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RESEARCH ARTICLE

Paving the way for curriculum innovation through participatory action research in bilingual chemistry and bilingual biology lessons at German secondary schools: Results from a survey among teachers concerning their material demands

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This paper underlines the ongoing necessity of innovating school chemistry curricula in Germany, while acknowledging that both regular chemistry and bilingual/CLIL[1] chemistry lessons rely on the same governmental guidelines. The paper points out that in order to achieve curricular innovation successfully, cutting-edge curricular innovation research should be combined with participatory action research (PAR). In view of the fact that there is not a network of collaborating bilingual chemistry teachers in Germany, it is first described how a database of CLIL chemistry at German secondary schools is built up – and why CLIL biology teachers have been included. Afterwards, this paper describes how one suitable innovative topic for CLIL chemistry and CLIL biology has been chosen by means of a needs analysis among aforementioned teachers. Finally, the results of the survey are presented and discussed, in particular as regards the teachers' needs for teaching materials.

Keywords: participatory action research (PAR), bilingual chemistry education, content and language integrated learning (CLIL), cutting-edge curricular innovation research

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[1] CLIL (Content and language integrated learning) and bilingual education are used synonymously in this article. For a presentation of the origins of CLIL and developments in Europe see Nikula (2016) or Pérez-Cañado (2012).

Introduction

Chemistry education research departments lay emphases on different segments (cf. Taber 2013). One of the branches in Germany called experimental-conceptual research ("experimentell-konzeptionelle Forschung" (Tausch/Flint 2017)) is devoted to innovating school chemistry as regards both experiments and didactics. At least four major subdivisions can be identified, whose boundaries are often blurred so that they sometimes overlap. The following brief overview is meant to help understand the different main efforts – it is neither meant complete nor static: Firstly, prominent representatives have focused on developing concepts largely based on "substances from daily life" (Flint 2011:82). Secondly, there is "Chemie im Kontext" (Parchmann et al. 2006), which shares a somewhat similar approach with the third branch, "Societal Driven Science Education" (Eilks/Hofstein 2017). Finally, there is the branch of cutting-edge curricular innovation, which adapts new developments in science and technology for the integration at school (cf. the articles compiled in Habekost 2019 for a first overview).

Our department's efforts have been devoted to the last branch. In this sense, relevant[2] aspects from current technological advancement in academia and society are adapted for school. This process of research and development results in various teaching materials based on newly conceptualized experiments (Tausch 2009; Parchmann et al. 2017). A prime example of the iterative developmental process would be the innovative Photo-Blue-Bottle experiment (PBB) – a model experiment for photosynthesis and respiration (cf. Yurdanur/Tausch 2019 and Brunnert/Yurdanur/Tausch 2019).

Solar power and ongoing cutting-edge curricular innovation research

The main focus of our research and development efforts has been on energy conversion and on light-induced processes as the possible potential of solar energy has not been fully exploited as yet, which has been the main impetus for the ongoing devotion to this topic. The field of solar energy is informed by ongoing scientific research and development, which is pointed out by the WBGU: "Solar power has also seen considerable progress, for example in the conversion efficiency of amorphous silicon and thin film technologies. New experiences have been gathered with plants which generate electricity" (2011:118).

Despite technological progress, only a tiny fraction of solar energy has been used so far. Moreover, more than three-quarters of the global carbon dioxide emissions must be attributed to energy production based on fossil fuels, which entails the necessity of finding means that help decrease these emissions. For instance, this is possible by enhancing alternative power generators

[2] We are aware of the fact that the term 'relevance' bears potentially conflicting meanings (Stuckey et al. 2013). Taber (2015:89) identifies four equally important facets of course materials' relevance. Our materials are intended to fulfil and extend curricular aims, which we strive to attain by the development of motivating experiments and materials that are geared towards the respective students' current levels of knowledge.

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or by inventing new technologies in this field (ibid.:113ff, 119f). All these points emphasize that scientific research into technologies exploiting the potentials offered by renewable energy sources is still needed. At the same time, it implies that this research will, in turn, impact school curricula. It can thus be said that development of school materials dealing with light is an ongoing, dynamic process.

The outcome of our work has been made available to the public via various papers, lectures, and our homepage. While we mainly focused on light-induced processes to a large extent, we also explored other topics such as cyclodextrins, liquid crystals, and silicones (cf. https://chemiedidaktik.uni-wuppertal.de). Thus, there is an abundance of materials that can be connected to already existing core concepts within worldwide chemistry education (cf. Brunnert et al. 2018:114ff). A recent research project by Yurdanur (ongoing) suggests that the potentials of light-induced processes for chemistry lessons in Germany have remained largely unexploited as yet, indicating that the materials have not reached the target groups to satisfactory extents.

CLIL chemistry in Germany

CLIL in Germany still mainly focuses on geography, the social sciences, history, and biology. According to Bonnet (2012:201), the number of German schools offering CLIL chemistry has remained rather low despite some moderate growth. In the federal state of North Rhine-Westphalia (NRW), there was an overall number of 109 grammar schools offering CLIL, of which only one offered chemistry, whereas biology could be found 19 times (Bohrmann-Linde 2013:296; these numbers from 2006 refer to the subjects the schools have officially selected for bilingual education at their schools, i.e. as a part of their school programs). As of 2013, schools in eight federal states offered bilingual chemistry (Bohrmann-Linde/Strippel 2018). The low number notwithstanding, these are twice as many cases as in 2006 (Bohrmann-Linde 2013). Scholars unanimously agree on chemistry's potentials for CLIL, which is also reflected in governmental guidelines fostering CLIL in the sciences and the various reasons are discussed by Bohrmann-Linde/Strippel (2018), Bonnet (2012), or Rittersbacher (2007). Main reasons are seen in the authentic communication situation during experiments, the usage of English as the lingua franca in science contexts, or the opportunity of a deeper level of understanding as a consequence of reflecting on the language of instruction (cf. Heine 2010; confirmed by Rodenhauser/Preisfeld 2015 for biology), for example. Recently, Ohlberger/Wegner found that "CLIL modules [in biology] are helpful to reduce English anxiety and increase self-efficacy" (2019:11). Their research focused on much more diverse groups than those found in schools with bilingual streams, examining also the impact on students who would usually not opt for taking part in CLIL provision.

Usually, CLIL chemistry takes place either as a part of a bilingual stream or in modules and, as it is the case for all subjects taught bilingually, it follows the subject curriculum of the federal state it belongs to (Bohrmann-Linde/Strippel 2018). Nevertheless, the guidelines grant some room for the teacher's individual emphases. Curriculum innovation hence affects regular (monolingual) as well as bilingual lessons. The fact that CLIL chemistry it is usually offered in modules suggests that some topics are considered more suitable for bilingual instruction than others, for which the reasons have remained unknown. It could be due to a lack of teaching materials tailored to the demands of bilingual chemistry, which is also suitable for German school curricula. Recently, some governmental efforts have been undertaken (ISB 2019), and there are the occasional publications by teachers at tertiary or secondary level (for an overview cf. Bohrmann-Linde/Strippel 2018; for topical material development trends see Bohrmann-Linde 2016 and Diehr 2018). In addition, the specific linguistic demands on part of the learners and the resulting interplay between content knowledge and linguistic skills (Coyle/Hood/Marsh 2010:38ff; cf. Zydatiß 2012) can play a crucial role when deciding on a module topic.

Innovative teaching materials in bilingual chemistry education

When deciding on topics suitable for the usage in CLIL modules, we particularly returned to the interplay between linguistic demand and subject matter. Light-induced topics we consider suitable for CLIL chemistry can be found in the bulleted list below. They all deal with light in different ways and on different levels. Sometimes the students learn in a rather concrete way about colours and colour mixing (e.g. chromatography). Other settings help them understand rather abstract and cognitively demanding aspects (e.g. the carbon cycle). Yet, no matter which level of abstraction has been selected, the topics are based on the excited state – a concept we believe should become an integral part of the chemistry curriculum. The following comments help understand the subject matter:

- Chromatography/Chromatography and highlighters: At a very early stage, students can investigate into whether substances are pure or mixtures. It can be done with regular felt tips, or highlighters containing luminescent dyes.
- Learning stations on energy conversion and storage: These stations deal with different forms of energy, but the focus is laid on solar energy.
- A carbon cycle in animate nature: Photosynthesis and respiration form a cycle which can be introduced and elaborated on with the PBB experiment. There are follow-up experiments and digital materials that help investigate the topics of energy transformation, energy storage, photocatalysis, and the electronically excited state. This is the reason why the topic is offered at two different levels. The original PBB experiment has been enhanced in a crucial as the current set-up comprises inexpensive vials and only harmless substances. Also concrete teaching units ready to be transformed for CLIL lessons have been developed (cf. Brunnert/Yurdanur/Tausch 2019).
- Fluorescence and phosphorescence: Starting out with the phenomenon, students explore differences between the two different forms of luminescence. Furthermore, the topic is connected to processes in plants.

There are many teaching materials available for school chemistry, but at this stage they have been ignored for CLIL (and for the questionnaire for our survey, cf. next paragraphs) due to their linguistic complexity. For instance, English hands-on teaching resources for OLEDs, photogalvanic cells, or the photostationary state are provided open access on a new website by Tausch/Meuter et al. (2019).

Bottom-up innovation by means of participatory action research (PAR)

Innovation can take place by top-down or bottom-up processes (Eilks/Hofstein 2017:175; Mamlok-Naaman 2017:202). One of the major factors influencing curricular transformation in the sciences at secondary level have been "[c]hanges and cutting-edge developments in science and technology, namely, contemporary scientific and technological knowledge" (ibid.:201). Practitioners are identified as "the key components in implementing any curriculum, and therefore, extensive, dynamic, and long-term professional development of science teachers should take place" (ibid.:199).

At this stage, cutting-edge curricular innovation research and PAR (for detailed descriptions see Eilks/Ralle 2002, and Krause/Eilks 2019:16f), which encourages the joint collaboration between university teachers and school teachers, should be combined as the latter is considered a suitable tool of "improving the curriculum and pedagogy [of elementary, secondary, and tertiary education]" (Laudonia et al. 2018:484). For us it is decisive that it has already "proved itself effective in many projects for secondary school curriculum innovation" (Krause/Eilks 2019:16), resulting in "positive experiences [and the creation of] many useful materials" (Tolsdorf/Markic 2018:94). These arguments are important for us as we seek to innovate curricula with our didactical materials. Accordingly, this overarching aim can be achieved by focusing on the circular, iterative development together with teachers. This procedure is essential to successful develop-mental processes and an integral part of PAR (cf. Eilks/Ralle 2002).

It has been mentioned above that CLIL follows the respective subject's curriculum. That is, curricular changes affect CLIL. In comparison with regular monolingual classes, CLIL offers a further dimension which has to be considered, as the teaching language is different from the school language. From this perspective, curricular innovation can also take its point of origin in CLIL because the dimension of the foreign language might allow for a new approach – method- or content-wise.

Teachers must be found who support the intended innovation and help enhance the innovative material according to the principles of PAR. Regarding the topic of light-induced processes, it would thus be helpful to select different starting points which can be offered to interested teachers, who could become future members of a CLIL chemistry education network and specialized PAR groups. In this sense, our needs analysis serves to create a sound foundation for our intended PAR. Accordingly, we wanted to investigate the following research question:

a) *Where are the secondary schools that offer CLIL chemistry in Germany?*

Therefore, topical data about bilingual chemistry in Germany has to be retrieved and a database containing teacher contacts has to be created. Secondly, we need to address the newly-found practitioners and conduct a survey among them. We wanted to investigate the following two additional research questions:

b) *Which topics concerning light-induced processes are teachers interested in?*
c) *Which further general topics do teachers want to cover but lack material?*

A topical overview of CLIL provision in North Rhine-Westphalia (NRW)[3]

We are interested in CLIL as regards the languages German and English. By retrieving information from the NRW-database and by contacting secondary schools,[4] we gathered data on which subjects are taught at secondary level in NRW. In our February 2017 query, we found that in total there are 337 secondary schools (227 grammar schools, 50 comprehensive schools, 60 secondary modern schools)[5] that provide CLIL 727 times – many schools run three subjects, usually history, geography, and political sciences/social sciences –, the average number of CLIL subjects being 2.16. We expected chemistry to rank lower than biology, but it comes at a surprise to see even maths or physics offered more often (cf. **Table 1**).

The low number of chemistry schools and the interdisciplinary qualities of some of our materials prompted us gathering addresses of CLIL schools offering chemistry or biology. While CLIL chemistry at schools all over Germany were considered – entailing further queries comparable to the ones above[6] – only CLIL biology at schools in NRW was involved as our institute is located in NRW. That is, by the end of October 2018, we gathered 92 addresses in total (CLIL chemistry: 30; CLIL biology: 62). The 30 schools running CLIL chemistry are placed in only six different states (Bavaria, Lower Saxony, NRW: 7 schools each; Hesse: 4; Rhineland-Palatinate: 3; Saxony: 2), thus answering the first research question "*a) Where are the secondary schools that offer CLIL chemistry in Germany?*"

[3] NRW is the most populous federal state with approximately 18 million inhabitants (cf. Federal Statistical Office 2011; data based on the 2011 census).
[4] An address list of the contacted schools, governmental ministries and institutions is available on request.
[5] We do not focus on vocational schools in this paper.
[6] An address list is available on request.

Table 1. Number of CLIL subjects at 337 secondary schools in NRW, Germany (Feb. 2017)

Position	Subject	Total number	%
1	History	231	31.8
2	Geography	207	28.5
3	Political Sciences/Social Sciences	150	20.6
4	Biology	65	8.9
5	Maths	10	1.4
5	Physics	10	1.4
6	Economics	9	1.2
7	Chemistry	7	1.0
7	Philosophy	7	1.0
7	Religious Education	7	1.0
8	Art	6	0.8
9	Physical Education	5	0.7
10	Music	4	0.6
11	Literature Course/Drama Course	2	0.3
12	Business and Employment Studies	1	0.1
12	Educational Sciences	1	0.1
(-)	School pilot projects (without mentioning a particular subject)	5	0.7
	Sums:	**727**	**100**

A survey among CLIL chemistry teachers in Germany and CLIL biology teachers in NRW

The questionnaire is intended to help understand which topics teachers would like to teach and which teaching materials they need. The questionnaire is not intended to yield an overview of which topics have already been taught. Rather, it is intended to provide insights into potential access points for implementing an innovative approach, or improvement of the current teaching situation. These pieces of information will be used for selecting innovative materials, and recruiting teachers – all of which leading to PAR.

The questionnaire comprises of two parts. The first part is an open one, in which the teachers are asked to write down which topics they need teaching materials for and add particular information about the intended grade and the intended type of material (e.g. experiment, worksheet, factual text linguistically geared towards a certain group of students). The second one explicitly offers topics that are directly related to material which can be used for innovative modules (cf. **Table 2**). Here, the teachers are asked to tick off these items they would like to teach. The topics or contexts are based on or derived from the NRW chemistry curricula.

The topics marked with an asterisk (*) contain light-induced processes, but they were not marked in the original questionnaire. Reasons for the choice of these topics have been presented above. The other ones have been chosen because there is either further available innovative material, or there are ideas for innovative approaches to be tested in CLIL contexts.

Table 2. Items in the closed part of the questionnaire

Topics at lower secondary level
Acids and bases - exploring cleansing agents
Energy from chemical reactions - working stations on energy supply and energy transformation*
Material properties and separation techniques: Chromatography and marker pens/highlighters*
Material properties and separation techniques: Chromatography of felt tips*
Photosynthesis/respiration: a carbon cycle in animate nature*
Water - more than a simple solvent - exploring covalent bonds
Topics at upper secondary level
Colour by light emission - fluorescence and phosphorescence*
Nanomaterials made from carbon
Photosynthesis/respiration: a carbon cycle in animate nature*

Outcome

The questionnaires were sent out in the winter of 2017/18. 17 of 30 chemistry schools (response rate 57%) and 24 of 62 biology schools (response rate 39%) sent back the filled-in questionnaires. Some of the teachers already mentioned topics in the open part that we specifically asked for in the closed part. In these cases the items were combined. When adding the items of open part and closed part of the questionnaire, 15 chemistry-schools (88%) and 13 biology-schools (46%) are interested in topics drawing on light-induced processes (i.e. the ones marked with an asterisk). **Table 3** contains an overview of the responses:

Table 3. Responses from the open and the closed part of the questionnaire

	Requests by teachers of …		
	… *chemistry*	**… *biology***	**… in total**
Topics at lower secondary level:			
Acids and bases	12	3	15
Energy from chemical reactions*	12	3	15
Chromatography of marker pens*	10	1	11
Chromatography of felt tips*	7	3	10
Photosynthesis/respiration*	10	12	22
Water	11	4	15
Topics at upper secondary level:			
Fluorescence and phosphorescence*	7	2	9
Nano materials	6	1	7
Photosynthesis/respiration*	5	12	17

The survey shows that chemistry teachers are mostly interested in the content for lower secondary lessons. Especially prominent is their interest in the topics of acids and bases, energy from chemical reactions, and water. All of these topics are deeply rooted in classical chemical education and are explicitly listed in the states' curricula. Biology teachers are mostly interested in photosynthesis/respiration, while all the other topics have not been requested more than four times. The reason for the biology teachers' rare selection of these topics relates to the fact that all of them stem from chemistry curricula, whereas photosynthesis/respiration is a part of both lower and upper secondary biology curricula. All in all, the topic of photosynthesis/respiration ranks first as it has been requested 22 and 17 times, respectively. It is the only topic selected rather equally often at the level of lower secondary education. It is demanded, however, more than twice as much by biology teachers at the level of upper secondary education. With an overall selection of 15 times, the topics of acids and bases, energy from chemical reactions, and water rank second. As a consequence, to a great extent, **Table 3** illuminates the second research question "*b) Which topics concerning light-induced processes are teachers interested in?*" Furthermore, one additional topic drawing on light-induced processes was mentioned in the open part: *The human eye and the perception of colours* was mentioned three times – although twice without mentioning colour perception explicitly. Chemistry teachers did not mention comparable items in the open part.

All in all, seven chemistry teachers and 19 biology teachers filled in the open part. The chemistry teachers explicitly requested 51 items from various fields, all of which located at lower secondary level. (Additionally, one person asked for material for all topics at all levels.) They can be grouped in five domains: different types of covalent bonds in molecules and resulting material properties based on intermolecular interactions (mentioned 5x), redox reactions (4x), atomic theory (Bohr, Rutherford) (4x), ionic bonds in salts and resulting material properties (4 times), and protolysis (4x). Light-induced topics were mentioned only three times implicitly (including the person asking for all material): The topics of geochemical cycles (carbon, nitrogen) (1x) and energy conversion (1x) were named. Experiments were only asked for in three cases (combustions, endothermic and exothermic chemical reactions, and ionic bonds).

The biology teachers explicitly requested 79 items from various fields, of which approximately 50 % (42 items) are located at lower secondary level. Five domains are requested predominantly: Genetics and epigenetics (12x), evolution (10x; sometimes specified: viral evolution; evolution and behaviour), ecology (9x; sometimes specified: neobiota, woods, woods: anthropogenic influences, biotic/abiotic factors, the sea, human influence and environmental protection; lake: geochemical cycle, exemplary animals; microorganisms in hay infusion), immunobiology (7x; sometimes specified: healthy living; HIV; vaccines), neurobiology (6x; sometimes specified: fMRT, Alzheimer's disease; learning on the molecular level; brain plasticity; Markowitsch's memory models), and the senses (3x; sometimes specified: human eye – perception of colours; human eye). Light-induced topics were mentioned six times implicitly (including the person asking for all topics): The topics of photosynthesis (2x), human eye (2x), and ecology/geochemical cycle (1x) were named. Occasionally, experiments were asked for the topics of photosynthesis, ecology, neurobiology, evolution, human eye, or immunobiology. Hence, the third research question "*c) Which further general topics do teachers want to cover but lack material?*" could be answered.

In several cases, the teacher emphasized that they are happy for any help as material development is largely their own responsibility. Sometimes, biology teachers made clear that new topics have not been covered by text books – and that new CLIL text books are not being planned by publishing houses.

Conclusion and outlook

When compared with the data presented by Bohrmann-Linde (2013), there is an overall increase in CLIL provision. This holds true for the subjects of chemistry and biology, too.

The survey among teachers shows that topics revolving around light-induced processes are demanded by both practitioners of CLIL chemistry and biology – mentioning topics on the teachers' initiative occurred scarcely, however. The predominant field of interest is the one of photosynthesis and respiration at lower and upper secondary level. As a result, materials revolving around the PBB experiment have been further developed and transformed (see above), taking into consideration recent changes in CLIL (cf. Meyer/Coyle/Halbach et al. 2015). In the meantime, first explorations of the chemistry teaching materials have already been carried out at several grammar schools.

A database containing CLIL chemistry and CLIL biology teachers was created. A PAR group consisting of two bilingual biology teachers and a member of our faculty has been founded, which develops materials based on the innovative PBB experiment. The target group is students at lower secondary level. Thereby, the group seeks to fill the gap that Steigert (2012) has detected for biology education in general: There is a lack of student experiments that help explore photosynthesis.

Additionally, it has become apparent that CLIL teachers need material in order to fulfil their need of teaching a wide range of curricular topics and contexts, adding considerable momentum to our development of readily usable CLIL material for chemistry lessons (cf. Bohrmann-Linde/Brunnert/Kiesling (eds.) ongoing).

Finally, further research by science education departments (e.g. Prediger et al. 2019) underlines interest in psycholinguistic issues that also Diehr (2018) discusses – and which will inform parts of our research into bilingual chemistry education, too.

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Conflict of Interest

The corresponding author states that there is no conflict of interest.

References

Bohrmann-Linde, C. (2013). Chemie. In Hallet/Königs (pp. 295–302).

Bohrmann-Linde, C. (2016). Funktionale Sprachwechsel und Wechsel der Darstellungsform im bilingualen Chemieunterricht. In B. Diehr, A. Preisfeld, & L. Schmelter (Eds.), *Bilingualen Unterricht weiterentwickeln und erforschen* (pp. 165–182). Frankfurt: Lang.

Bohrmann-Linde, C., & Strippel, C. (2018). Sprachliche Interaktionen und sprachsensibler Chemieunterricht. In K. Sommer, J. Wambach-Laicher, & P. Pfeifer (Eds.), *Konkrete Fachdidaktik Chemie.* (pp. 709–721). Seelze: Friedrich/Aulis.

Bonnet, A. (2012). CLIL im Fach Chemie. In B. Diehr & L. Schmelter (Eds.), *Bilingualen Unterricht weiterdenken* (pp. 201–218). Frankfurt: Lang.

Brunnert, R., Bohrmann-Linde, C., Meuter, N., Pereira Vaz, N., Spinnen, S., Yurdanur, Y., & Tausch, M. W. (2018). The fascinating world of photochemistry. Video tutorials for core concepts in science education. *Educación Química*, *29*(3), 108–117. https://doi.org/10.22201/fq.18708404e.2018.1.63736

Brunnert, R., Yurdanur, Y., & Tausch, M. W. (2019). Towards artificial photosynthesis in science education. *World Journal of Chemical Education*, *7*(2), 33–39. https://doi.org/10.12691/wjce-7-2-1

Coyle, D., Hood, P., & Marsh, D. (2010). *CLIL: Content and language integrated learning*. Cambridge: CUP.

Diehr, B. (2018). Language, cognition, and culture - a model of the bilingual learner's mental lexicon. In H. Böttger & M. Sambanis (Eds.), *Focus on Evidence II* (pp. 151–162). Tübingen: Narr.

Eilks, I., & Hofstein, A. (2017). Curriculum development in science education. In Taber/Akpan (pp. 169–181).

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

Federal Statistical Office (2011). Population (Census): Länder, reference date, nationality, sex. Result – 12111-0101. https://www-genesis.destatis.de/genesis/online/ (23.10.2019)

Flint, A. (2011). Chemistry for life – a new way to teach and learn chemistry. In D. Cedere (Ed.), *Science and technology education.* (pp. 82–86). Riga: U of Latvia.

Habekost, A. (Ed.). (2019). Transformation of knowledge in chemistry into didactical experiments [Special issue]. *World Journal of Chemical Education*, *7*(2). http://www.sciepub.com/WJCE/content/7/2 (23.10.2019)

Hallet, W., & Königs, F. G. (Eds.). (2013). *Handbuch bilingualer Unterricht: Content and language integrated learning*. Seelze: Klett/Kallmeyer.

Heine, L. (2010). *Problem solving in a foreign language. A study in content and language integrated learning*. Berlin: de Gruyter.

ISB (2019). Chemie auf Englisch. http://www.bayern-bilingual.de/gymnasium/index.php?Seite=8533& (23.10.2019).

Krause, M., & Eilks, I. (2019). Using action research to innovate teacher education concerning the use of modern ICT in chemistry classes. *Action Research and Innovation in Science Education*, *2*(1), 15–21. https://doi.org/10.12973/arise/109969

Laudonia, I., Mamlok-Naaman, R., Abels, S., & Eilks, I. (2017). Action research in science education – an analytical review of the literature. *Educational Action Research*, *26*(3). https://doi.org/10.1080/09650792.2017.1358198

Mamlok-Naaman, R. (2017). Curriculum implementation in science education. In Taber/Akpan (pp. 199–210).

Marks, R., & Eilks, I. (2009). Promoting scientific literacy using a sociocritical and problem-oriented approach to chemistry teaching - concept, examples, experiences. *International Journal of Environmental & Science Education*, *4*(3), 231–245.

Meyer, O., Coyle, D., Halbach, A., Schuck, K., & Ting, T. (2015). A pluriliteracies approach to content and language integrated learning – mapping learner progressions in knowledge construction and meaning-making. *Language, Culture and Curriculum*, *28*(1), 41–57. https://doi.org/10.1080/07908318.2014.1000924

Nikula, T. (2016). CLIL: A European Approach to Bilingual Education. In N. van Deusen-Scholl & S. May (Eds.), *Second and Foreign Language Education* (pp. 1–14). Cham: Springer. https://doi.org/10.1007/978-3-319-02323-6_10-1

Ohlberger, S., & Wegner, C. (2019). CLIL modules and their affective impact on students with high English anxiety and low self-efficacy. *Apples – Journal of Applied Language Studies, 13*(3), 1–15. http://dx.doi.org/10.17011/apples/urn.201906253409

Parchmann, I., Gräsel, C., Baer, A., Nentwig, P., Demuth, R., & Ralle, B. (2006). "Chemie im Kontext": A symbiotic implementation of a context-based teaching and learning approach. *International Journal of Science Education*, *28*(9), 1041–1062. https://doi.org/10.1080/09500690600702512

Parchmann, I., Schwarzer, S., Wilke, T., Tausch, M. W., & Waitz, T. (2017). Von Innovationen der Chemie zu innovativen Lernanlässen für den Chemieunterricht und darüber hinaus. *CHEMKON*, *24*(4), 161–164. https://doi.org/10.1002/ckon.201790001

Pérez-Cañado, M. L. (2012). CLIL research in Europe: past, present, and future, *International Journal of Bilingual Education and Bilingualism*, *15*(3), 315-341, DOI: 10.1080/13670050.2011.630064

Prediger, S., Kuzu, T., Schüler-Meyer, A., & Wagner, J. (2019). One mind, two languages – separate conceptualisations? A case study of students' bilingual modes for dealing with language-related conceptualisations of fractions. *Research in Mathematics Education, 21*(2), 188-207. DOI: 10.1080/14794802.2019.1602561

Rittersbacher, C. (2007). Zur Eignung der Naturwissenschaften - insbesondere der Chemie - für den bilingualen Unterricht. *Fremdsprachen Lehren und Lernen*, *36*(1), 111–125.

Rodenhauser, A., & Preisfeld, A. (2015) Bilingual (German–English) molecular biology courses in an out-of-school lab on a university campus: cognitive and affective evaluation. *International Journal of Environmental & Science Education, 10*(1), 99-110.

Steigert, T. (2012). *Schülervorstellungen zum Pflanzenstoffwechsel und die Bedeutung von Experimenten bei der Entwicklung von Konzepten*. Hamburg: Kovač.

Stuckey, M., Hofstein, A., Mamlok-Naaman, R., & Eilks, I. (2013). The meaning of 'relevance' in science education and its implications for the science curriculum. *Studies in Science Education*, *49*(1), 1–34. https://doi.org/10.1080/03057267.2013.802463

Taber, K. S. (2013). Three levels of chemistry educational research. *Chemistry Education Research & Practice*, *14*(2), 151–155. https://doi.org/10.1039/c3rp90003g

Taber, K. S. (2015). Epistemic relevance and learning chemistry in an academic context. In I. Eilks & A. Hofstein (Eds.), *Relevant chemistry education: From theory to practice* (pp. 79–100). Rotterdam: Sense.

Taber, K. S., & Akpan, B. (Eds.). (2017). *Science education: An international course companion.* Rotterdam: Sense.

Tausch, M. W. (2009). Innovationen: In Zeiten von Kerncurricula und PISA. *Praxis der Naturwissenschaften - Chemie in der Schule*, *58*(2), 35–37.

Tausch, M. W., & Flint, A. (2017). Chemiedidaktik 2016: Experimentell-konzeptionelle Forschung. *Nachrichten aus der Chemie*, *65*(3), 383–384. https://doi.org/10.1002/nadc.20174060851

Tausch, M. W., Meuter, N., et al. (2019) https://chemiemitlicht.uni-wuppertal.de/en/models-animations.html and https://chemiemitlicht.uni-wuppertal.de/en/experiments.html (23.10.2019)

Tolsdorf, Y., & Markic, S. (2018). Participatory action research in university chemistry teacher training. *Center for Educational Policy Studies Journal*, *8*(4), 89–108. https://doi.org/10.26529/cepsj.269

WBGU (2011). *World in transition: A social contract for sustainability*. Berlin: WBGU.

Yurdanur, Y., & Tausch, M. W. (2018). Metamorphoses of an experiment – from hightech UV immersion lamp reactor to low-cost TicTac®-cell. *CHEMKON*, *26*(3), 125–129. https://doi.org/10.1002/ckon.201800095

Zydatiß, W. (2012). Linguistic thresholds in the CLIL classroom? The threshold hypothesis revisited. *International CLIL Research Journal, 4*(1), 17-28.