Content and Language Integrated Learning in Physics Teaching: Benefits, Risks, Requirements and Empirical Studies

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1. Introduction

Content and Language Integrated Learning (CLIL) is a bilingual teaching method, where content area subjects are taught with a foreign language as a medium of instruction while the first-language plays no or only a very subordinate role. This concept was introduced by the Ministry of Education in Austria in the mid 1990. The two major aims followed by CLIL were first to improve foreign language education, as the output of language teaching showed deficits in communicative competence, and secondly to deepen intercultural learning.

The core idea was CLIL being a flexible concept compared to conventional bilingual school programmes. It can be used in all non language subjects in all school forms on secondary level and its intensity can range from teaching isolated topics in one subject to courses lasting for a school year in one or more subjects.

During the last decade Content and Language Integrated Learning (CLIL) has become quite popular in German speaking countries. An increasing number of schools are offering programs which are based on this bilingual approach in content subjects. However, this trend is not equally true for science subjects, especially not for Physics. Science teachers seem to be quite concerned how their students’ subject achievement and motivation are influenced by the use of a foreign language as a medium of instruction. This contribution gives a short overview on research done on CLIL so far. The main part focuses on two studies investigating the effects of language integrated Physics lessons on several levels.

2. Benefits and Risks connected with the CLIL Method

When discussing benefits and risks connected to CLIL there are two different domains which have to be considered: the aspect of second-language learning and that of content learning.

As far as students’ achievement in second-language learning is concerned, quite a number of studies have proved that CLIL offers linguistic advantages. Positive effects on language learning already known from Canadian Immersion programmes were also confirmed in several investigations of CLIL.

Compared to conventionally instructed students CLIL students are significantly more competent in their second-language. They are more fluent and possess a significantly larger active and passive range of vocabulary. Grammar, however, is not significantly influenced by CLIL. As far as pronunciation is concerned, students’ achievement depends
on the availability of a native speaker, which echoes a known effect of second-language teaching in general.\(^3\)

Accuracy, on the other hand, is controversially discussed. There are concerns that non-native teachers with low qualifications in the second-language might have negative impact on students’ accuracy and might hinder their foreign language development in general. There is no empirical evidence for this concern, as there are simply no investigations which test and relate CLIL teachers’ foreign language abilities and those of their students.

When focusing on subject specific aspects linked to CLIL, three controversially discussed issues can be highlighted. The first is the influence of CLIL on subject related motivation. Frequently CLIL is said to have a potential to increase students’ motivation. Another line of argumentation, however, states that especially weak students or students not interested in languages might get frustrated by the CLIL approach.

Secondly, CLIL might also contribute to a deeper subject understanding due to deeper information processing.\(^4\) It cannot be denied that CLIL lessons are cognitively more demanding than native language instruction. Especially due to the additional code system of the second-language information processing is slowed down. Therefore special teaching strategies and methods are required, which for instance support a recurrent treatment of the core issues of a topic.

Thirdly, CLIL might facilitate the acquirement of solid scientific concepts. The use of a second-language may reduce the risk of mixing up everyday concepts with scientific concepts linked to the same term.\(^5\) When little children acquire their first-language they learn to match words with concepts acquired through everyday experience. When students are instructed in Physics it is very difficult for them to add an extra scientific meaning to an already familiar term. The resulting confusion of scientific and everyday concepts often leads to inadequate ideas about physical phenomena. CLIL, however, makes it easier to acquire scientific concepts since there usually is no temporal gap between the acquisition of a term and the matching scientific concept.

Beliefs of current teaching practice rather than empirically proved arguments were the basis for this collection of ideas concerning the effectiveness of CLIL in the field of content learning. What we know from research shows a different picture. Although several evaluations classify CLIL as successful on the level of content-achievement, a closer examination of these results reveals weak spots. On the one hand the comparison of grades or examination papers of CLIL and non CLIL students, or mere teacher reflection served in the majority of cases as indicators for student’s content-achievement. On the other hand most investigations were carried out in subjects like History or Geography, since these are the subjects most frequently using a language integrated approach.\(^6\) So the question arises whether these results can be replicated with standardized knowledge tests or concept inventories and second, whether they can be transferred between two subject (e.g. History and Physics) being rooted in different epistemological traditions and subject cultures.

\(^1\) The predicate successful is used here for content achievement that ranks at least as high as achievement by students instructed in their first-language.
3. **Requirements for a good CLIL Practice**

The guidelines for a good practice of content and language integrated teaching mainly originate from teaching experience and didactical knowledge about second-language learning. Focusing on teacher related aspects of teaching, some of the most prominent factors are discussed in this section.

A main factor for successful content and language integrated teaching is teacher qualification. Teacher qualification does not only entail a certain level of proficiency in the second-language, but also knowledge about the basic mechanisms of second-language learning and instructional requirements associated with students’ needs in language integrated learning environments. As already mentioned, CLIL students are clearly subjected to higher cognitive demands. Therefore CLIL teachers must have a large methodological repertoire to meet their students’ needs. There are several basic scaffolding strategies teachers need to be familiar with7–9:

- **Comprehensible input**: Additional non verbal representations and input on different sensory channels at the same time.
- **Bridging / Prompting strategies**: Prevent the breakdown of communication, when students are struggling with what they want to say.
- **Code switching**: Keeping the first-language to a reasonable limit.
- **Language support**: Provide lexis and basic language functions relevant for the topic treated.

These scaffolding strategies are predominantly from language teaching. Additionally, CLIL lessons should be informed by the following general didactic principles:

- **Alternating levels of abstraction / representation**
- **Activity based, student centred lesson designs**
- **Communicative instead of instructive teaching**

4. **Empirical Studies in the field of Physics**

The summary of current research has shown (see above) that little is known about the effects of CLIL on students’ content-achievement in Physics. The same is true for the development of motivation in Physics classes instructed with a second-language. In the following section two empirical studies dealing with these issues are presented: The development of individual motivation during CLIL phases in Physics lessons was evaluated in a case study named “Energy Crisis & Solar Power”. In addition a field study focusing on the content-achievement of students in introductory magnetism was carried out in the course of a PhD project10.

4a. **Effects on Motivation and Interest**

The case study “Energy Crisis & Solar Power” was done in the course of a cooperative teaching project, where Physics and English lessons were taught coordinated in Year 11 (N=27) of an Austrian High School. During the four months of this project, topics like the nature of light, the electromagnetic spectrum, semiconductors, solar power, greenhouse effect etc. were treated in Physics lessons. Coordinated English lessons were used to provide language support and to treat environmental issues related to the energy topic. For evaluation we used mixed methods, administering pre and post questionnaires, and interviews as well as lessons videos.
RESULTS

The impact of CLIL on individual student’s motivation was evaluated by pre and post questionnaires using items from the IPN survey on interest. For motivation we used five items with rating scales. The maximum absolute score for motivation was 25, the minimum score 5. The bar graph below (see picture 1) provides a good overview of changes in individual motivation within the four months of the project. The code for each student taking part in the project can be seen on the horizontal axis. The last letter contains information on the participant’s sex (w=female, m=male). The vertical axis shows the fall or rise of motivation during the project. The motivational gain was calculated based on pre and post results. One interesting trend can be spotted, when looking at those students with the highest gains and losses in motivation. In both cases they are predominantly girls.

![Picture 1: The development of motivation for the subject Physics during the project (pre scores minus post scores)]

Pre-test scores served as indicator for student’s (motivational) preferences for either the subject Physics or English. Each student’s motivational profile was compared with his motivational development in the subject Physics during the project. For those cases with a considerable decrease in motivation during the project no correlation could be found to their motivational bias. So, additional interviews were made to reveal motives behind these drops. Two participants blamed either the CLIL approach or the topic itself for their drop in motivation, the rest named private problems including facing the risk of not finishing the class. Analyzing the results for those students with high motivational gains showed in the majority of cases a correlation to a high motivation in the subject English and a medium to low motivation in Physics.
The relationship between motivation and content-achievement in terms of school grades was also analysed for the subject Physics. The bar diagram (see picture 2) relates grades ranging from 1 (=best mark) to 5 (=fail) with the scores achieved in the items on motivation. There is hardly any difference in the motivation score of high achievers (1=best mark) and low achievers who passed Physics (4=pass). So the frequently articulated hypothesis that CLIL necessarily frustrates weak students could not be confirmed. Those who did not pass Physics in the first term showed, however, low motivation. From interviews we know that this group consisted of students with serious problems in several subjects and thus being in general danger of not passing this class. They showed a generally low motivation for school related issues.

b) Effects on Content Knowledge in Magnetism

The main research questions of the field study “Introduction into Magnetism” focused on effects of CLIL on content-achievement, gender performance and lesson communication. The investigation was based on a pre and post-test design, with test and control group. The population consisted of 205 Year 11 students from 6 different Austrian High Schools. The 11 classes selected did not have any experience with CLIL. 78 students were instructed in their first-language (control group) and 127 in English as working language (test group).

For the treatment an instructional arrangement of four lessons\(^2\) on introductory magnetism was developed based on methodological guidelines for CLIL mentioned earlier. To provide quite similar conditions for all groups and to minimize the influence of variables like teaching methods, teaching style etc. teachers were equipped with a detailed lesson script including didactical, methodical and content related guidelines. The instructional setting, except the language of instruction, was identical for test and control group.

Students’ content knowledge in the field of magnetism was measured with assessment tools developed for this study. The knowledge test consisted of 21 items (6 scales) in the pre-test version (\(\alpha=.716\)) and of 27 items (8 scales) in the post-test version (\(\alpha=.775\)). Non cognitive items of the test focused on lesson communication and on personal data. All tests were administered for both groups in their first-language, the pre-test at the beginning of the first lesson of the treatment, the post-test after the last lesson.

\(^2\) In the Austrian educational system a lesson last 50 minutes.
RESULTS

A frequently used argument against CLIL is that it is supposed to influence lesson communication and thus content learning negatively. Students were asked to evaluate the effects CLIL had on the lesson communication in the module on introductory magnetism. As picture 3 shows, the majority experienced a balance between positive and negative effects, although these students had not had any CLIL experience before. For less than 20% negative effects prevailed. Nearly a quarter of the students had the impression that CLIL influenced the classroom communication in a positive way.

![Bar chart showing lesson communication effects caused by CLIL](image)

**Picture 3: Effects on lesson communication caused by CLIL**

These outcomes go along investigations in other school subjects. Some authors\textsuperscript{5,4} even draw the conclusion that language difficulties might be an opportunity for fostering subject understanding. According to them language difficulties are often – even in the first-language – just symptoms for general problems in understanding. In first-language lesson set ups these problems usually remain under the surface. A second-language, however, provides the necessity for additional phases of intense negotiation of meaning which can support conceptual understanding.

Besides lesson communication, the influence of CLIL on content-achievement is another controversially discussed issue. In this study the subject related performance of both groups was analyzed in two categories; students’ self evaluation was checked and measurements were taken by a knowledge test.

In both categories the test and control group showed no significant differences at the pretest stage. According to the comparison of pre and post-test data the subjective learning effects due to the treatment were evaluated as moderate by the test group (d=0.7) and as big by the control group (d=0.81).

The average number of correctly solved items in the post knowledge test is similar for both groups (see picture 4). Statistical analysis also proves, that there is no significant difference between test and control group. Learning effects achieved by the treatment are medium for both languages of instruction (\(d_{\text{treatment group}}=0.602; d_{\text{control group}}=0.640\)).
The gender analyses of the knowledge test shows again the well known effect, that male students achieve significantly better results than female students. Achievement gains in the post-test showed a small advantage for female students of both groups. This trend could, however, not be confirmed by further statistical analysis. The analysis of covariances revealed that there is no significant difference in learning success between male and female students of both groups, when differences due to prior knowledge are taken into consideration.

5. Conclusion

Research on the influence of CLIL on content-achievement is at the very beginning, while language learning advantages are already empirically proved. The two studies presented in this paper may be seen as a first step. The case study “Energy Crises & Solar Power” showed that CLIL positively influenced the motivation of female students with generally medium to low motivation for Physics. For the population of this case study the hypothesis that CLIL leads to a fall in motivation especially of low achievers in Physics could not be confirmed. It, however, is still left open weather the shown development of motivation can also be shown for a bigger population and independent from the topic chosen for instruction.

The field study on magnetism shows that CLIL can be as successful as instruction in the first-language in terms of content-achievement. Although the test group did not have any experiences with CLIL before, they did equally well in the knowledge test. However, these results cannot be generalized for the effect of CLIL on content-achievement in Physics, since they were achieve in a certain age group and with a certain topic.

As far as gender is concerned in both studies male students are again superior in terms of content-achievement. On the other hand, the relative gain in content knowledge is rather equally distributed among sexes. This might be a hint that CLIL can provide a learning environment quite equivalent in terms of gender.

In conclusion it can be said that the studies presented show, that CLIL might have the potential to contribute to a better content understanding and to motivate especially students motivated in languages rather than in Physics. However, more studies investigating different topics and different populations are necessary.


5. A. Bonnet, *Chemie im bilingualen Unterricht* (Leske und Budrich, Opladen, 2004).


