying structural discriminations in the field of chemistry. Moreover, it can inform application-based research because it can identify factors and processes that support students' chemistry learning. It shifts the analytical focus towards the students' resources and structures in their environments, thereby allowing for a contextualised view on students' chemistry learning.

Notes

1. The expected age range of students in grades 8–10 is of 13–17 years. However, grade repeating is still common practice for low achieving students in the part of Germany where the study was conducted. The students who are 18 years old had probably repeated a grade.
2. The concept of migration background was used as defined in the official census in Germany (Statistisches Bundesamt, 2013). Having a migration background depends on a person's individual migration history and on those of his or her parents.

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References

Archer, L., Dawson, E., DeWitt, J., Seakins, A., & Wong, B. (2015). "Science capital": A conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching*, *52*(7), 922–948. https://doi.org/10.1002/tea.21227.

Archer, L., DeWitt, J., & Willis, B. (2014). Adolescent boys' science aspirations: Masculinity, capital, and power. *Journal of Research in Science Teaching*, *51*(1), 1–30. https://doi.org/10.1002/tea.21122

Areepattamannil, S. (2012). First- and second-generation immigrant adolescents' multidimensional mathematics and science self-concepts and their achievement in mathematics and science. *International Journal of Science and Mathematics Education*, *10*(3), 695–716. https://doi.org/10.1007/s10763-011-9319-7

Batyra, A. (2017a). *Gender gaps in student achievement in Turkey: Evidence from the Programme for International Student Assessment (PISA) 2015*.

Batyra, A. (2017b). *Gender gaps in student achievement in Turkey: Evidence from Trends in International Mathematics and Science Study (TIMSS) 2015*.

Bauer, C. F. (2005). Beyond "student attitudes": chemistry self-concept inventory for assessment of the affective component of student learning. *Journal of Chemical Education*, *82*(12), 1864–1870. https://doi.org/10.1021/ed082p1864

Bodovski, K. (2014). Adolescents' emerging habitus: The role of early parental expectations and practices. *British Journal of Sociology of Education*, *35*(3), 389–412. https://doi.org/10.1080/01425692.2013.776932

Bourdieu, P. (1979). *La distinction: Critique sociale du jugement* [Distinction: A social critique of the judgment of taste]. Minuit.

Bourdieu, P. (1986). The forms of capital. In J. G. Richardson (Ed.), *Handbook of theory and research for the sociology of education* (pp. 241–258). Greenwood.

Bourdieu, P. (1994). *Raisons pratiques: Sur la théorie de l'action [practical reason: On the theory of action]*. Seuil.

Byrne, B. M. (2002). Validating the measurement and structure of self-concept: Snapshots of past, present, and future research. *American Psychologist*, *57*(11), 897–909. https://doi.org/10.1037/0003-066X.57.11.897

Byrne, B. M., Oakland, T., Leong, F. T. L., van de Vijver, F. J. R., Hambleton, R. K., Cheung, F. M., & Bartram, D. (2009). A critical analysis of cross-cultural research and testing practices. *Training and Education in Professional Psychology*, *3*(2), 94–105. https://doi.org/10.1037/a0014516

Cacioppo, J. T., & Petty, R. E. (1982). The need for cognition. *Journal of Personality and Social Psychology*, *42*(1), 116–131. https://doi.org/10.1037/0022-3514.42.1.116

Cohen, R., & Kelly, A. M. (2019). Community college chemistry coursetaking and STEM academic persistence. *Journal of Chemical Education*, *96*(1), 3–11. https://doi.org/10.1021/acs.jchemed.8b00586

Creswell, J. W. (2009). Editorial: Mapping the field of mixed methods research. *Journal of Mixed Methods Research*, *3*(2), 95–108. https://doi.org/10.1177/1558689808330883

DeWitt, J., Archer, L., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2011). High aspirations but low progression: The science aspirations-careers paradox amongst minority ethnic students. *International Journal of Science and Mathematics Education*, *9*(2), 243–271. https://doi.org/10.1007/s10763-010-9245-0

Dickhäuser, O., & Reinhard, M.-A. (2006). Factors underlying expectancies of success and achievement: The influential roles of need for cognition and general or specific self-concepts. *Journal of Personality and Social Psychology*, *90*(3), 490–500. https://doi.org/10.1037/0022-3514.90.3.490

Dishon-Berkovits, M. (2014). A study of motivational influences on academic achievement. *Social Psychology of Education*, *17*(2), 327–342. https://doi.org/10.1007/s11218-014-9257-7

Dweck, C. S. (1986). Motivational processes affecting learning. *American Psychologist*, *41*(10), 1040–1048. https://doi.org/10.1037/0003-066X.41.10.1040

Dweck, C. S. (2000). *Self-theories: Their role in motivation, personality, and development. Essays in social psychology*. Psychology Press.

Dweck, C. S., & Leggett, E. L. (1988). A social cognitive approach to motivation and personality. *Psychological Review*, *95*(2), 256–273. https://doi.org/10.1037/0033-295X.95.2.256

Eccles, J. S., & Wang, M.-T. (2016). What motivates females and males to pursue careers in mathematics and science? *International Journal of Behavioral Development*, *40*(2), 100–106. https://doi.org/10.1177/0165025415616201

Guest, G. (2013). Describing mixed methods research: An alternative to typologies. *Journal of Mixed Methods Research*, *7*(2), 141–151. https://doi.org/10.1177/1558689812461179

Huang, C. (2012). Discriminant and incremental validity of self-concept and academic self-efficacy: A meta-analysis. *Educational Psychology*, *32*(6), 777–805. https://doi.org/10.1080/01443410.2012.732386

Lin, C.-J., Hung, P.-H., Lin, S.-W., Lin, B.-H., & Lin, F.-L. (2009). The power of learning goal orientation in predicting student mathematics achievement. *International Journal of Science and Mathematics Education*, *7*(3), 551–573. https://doi.org/10.1007/s10763-008-9132-0

Liou, P.-Y. (2014). Examining the Big-Fish-little-Pond effect on students' self-concept of learning science in Taiwan based on the TIMSS databases. *International Journal of Science Education*, *36*(12), 2009–2028. https://doi.org/10.1080/09500693.2014.889331

Lüdtke, O., Baumert, J., & Koller, O. (2007). The big-fish-little-pond effect: Persistent negative effects of selective high schools on self-concept after graduation. *American Educational Research Journal*, *44*(3), 631–669. https://doi.org/10.3102/0002831207306728

Makwinya, N. M., & Hofman, R. H. (2015). Gender disparities in sciences: The question of parental influence on children's self-concept and utility-value. *Journal of Education and Practice*, *6*(13), 70–75.

Marsh, H. W. (1986). Verbal and math self-concepts: An internal/external frame of reference model. *American Educational Research Journal*, *23*(1), 129–149. https://doi.org/10.3102/00028312023001129

Marsh, H. W. (1987). The big-fish-little-pond effect on academic self-concept. *Journal of Educational Psychology*, *79*(3), 280–295. https://doi.org/10.1037/0022-0663.79.3.280

Marsh, H. W., & Craven, R. G. (2006). Reciprocal effects of self-concept and performance from a multidimensional perspective: Beyond seductive pleasure and unidimensional perspectives. *Perspectives on Psychological Science*, *1*(2), 133–163. https://doi.org/10.1111/j.1745-6916.2006.00010.x

Marsh, H. W., & Yeung, A. S. (1998). Top-down, bottom-up, and horizontal models: The direction of causality in multidimensional, hierarchical self-concept models. *Journal of Personality and Social Psychology*, *75*(2), 509–527. https://doi.org/10.1037/0022-3514.75.2.509

OECD. (2008). *Encouraging student interest in science and technology studies*. OECD Publishing.

OECD. (2009a). *Chart A4.6 Tertiary graduates in science-related fields among 25-34 year-olds in employment, by gender (2009)*. https://doi.org/10.1787/888932460192

OECD. (2009b). *PISA 2006 Technical report*. OECD Publishing.

Prieur, A., & Savage, M. (2013). Emerging forms of cultural capital. *European Societies*, *15*(2), 246–267. https://doi.org/10.1080/14616696.2012.748930

Qu, S. Q., & Dumay, J. (2011). The qualitative research interview. *Qualitative Research in Accounting & Management*, *8*(3), 238–264. https://doi.org/10.1108/11766091111162070

Riegle-Crumb, C., Moore, C., & Ramos-Wada, A. (2011). Who wants to have a career in science or math?: Exploring adolescents' future aspirations by gender and race/ethnicity. *Science Education*, *95*(3), 458–476. https://doi.org/10.1002/sce.20431

Rüschenpöhler, L., & Markic, S. (2019a). A mixed methods approach to culture-sensitive academic self-concept research. *Education Sciences*, *9*(3), 240. https://doi.org/10.3390/educsci9030240

Rüschenpöhler, L., & Markic, S. (2019b). Self-concept research in science and technology education: Theoretical foundation, measurement instruments, and main findings. *Studies in Science Education*, *55*(1), 37–68. https://doi.org/10.1080/03057267.2019.1645533

Rüschenpöhler, L., & Markic, S. (2020a). Secondary school students' acquisition of science capital in the field of chemistry. *Chemistry Education Research and Practice*. Advance online publication. https://doi.org/10.1039/C9RP00127A

Rüschenpöhler, L., & Markic, S. (2020b). Secondary school students' chemistry self-concepts: Gender and culture, and the impact of chemistry self-concept on learning behaviour. *Chemistry Education Research and Practice*. Advance online publication. https://doi.org/10.1039/C9RP00120D

Shavelson, R. J., Hubner, J. J., & Stanton, G. C. (1976). Self-concept: Validation of construct interpretations. *Review of Educational Research*, *46*(3), 407–441. https://doi.org/10.3102/00346543046003407

Silinskas, G., & Kikas, E. (2019). Parental involvement in math homework: Links to children's performance and motivation. *Scandinavian Journal of Educational Research*, *63*(1), 17–37. https://doi.org/10.1080/00313831.2017.1324901

Simpkins, S. D., Price, C. D., & Garcia, K. (2015). Parental support and high school students' motivation in biology, chemistry, and physics: Understanding differences among latino and caucasian boys and girls. *Journal of Research in Science Teaching*, *52*(10), 1386–1407. https://doi.org/10.1002/tea.21246

Statistisches Bundesamt. (2013). *Bevölkerung und Erwerbstätigkeit Bevölkerung mit Migrationshintergrund – Ergebnisse des Mikrozensus* 2013 [Population and employment: Population with a migration background – results from the micro-census 2013]. Statistisches Bundesamt.

Taskinen, P. H., Schütte, K., & Prenzel, M. (2013). Adolescents' motivation to select an academic science-related career: The role of school factors, individual interest, and science self-concept. *Educational Research and Evaluation*, *19*(8), 717–733. https://doi.org/10.1080/13803611.2013.853620

van de Vijver, F. J. R., & Poortinga, Y. H. (2005). Conceptual and methodological issues in adapting tests. In C. D. Spielberger, P. F. Merenda, & R. K. Hambleton (Eds.), *Adapting educational and psychological tests for cross-cultural assessment* (pp. 39–63). Lawrence Erlbaum.

Wang, C.-L., & Liou, P.-Y. (2017). Students' motivational beliefs in science learning, school motivational contexts, and science achievement in Taiwan. *International Journal of Science Education*, *39*(7), 898–917. https://doi.org/10.1080/09500693.2017.1310410

World Medical Association. (2013). World Medical Association declaration of Helsinki: Ethical principles for medical research involving human subjects. *Journal of the American Medical Association*, *310*(20), 2191–2194. https://doi.org/10.1001/jama.2013.281053

Xu, X., & Lewis, J. E. (2011). Refinement of a chemistry attitude measure for college students. *Journal of Chemical Education*, *88*(5), 561–568. https://doi.org/10.1021/ed900071q

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Work experience

since January 2020	**Trainee teacher** Königin-Katharina-Stift, Gymnasium, Stuttgart
since March 2017	**Pre-doctoral research fellow** Ludwigsburg University of Education and project *DiSenSu*
2016 – 2017 (6 months)	**Science teacher** Wilhelm-Kaisen-Oberschule, Bremen
2015 – 2017 (2 years)	**Research assistant** Project *Fach + Sprache*, University of Bremen

Education

2017-2020	**PhD student in chemistry education** Ludwigsburg University of Education
2014 – 2016	**Master of education in chemistry and French for secondary school** University of Bremen
2011 – 2014	**Bachelor of arts in chemistry and French for secondary school** University of Bremen
2008 – 2011	**Bachelor of arts in philosophy and political science** University of Bremen
2008	**Abitur** Gymnasium Schloß Neuhaus, Paderborn

Education abroad

2009/2010	9 months in Paris (FR), Sorbonne University, faculty of arts and humanities
2005/2006	8 months in Poznań (PL), XVI Liceum Ogólnokształcące Charles de Gaulle'a (secondary school)

Grants

2019	ESERA Travel Award
2017 – 2019	Internal research funds of the Research Development and Funding Center at Ludwigsburg University of Education
2017 & 2019	DAAD scholarship for the ESERA conferences in Dublin und Bologna

Memberships

ESERA (SIG science identities)
GDCP
Nominated for committee membership of CERG (Chemistry Education Research Group, Royal Society of Chemistry)
NiNU
Network „Stark durch Diversität", Stifterverband (2017-2019)