



Cite this: DOI: 10.1039/c9rp00127a

Secondary school students' acquisition of science capital in the field of chemistry

Lilith Rüschenpöhler * and Silviya 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.

Received 5th June 2019,
Accepted 25th August 2019

DOI: 10.1039/c9rp00127a

rsc.li/cerp

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

Ludwigsburg University of Education, Reuteallee 46, D-71634 Ludwigsburg, Germany. E-mail: rueschenpoehler@ph-ludwigsburg.de

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 (Rüschepöhler 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.

(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)

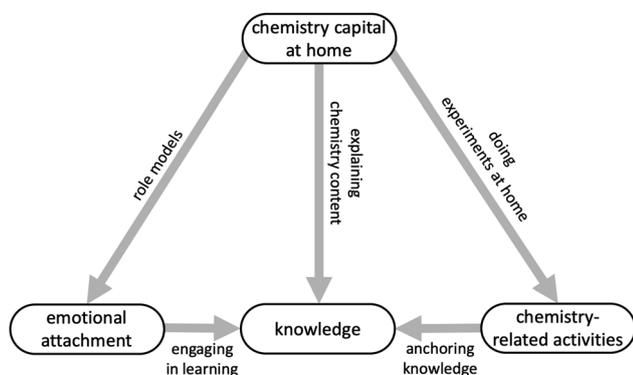


Fig. 1 Interactions between home environments in which chemistry capital is present and the students’ acquisition of chemistry capital. The arrows symbolise contributions.

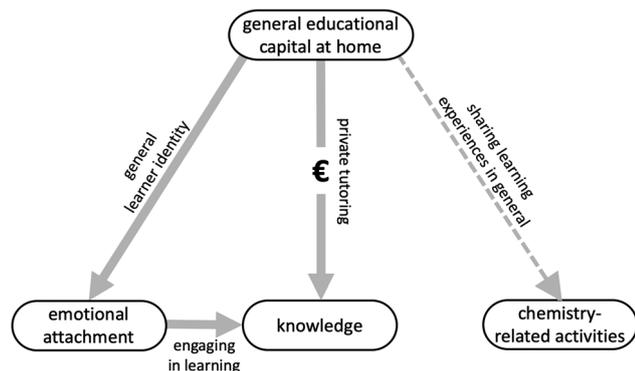


Fig. 2 Interactions between home environments in which general educational capital is present and the students' acquisition of chemistry capital. The dashed line symbolises a rather weak relation.

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).

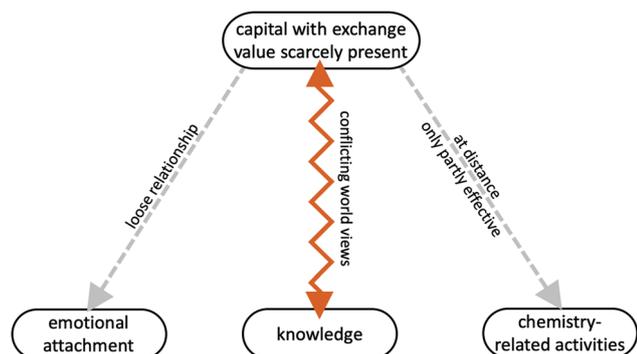


Fig. 3 Interactions between home environments in which capital with exchange value in the field of chemistry is scarcely present and the students' acquisition of chemistry capital. The dashed lines symbolise weak relationships, and the red zigzag line indicates a conflict.

“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

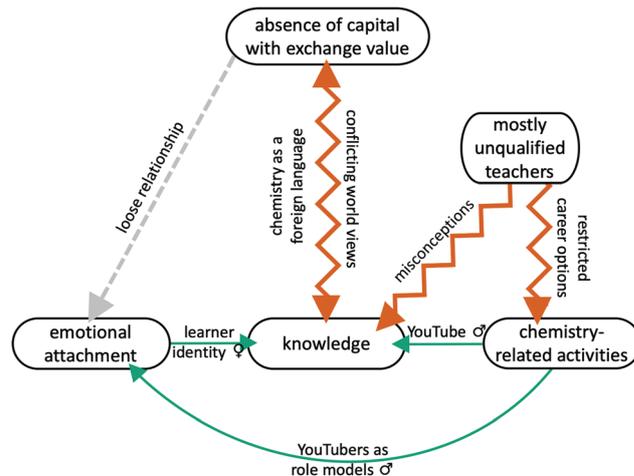


Fig. 4 Interactions between home environments in which capital with exchange value in chemistry is absent and the students' acquisition of chemistry capital. The green arrows constitute mechanisms of chemistry capital acquisition that the students deploy independent of external sources. The influence of unqualified chemistry teachers is added in this group 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 over-represented 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 disproportionately 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:

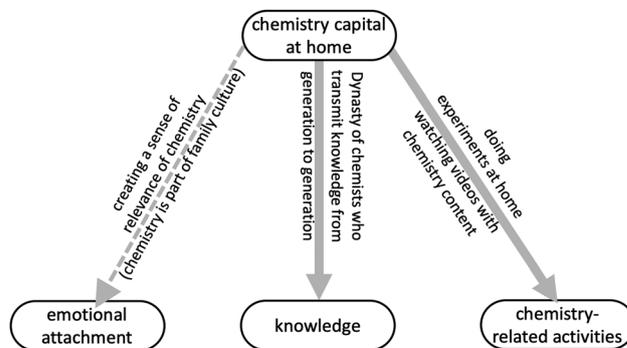
- (a) chemistry is not talked about at home,
- (b) significant others such as parents do not have a positive attitude or even a negative attitude towards chemistry,
- (c) talking about chemistry content has a negative influence on social relations (*e.g.*, conflicts emerge such as between religious and 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.

Acknowledgements

This research was partly funded by a grant of the internal research funding at Ludwigsburg University of Education. In addition, we would like to thank Louise Archer and Jennifer DeWitt and their research group for the discussion about science capital. The exchange was made possible through the ESERA 2019 travel award the first author was presented with.

Notes and references

- Agasisti T., Avisati 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, Maßnahmen*, 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: 10.1191/1478088706qp0630a.
- 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.
- Rüschepöhler 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 Efinger 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.