

A Model for Teaching Informatics to German Secondary School Students in English-language Bilingual Education

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Abstract. Informatics as a school subject has been virtually absent from bilingual education programs in German secondary schools. Most bilingual programs in German secondary education started out by focusing on subjects from the field of social sciences. Teachers and bilingual curriculum experts alike have been regarding those as the most suitable subjects for bilingual instruction – largely due to the intercultural perspective that a bilingual approach provides. And though one cannot deny the gain that ensues from an intercultural perspective on subjects such as history or geography, this benefit is certainly not limited to social science subjects. In consequence, bilingual curriculum designers have already begun to include other subjects such as physics or chemistry in bilingual school programs. It only seems a small step to extend this to informatics.

This paper will start out by addressing potential benefits of adding informatics to the range of subjects taught as part of English-language bilingual programs in German secondary education. In a second step it will sketch out a methodological (= didactical) model for teaching informatics to German learners through English. It will then provide two items of hands-on and tested teaching material in accordance with this model. The discussion will conclude with a brief outlook on the chances and prerequisites of firmly establishing informatics as part of bilingual school curricula in Germany.

1 Setting course for informatics in English-language bilingual education

1.1 The situation as is

At the time of this paper, informatics as a school subject is virtually absent from bilingual¹ curricula in German secondary education. According to ([10], p. 96) there are merely one “Gymnasium” and one comprehensive school that offer bilingual informatics classes in North Rhine-Westphalia, the most populous German state. The latter of these schools even limits the classes to one hour of instruction per week. There are various reasons for this apparent reluctance to take up informatics into the range of subjects taught through English:

¹ As the title suggests, the scope of this paper is limited to bilingual programs in Germany that use English as the language of instruction.

- a dramatic shortage of informatics teachers with professional qualifications in both informatics and English
- a lack of teaching materials
- informatics classes are not compulsory in most German states

However, the low prevalence of informatics in bilingual school curricula may also create the impression that *informatics as a school subject* does not lend itself very well to a bilingual approach per se. On the contrary, as one of its key points, this paper will strongly contradict this view. It will propagate informatics as one of the subjects best suited for bilingual education. The discussion will start with a brief glance at the characteristics of secondary school informatics education. It will then move on to propose a conceptual framework for bilingual informatics education in secondary schools. And finally, the paper will provide two examples of hands-on teaching materials that enable a first glimpse at what bilingual informatics classes could look like. Plus, it might well be a motivation for informatics teachers to start using bilingual elements in their teaching.

1.2 The “why” of bilingual informatics education

Most bilingual programs in German secondary education started out with a strong focus on social science subjects. Teachers and bilingual curriculum experts traditionally regarded those as most suitable for bilingual instruction (cf. [6]). This was largely due to the intercultural perspective that a bilingual approach provides.

It is no surprise that, with globalization at its fullest, this limited perspective has recently come under somewhat heavy attack. The interconnected world has continually been placing greater demands on people’s control of a lingua franca such as English. Education experts and school administrators alike have begun to see the value of other subjects taught through a foreign language. Many publications from the area of bilingual education focusing on the natural sciences (such as [13]) have explored four main lines of argument:

1. *The main language of academic discourse* in the subjects under consideration is English. High-quality translations to other languages take time – which means that secondary school students only have access to recent findings/publications if they have advanced English skills which are linked with content knowledge.
2. With regard to *subject-specific terminology*, there are usually only small differences between German and English. This is because both versions are often rooted in either Latin or ancient Greek.
3. New findings/developments in the natural sciences also have a *cultural dimension* (as much or maybe today even more so than in the social sciences).
4. *English-language publications* (such as US and UK textbooks) are often much more geared towards accessibility than their German-language equivalents. Hence they are a valuable resource for learners in Germany. Yet their classroom use places high demands on the students’ English-language skills.

These points are certainly also valid for informatics education, but this is not the whole story. There is an even stronger argument that does not merely ‘qualify’ informatics as a school subject fit for bilingual approaches. In fact, it makes it seem strange that there

is so little tangible interest in bilingual informatics classes: namely that it is hard to conceive of informatics education in a complete absence of English. Why is that?

Major parts of what students have to grapple with right from the start when taking informatics classes are only accessible through English. Quite frequently they *must* understand *technical specifications* if they want to be successful learners. For instance, learners often need to understand and make use of original API documentations. They are supposed to gain an understanding of established network protocols such as RFC 868, which has even made it into the *Standards for informatics Examinations* (cf. [8], pp. 54 ff) in its original (i.e. English) version. And even today's centralized A-level requirements make explicit reference to English-language versions of data structures and abstract data types. Hence students need advanced English language skills integrated with content (= informatic) knowledge, especially if classrooms are to be student-centered. On a different note even a brilliant teacher could not possibly provide a translation of every such item. What this means is that English and its content-based application are *already* a crucial element in informatics classrooms.

If one takes these aspects just a step further, a new dimension of informatics in bilingual education opens up: programming *languages* – including those used in German classrooms – are also *languages*. And they are usually based on English keywords. This applies to control structures (if, while, for, ...) and other linguistically-anchored identifiers (public, class, ...). Plus, there is usually a strong relation between the functions these tokens exhibit in the programming language and the meaning of these words in the English language. Consequently, one of the most interesting questions to investigate is whether there is a correlation between a high degree of competence in English and a reasonable understanding of basic constructions in programming languages. Unfortunately there is a dramatic lack of research in this area, but what little we know about natural language acquisition makes it seem improbable that there is no such connection at all. If the answer is positive, this may be the key to reducing common misconceptions in informatics rooted in everyday language (e.g. when students talk about “if-loops” (if-Schleifen) instead of “if-statements” (if-Abfragen) – something that occurs quite frequently in German-language informatics classes and requires much effort and time to eradicate (cf. [7], p. 28).

It is a logical conclusion that high-quality informatics instruction is necessarily – at least in part – bilingual. This is even true if it takes place outside any official bilingual school curriculum. It is thus hard to imagine any subject better suited to a bilingual approach. After all, *language* is one of the most fundamental concepts in informatics instruction (cf. [5]) – as it is in language teaching. This reflects in much of the core content informatics lessons revolve around (modeling *languages*, programming *languages*, formal *languages*).

1.3 Two-fold relevance? An unsubstantiated hypothesis based on mathematics and the natural sciences

While a vast body of research in the field of bilingual education suggests that a student's general cognitive abilities, cultural competencies, and foreign language skills improve through bilingual education, this paper has not yet addressed the potential relevance for informatics as a school subject – and thus a student's informatic competencies. The bad

news first: There is virtually no present research on bilingual informatics education and hence no reliable data to support the claim that teaching informatics in any language other than a student's L1² is also relevant to informatics education itself.

However, there is such evidence for various other subjects from the field of natural sciences (cf. [13], p. 116 f) or mathematics (cf. [14], p. 31 f.). The sources point out that bilingual education, on the one hand, prepares students for work in these fields after they graduate. This is due to the fact that the aforementioned areas actually require both applicants and professionals to have subject-specific foreign language competencies, mostly in English (cf. [6], p. 3). On the other hand (and this is more on the didactical side of the benefit) bilingual education provides a second point of access to abstract subject-specific knowledge through the foreign language:

“[...] the availability of both languages in bilingual mathematics education has a positive effect on the acquisition of mathematical competencies; bilingual education in mathematics can thus benefit from relying on two languages.”³(cf. [14], p. 33).

If this is true of mathematics classrooms, why would it not be true of informatics education in schools? In fact, informatics and mathematics are highly interconnected and therefore often similar with regard to the level of abstraction they demand of students. What is more, informatics, like mathematics, uses symbolic codes of representation that students must first access through natural language. If it is beneficial in mathematics that the subject is taught in a second language, why not draw the same conclusion as far as informatics is concerned – in particular against the background of the observations in section 1.2? The author does realize the hypothetical nature of this claim, which results from the lack of research in the field. Unfortunately though, a thorough exploration would go beyond the scope of this paper, whose primary aim is a first attempt at providing a didactical teaching model for bilingual education in informatics.

2 The Teaching Model

The following is an outline of a methodological framework for teaching informatics in the bilingual classroom. It is based on a model developed by J. Leisen, which proposes a “change of representation forms” as a general instruction principle for all subjects in bilingual education. Although Leisen considers his approach equally suitable for all kinds of subjects, his own examples are mostly from the field of natural sciences:

“It is crucial for school subjects to present their facts in various ways. These forms of representation differ with respect to their levels of abstraction. A

² In language acquisition theory, L1 commonly refers to a person's native language whereas L2 stands for a language (usually a foreign one) learned later on in life.

³ Translated from the German: “Hiermit kommt zum Ausdruck, dass das Heranziehen beider Sprachen sich im Rahmen des bilingualen Mathematikunterrichts positiv auf den Erwerb mathematischer Kenntnisse auswirkt; der bilinguale Mathematikunterricht kann sich vorteilhaft auf zwei Sprachen stützen.” (Ibid)

constant change from one form to another is the methodological key to ‘understanding’ in a subject and it can serve as an incentive for subject-related discussion. It is methodologically wise to make this change of representation forms the focus of bilingual teaching methodology.”⁴ ([9], p. 10)

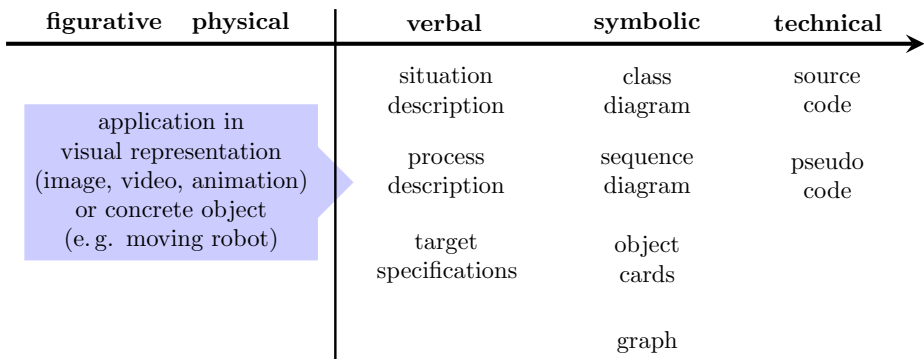


Fig. 1. Various forms of representation in informatics and their increasing levels of abstraction (based on [9], p. 2)

Bilingual lessons designed on the foundations of this approach will exhibit a constant (and usually progressive) shift in abstraction levels with regard to how facts are dealt with in class (cf. [9], p. 11): *The starting point* is usually a *physical* representation of a piece of content (e.g. through a concrete object, an experiment, or actions). → *In a second step*, the teacher or his students ‘translate’ this item into a *figurative* form of representation (such as an image, a pictogram, a schematic drawing, etc.) → *with the aim* of providing a precise (written or oral) *verbal* description . → *This description* then serves as a basis for a *symbolic* form of representation (object diagrams, Nassi-Shneiderman diagrams, graphs, etc.) → *before* it is eventually transposed into a *mathematical/formula-based* form of representation.

This model contains *all* major aspects of a bilingual teaching methodology: content learning, language learning, and foreign language learning. The foreign language serves as a *language of learning*, *language for learning*, and *language through learning* (cf. [3], p. 36) which is in line with the Content and Language Integrated Learning (CLIL) approach to bilingual education (cf. Ibid).

Informatics as a school subject is ideally suited for the approach just described. This is largely owed to the core element of informatics education: modeling. Curriculum

⁴ Translated from the German: “Es ist grundlegend für die Sachfächer, dass sie die Sachverhalte [...] in verschiedenen Darstellungsformen darstellen [...]. Diese liegen auf Ebenen unterschiedlicher Abstraktion. [...] Der Wechsel [...] erweist sich als der didaktische Schlüssel zum fachlichen Verstehen und ist ein Anlass zur fachlichen Kommunikation. Es ist didaktisch klug, [...] diesen Wechsel der Darstellungsformen in das Zentrum der Didaktik des bilingualen Sachfachunterrichts zu stellen” (Ibid)

experts agree that modeling is so essential (because it is key in gaining informatics literacy) that it must not be omitted from informatics education in schools. In fact, it should be omnipresent as its very foundation (cf. [15]).

No matter what the content of a specific lesson, the underlying progression is therefore always similar:

- (1) Starting out from a real-world problem/phenomenon
- (2) students follow various modeling steps
- (3) to create an informatics system that solves the problem under consideration.

Hence, modeling is the very link between real-world and informatics systems. This is particularly evident in lesson series on *object-oriented programming* or *finite-state machines*, which commonly follow the three-phase process laid out above.

But from a scientific perspective *modeling* is nothing other than a change of representation forms. One might thus argue that a “change of representation forms” is a fundamental informatic principle per se – whereas it may be a mere approach to teaching in other subjects. Against this background, Fig. 1 suggests itself as the *informatics version* of the process diagram published in [9]. The diagram shows various forms of representation in connection with their levels of abstraction.

Two aspects of this diagram require further attention:

1. From the “verbal” abstraction level onward there are only explicitly computer-scientific forms of representation. These are well-known concepts in informatics anyway.
2. It is not necessary for learners to always start at the lowest level of abstraction. Once learners have gotten used to how real-world situations can be adequately described via language, teachers can slightly neglect lower levels and supply a *verbal* representation as the starting point – possibly with some kind of visual support. However, one should keep in mind that the translation from a figurative form of representation into a verbal one is modeling as well.

3 Ideas for teaching

3.1 Object diagrams

The following is an English translation of a (previously German) *situation description* from [1]. It might serve as the starting point for a lesson on object-oriented modeling.

“Bookworm” – An Online Bookstore

“Bookworm” currently has a special offer on three books:

- “Lord of the Rings”, author: J. R. R. Tolkien, ISBN: 978-0261102385, price: \$32.50
- “Angels & Demons”, author: Dan Brown, ISBN: 978-0552150736, price: \$6.45
- “Objects First with Java”, author: David J. Barnes, ISBN: 978-0132835541, price: \$40

There are 10 remaining copies of “Lord of the Rings”, 4 remaining copies of “Angels & Demons”, and 7 copies left of “Objects First with Java”.

Martin and Stephanie each have an account with “Bookworm”. Martin’s account number is 123-45A-X23 and his account balance is \$300. Stephanie’s account balance is \$125. Her account number is 123-45A-X25.

The basic idea is to provide students with the textual description and instruct them to use *Abbott’s approach*⁵ (a reduced variant is known as the *subject-verb method*) in order to elicit objects (including potential attributes and their values) from the written input. More advanced students can already go on to compiling their *object cards* into an *object diagram*. Of course, a teacher might want to acquaint his students with both *Abbott’s approach* and the above *situation description* at the same time. But for now let us just assume that the learners under consideration are well-acquainted with the technique. With prior experience, students might arrive at a model similar to the one depicted in Fig. 2.

The goal behind using *Abbott’s approach* in teaching is for students to transform verbal forms of representation into symbolic ones as they match word classes to items in an object-oriented model (cf. 2). This happens as they perform an analysis of word classes on an informal written description. Against the background of bilingual education, this process seems particularly promising:

- Textual descriptions use natural language. Consequently, students should understand them via the basic communication skills and knowledge acquired in their “English as a foreign language” classes. There is no need for additional, subject-specific language instruction.
- *Abbott’s approach* helps to integrate content and language learning. As students transform textual descriptions into *object diagrams*, they need to acquire and use computer-scientific language. Terms such as “object”, “attribute” and “attribute value” are so similar to their German equivalents that there is a high likelihood of positive transfer between the students’ L1 and L2.

⁵ The *subject-verb-method* involves developing a conceptual (object-oriented) model from a textual description in natural language. It focuses on “the use of nouns and noun phrases as references in natural language [...]. Proper nouns and references suggest objects.” (cf. [2]). At a later point, it attends to verbs (usually in a more elaborate *process description*), which yield potential methods (cf. *ibid*).

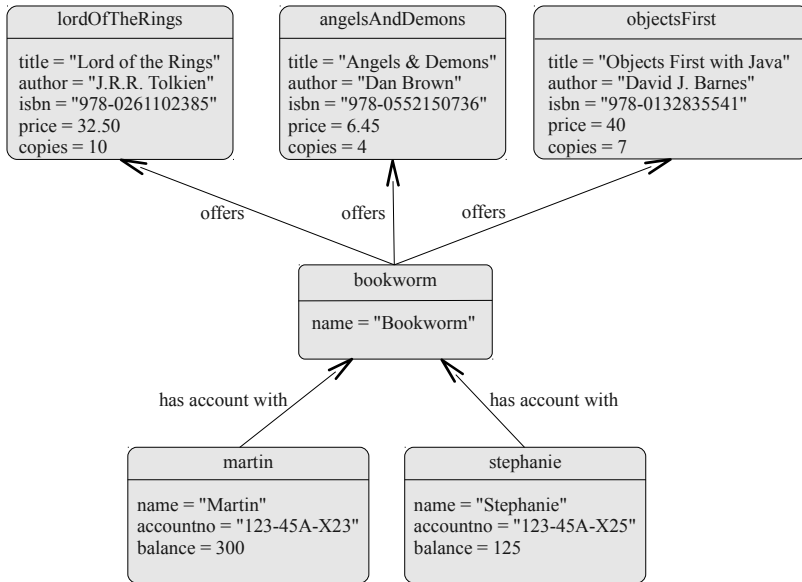


Fig. 2. A possible *object diagram* derived from the situation description (as suggested in [1]).

- *Abbott’s approach* is helpful to extract objects from written descriptions (especially since there are few other techniques to facilitate this process), but it is certainly far from being a formal method (cf. [4], ch. 4). This is mainly because real-life situations (or rather descriptions thereof) are usually much more complex than is permissible for the approach. There is often a plethora of different, but valid models for one and the same textual description. Instead of posing a problem, this is actually an advantage for bilingual classrooms: models thus derived are an opportunity for classroom discussion involving general as well as subject-specific language.

3.2 Lego Mindstorms NXT robots with Java

The task below is from the beginning of my lesson series on Lego NXT robot control via Java. It is part of a worksheet I have successfully used in 9th grade informatics classes. As a prerequisite, students must be acquainted with the basics of operating systems and standard applications (such as directory structures and opening/saving files). For step 1 of the task I usually set up an NXT brick with a small program which makes it travel 30cm in a straight line and then perform a right-angle turn.

Travel and turn

Robots cannot (yet) do everything humans can do. But they are pretty good (i.e. fast, accurate, and they do not get tired!) at carrying out repetitive actions. Let us take a look at some of the basic actions robots can perform.

1. Observe your teacher's NXT robot. Take exact notes about the actions it carries out.
2. Download `example.zip` and unpack it. Open the project using *BlueJ*.
3. Double-click the `MoveShape` class and look at the source code. Try to figure out which of the commands have made the robot do what it did. – Then upload the program and try it on your own robot.
4. Alter the program so that your NXT robot will travel 50cm instead of just 30.
5. Make your robot travel a square with a *diagonal* of 30cm. Then make your robot travel a triangle with a *side length* of 30cm.

The relevant part of the source code from `example.zip` looks like this:

```
1  public void go ()
2  {
3      //These commands tell your robot what to do:
4      gear.travel(300);
5      gear.rotate(90);
6  }
```

As far as the bilingual teaching model laid out in this paper is concerned, the most interesting aspect is that students must change between forms of representation numerous times to complete the steps above. They start out by observing a real *model* and have to describe its actions in standard *written language*. Then they move on to drawing connections between their observations/descriptions and the *source code* handed out to them. One might, of course, also provide another intermediate layer in the form of a Nassi-Shneiderman diagram for the robot's actions before moving on to the source code. However, my observations from the classroom suggest that this is not necessary. As a last step, students must *write their own source code* by making slight alterations to the code provided. In subsequent lessons I then continue with the same approach and quickly extend the set of Java commands my students analyze and use to include if-statements and loop constructs.

Furthermore, it is not difficult to add an ethical (and possibly also cultural) dimension: For instance, I usually have my students reflect on potential dangers the initial program might pose if their NXT robot was an industrial robot that weighs several tons. Without much difficulty, my students arrive at the conclusion that there are no safety mechanisms so far and that any unfortunate person happening to cross the robot's path would suffer severe injuries. Hence my students develop an intrinsic understanding of why sensors are crucial elements of robots and how they could affect a robot's behavior.

The same can be done if one puts emphasis on the effects simple robots (might) have had on the labor market.

Scholars in the area of bilingual education have been regarding such cross-references as particularly beneficial. This is not only because they provide ample opportunity for discussion, but also because they provide an opportunity for students to gain a broader perspective on subject-related aspects with regard to their cultural and ethical implications. A well-designed task should consequently contain potential for both, an ethical/cultural perspective *and* insights into new subject-specific content.

4 Conclusion and the Role of L2 Competence

This paper has laid out in English the major points I already made in German language in [11] and [12] about informatics classes in bilingual education. In addition, it provided support for its main argument from teaching methodologies in the natural science subjects and introduced new teaching materials in the context of robotics. Although the discussion in this paper is yet far from being a full-fledged theory, it does indicate that it is a promising idea to include informatics among the range of subjects taught in English.

As laid out in section 1.3, there is reason to believe that including the students' L2 (i.e. English) in teaching informatics to German learners will help to reduce subject-related misconceptions and ease understanding of informatic concepts. This can be aptly illustrated by Fig. 3, which was inspired by a diagram proposed by Schubnel depicting the contribution of L2 competence to bilingual education in mathematics ([14], p. 33). The idea behind this is that the students' L2 (English) can serve as a crutch (in addition to their L1!) in understanding subject content. In other words, it serves the purpose of providing a second column on which informatic competence can build up and rest, since learning in informatics necessarily takes place through natural language. Furthermore, the L2 at hand is the language of almost any workplace in the field of informatics.

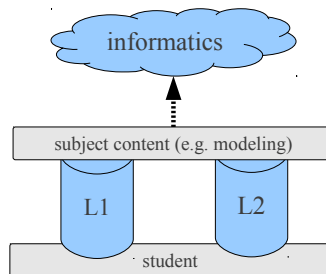


Fig. 3. Supposed role of L2 in bilingual informatics education

However, there are at least two major problems: Most German informatics teachers quite naturally lack C2⁶ (or at least C1) qualification in English, whereas most teachers of English as a foreign language lack informatics literacy. Moreover, with most of the assumptions in this paper about the beneficial effects of high L2 competence being based on mathematics and the natural sciences, scholarly research into the true contribution of L2 competence to understanding in *informatics* is a crucial next step.

References

1. Arbeiter, T.: Objektorientierte Modellierung und ihre Umsetzung inklusive Prüfung der erreichten Kompetenzen. Hausarbeit gemäß OVP, Studienseminar für Lehrämter an Schulen – Seminar für das Lehramt für Gymnasien und Gesamtschulen, Arnshausen (2008)
2. Boyd, N.: Using Natural Language in Software Development. <http://www.educery.com/papers/rhetoric/road/> (last checked 1/31/2013)
3. Coyle, D., Hood, P., Marsh, D.: CLIL. Content and Language Integrated Learning. Cambridge University Press, 3rd, 2011 edn. (2010)
4. Graham, I., Wills, A.: UML Tutorial. <http://uml-tutorials.ti-reme.com/> (last checked 1/31/2013) (2001)
5. Gramm, A.: Entwurf eines bilingualen Sachfachunterrichts Informatik (2002), http://andreasgramm.de/papers/Gramm_Bilingualer_Sachfachunterricht_Informatik.pdf (last checked 1/31/2013)
6. Hallet, W.: Bilingualer Unterricht: Fremdsprachig denken, lernen und handeln. Der fremdsprachliche Unterricht Englisch 78, 2–8 (2005)
7. Humbert, L.: Didaktik der Informatik – mit praxiserprobtem Unterrichtsmaterial. Leitfäden der Informatik, B.G. Teubner Verlag, Wiesbaden, 2nd edn. (August 2006), <http://humbert.in.hagen.de/ddi/> (last checked 1/31/2013)
8. Kultusministerkonferenz: Einheitliche Prüfungsanforderungen Informatik (1989, idF von 2004)
9. Leisen, J.: Wechsel der Darstellungsformen. Ein Unterrichtsprinzip für alle Fächer. Der fremdsprachliche Unterricht Englisch 78, 9–11 (2005)
10. Ministerium für Schule und Weiterbildung NRW: Das Schulwesen in Nordrhein-Westfalen aus quantitativer Sicht 2010/11. Statistische Übersicht 373 (2011)
11. Reinertz, M., Humbert, L.: Bilingualer Informatikunterricht. In: Thomas, M., Weigend, M. (eds.) Ideen und Modelle. 5. Münsteraner Workshop zur Schulinformatics (2012)
12. Reinertz, M., Humbert, L.: Informatik bilingual. In: Hallet, W., Königs, F.G. (eds.) Handbuch Bilingualer Unterricht/Content and Language Integrated Learning. Klett/Kallmeyer (2012)
13. Richter, R., Zimmermann, M.: Biology. Und es geht doch: Naturwissenschaftlicher Unterricht auf Englisch. In: Wildhage, M., Otten, E. (eds.) Praxis des bilingualen Unterrichts. Cornelsen Scriptor, 3rd edn. (2009)
14. Schubnel, Y.: Bilingualer Mathematikunterricht. Ein Beitrag zu einem zusammenwachsenden Europa. Ph.D. thesis, Pädagogische Hochschule Freiburg (2009)
15. Thomas, M.: Informatische Modellbildung – Modellieren von Modellen als ein zentrales Element der Informatik für den allgemeinbildenden Schulunterricht. Dissertation, Universität Potsdam, Didaktik der Informatik (2002), http://ddi.cs.uni-potsdam.de/Personen/marco/Informatische_Modellbildung_Thomas_2002.pdf (last checked 1/31/2013)

⁶ The term C2 refers to the highest possible competence level (“mastery or proficiency”) in a language as defined in the Common European Framework of Reference for Languages. C1 level is slightly below C2.