MIND THE GAP: HOW (OR HOW NOT) IS INQUIRY-BASED LEARNING INTEGRATED IN GERMAN BIOLOGY SCHOOL LESSONS?

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Abstract

International and national educational standards emphasise the importance to teach knowledge of basic scientific skills as well as teaching of scientific literacy. Several European projects propose that inquiry-based learning (IBL) can be a key method to reach these goals. In Germany, however, IBL is lacking as an integral part of biology school lessons. With the purpose of finding reasons of why IBL may be such a rarity we conducted a systematically conceptual review of literature.

We found no articles that deal empirically with the problem of why IBL is not used in German biology classes. The majority of articles concerns teaching material and research about IBL in the context of promoting competences. Consequently, we suggest that research is needed which illustrates possible reasons of why IBL is not implemented in the first place.

Keywords: inquiry learning, biology, Germany, teaching material

Introduction

International and national educational standards stress the significance of teaching scientific knowledge, such as basic scientific skills and basic knowledge of what science is and how it works (e.g. KMK 2004, NRC 1996). Promotion of scientific knowledge is an important part of general education because scientific literacy as well as scientific inquiry techniques provide students with skills important for self-dependent learning, choosing an academic career, and to participate in a democratic society (Bell, Urhahne, Schanze, & Ploetzner, 2010); reasons, which might especially be true for biology classes (Dittmer, 2010). Although discussed controversially (Hmelo-Silver, Duncan, & Chinn, 2007; Kirschner, Sweller, & Clark, 2006), inquiry-based learning has been proposed as a good means to provide students with such knowledge and skills, since students are supposed to actively use the same methods as scientists do and thus learn about scientific thinking and working processes (Abd-El-Khalick et al., 2004; Wichmann & Leutner, 2009).

However, as stated in PISA

> *"Experiments are an essential part of scientific school lessons; however, experiments are mainly of a presentational character. Student centred activities as required by IBL are rarely implemented in school lessons."*[1] ***(Prenzel, 2008)***

and supported by S-Team (2010), inquiry-based learning methods are still a rarity in classrooms, including Germany (Bohl, 2002; Hage et al., 1985; Meyer, Pfiffner, & Walter, 2007).

Although inquiry-based learning is scarce in German classrooms, not very much is known about the reasons for this circumstance. The preliminary S-Team report (2010) states that in Germany a "lack of support for teachers to adopt and develop the required teaching style" as well as "overcrowded curricula as a barrier to introducing inquiry-based methods" might be reasons that prevent

[1] correspondingly translated by first author

dissemination of inquiry-based teaching. However, several other reasons may apply as well, to which we refer as internal and external factors. Internal factors include issues that can be attributed to the teacher himself such as teachers' beliefs and attitudes towards IBL (Brown & Melear, 2006; Johnson 2006), anxiousness, and insufficient self-assurance of teachers (Aepkers & Liebig, 2002). External issues include factors of which teachers are not in control of, such as school ethos (Rutter, 1980), lack of time (45 min schedule for lessons) or insufficient infrastructure such as school laboratories or materials like test-tubes and petri dishes. Although these reasons are plausible and discussed in literature (Bohl, 2000), we are not aware of studies which empirically investigate whether there is a link between internal and external aspects and the lack of implementation of IBL in classrooms. However, establishing such a link would be an important factor to further the dissemination of IBL in German classrooms.

Therefore, we like to give a critical review about research in the context of inquiry-based learning in biology classes in Germany by conducting a systematically conceptual review as proposed by Amundsen and Wilson (2012). Our purpose is to i) find literature that deal with possible reasons of why inquiry learning may be such a rarity in biology class lessons and ii) name knowledge gaps which may propose additional fields of research.

Methods

We conducted a systematically conceptual review as proposed by Amundsen and Wilson (2012). As keywords for our search we used *inquiring (forschend), inquiry learning (forschendes Lernen), biology (Biologie), biology lesson (Biologieunterricht), Germany (Deutschland),* and *teaching material (Unterrichtsmaterial)*. In brackets the German translations are given. Within the search masks of the databases all keywords were used in different combinations (e.g. *inquiry* as keyword in the section 'general' or as keyword in the field 'title').

Search process

For the search process we followed multiple steps:

a) We searched four databases (Fachportal Paedagogik, DIPF, Lehrer-Online, Eric) from 01.01.2012 to 15.04.2012 using the keywords as mentioned above.
b) Additionally, we identified the most recent proceedings of conferences related to science & education in general (ESERA[2] 2009 & 2011), and biology education in particular (ERIDOB[3] 2008 and 2010 & FdDB[4] 2009 and 2011). Proceedings are a good source, since they often cover the latest research in very different contexts, including inquiry-based learning methods.
c) The search of databases and proceedings left us with a total of 113 articles, including all levels of education, sciences and mathematics, and duplicates.
d) Therefore, we finally refined our results by using the keywords again in order to select only articles dealing with inquiry learning in biology classes of secondary schools in Germany. Finally, we removed all duplicates. This final search left us with a total of 42 articles.

[2] European Science Education Research Association
[3] Conference of European Researchers in Didactics of Biology
[4] Internationale Tagung der Fachsektion Didaktik der Biologie im VBio

Categorisation

All 42 articles were read and assigned to different categories depending on their research question or the journal they were published in. Thereby, all articles could thematically be confined to one of the following categories: (1) Teaching material when published in journals such as *Praxis der Naturwissenschaften* or *Unterricht Biologie*[5], (2) promotion of competences, (3) learning success, and (4) school practice. A more detailed description is given in table 1. The categorisation was done by the first and second author of this paper. Some papers found during the search might appear in several categories when they investigated multiple research questions simultaneously.

Results

Interestingly, most studies were related to teaching material and promotion of competences. Three articles dealt with IBL in the context of learning success. The only study that considers the implementation of IBL in classrooms is part of a European project called COMPASS, in which the main focus is to

> *"evolve the teachers' thinking about teaching and learning mathematics and science as well as to improve the range and quality of their teaching behaviours by developing teaching and learning methods"* ***(Wilbers, Mikelskis-Seifert, Maaß, & Oettlin, 2011)****.*

Although this project is not directly addressed to biology, we thought it worth mentioning since it was the only article we were able to find with our search process. A summarised example for each category is given below.

Table 1: Categories and their descriptions summarising main characteristics of articles assigned to these categories

Teaching material (n=27)
• mostly consist of a classical format including factual information, intended teaching & learning process, and teaching material (e.g. masters & sample solution) • provide teachers with only rudimentary knowledge of how to design the intended inquiry based lesson • mostly practical for experienced teachers, which are already familiar to inquiry learning
Promotion of competences of pupils and students (n=14)
• emphasis on the scientific way of knowledge gain, including tasks such as asking scientific questions, generating hypothesis, and planning experiments • comparisons of IBL and other teaching methods (mostly teacher centered teaching) with a classic pre-post-test design
Learning success (n=3)
• effects of inquiry learning in different contexts, e.g. whether there is a trade-off between knowledge and competence gain or whether inquiry learning is detrimental to slow learners • comparison between inquiry learning and other teaching methods in the context of knowledge gain
School practice (n=1)
• implementation of inquiry learning in learning and teaching behaviour

[5] these are journals which exclusively publish teaching material

Summarised example for each category

Teaching material

Krämer, van de Sand, Schlüter, & Nessler (2012) describe a lesson dealing with nutrition of whales and other sea mammals. The teaching material is divided in two parts: Part I gives general information about basics of feeding, including different energy sources, predator-prey interactions and feeding strategies, followed by specific examples of different feeding strategies of whales, sea otters and others. Part I finishes with information about food webs in a marine habitat. In part II the authors give a broad outline of an inquiry-based lesson concerning feeding strategies of whales and a food web in the ecosystem "North Pacific". The material does not contain any information about time schedules or problems that might occur during the lessons, such as how to deal with hypotheses of pupils. Thus, the material is addressed to more experienced teachers already familiar with this method.

Promotion of competences of pupils and students

In a study of Hof (2011), the author investigated the development of inquiry skills, such as formulating questions and generating hypotheses by using an intervention study with a pre-post-follow-up testing design. Participating pupils (secondary school, 12-13 year old) were assigned to three different groups: i) treatment I – open inquiry (n=129), ii) treatment II – guided inquiry (n=80), and iii) control group (method of development by questions; n=42). The authors found a significant increase in the development of competences in treatment group I and II, but not in the control group.

Learning success

Larsen & Bogner (2011) presented a research project at the conference FdDB, in which they investigated learning success in dependence of various kinds of structural instructions. They argue that on the one hand open inquiry lessons are too challenging for pupils and thereby reduce the learning outcome, but on the other hand guided material might reduce the enquiring mind; an outcome that is undesired as well. Thus, they designed a learning circle dealing with the topic of renewable resources with two different types of instructions: The intervention group in this study is confronted with hands-on activities without any specific instructions, thereby resembling open inquiry-based learning. In a second treatment group pupils were assigned to different roles, such as reader or inspector, with specific instructions. The aim of this study is to compare the learning success with a pre-post-follow-up testing design. The research project was done with pupils of a 'Hauptschule' (secondary school, age 14-15 year old). Results are not shown in the proceedings paper, since the analysis has not been finished yet.

School practice

The focus of the project described by Wilbers et al. (2011) is on the implementation of IBL in German school practice. The project is part of the European venture COMPASS with the aim of developing, testing, and evaluating teaching materials for IBL as well as giving teachers advice for the use of IBL in class rooms. In a pre-post-test design the material designed is evaluated by using questionnaires discerning different aspects such as i) beliefs concerning teaching and learning and ii) perceptions of teaching activities before and after using the teaching material. All in all the researchers found that the "materials were well received by the participating teacher" and teachers reported a positive

impact on their teaching. The students' perceptions of teaching activities, however, mainly changed for mathematics, but not for the sciences.

Discussion

The purpose of this study was to evaluate the current state of research concerning the question of how (or how not) inquiry-based learning is implemented in German biology class lessons. As expected, our search suggests that investigations in this field of research are scarce. We found no articles asking directly why IBL is not used in biology classes. On the other hand, we found several articles which represent teaching material and the promotion of competences. The latter point is most likely a consequence of a shift from input oriented to competency oriented learning in Germany (Nentwig & Schanze, 2007). Given that IBL is proposed as the preferred means to promote scientific working skills (Rocard et al. 2007), it seems reasonable to investigate whether this method is suited to reach these aims in biology classes.

However, regarding our results and given that IBL is not very common in German biology classes (Prenzel 2008), we think that this line of research should be complimented by studies that analyse possible reasons of why IBL is not implemented in biology classes. For instance, future research should examine the impact of teacher's beliefs and attitudes towards IBL on the use of this method in their classrooms. This would be an important aspect since we believe that only convinced and competent teachers would willingly use IBL in school lessons. Concerning the studies we found, it would be interesting to evaluate whether teachers are more inclined to use IBL if promotion of competences is easier with IBL than with other methods.

Another way to stimulate the use of IBL is specific teaching material which helps teachers to give instructions for IBL based lessons. Although the material we found covers different aspect of IBL, it is mostly addressed to teachers, which are already familiar with this kind of teaching method. Thus, it would be desirable to design material which addresses teachers which are novices to IBL.

We are aware that our online search has its limitations and that we did not reveal all articles available, leaving our results incomplete. Thus, our search could be enlarged by additional sources such as journal homepages; however, we think that by using the most common and popular databases with the keywords in all possible combinations we most likely cover a high percentage of articles accessible. Additionally, we did a keyword scan within the current proceedings of three of the largest conferences for educational science (ESERA) and biology education (ERIDOB & FdDB) in particular, thereby including current research projects.

With the keywords used in this study we did not find any articles concerning teachers' in-service training. However, since this part of education probably plays a central role in the dissemination of IBL as well, it should be added to future research. Finally, we propose that a comparative approach regarding the dissemination of IBL in other countries might be rewarding. Such research could help to detect further problems as well as contribute to solutions to these problems which may apply to Germany as well.

To conclude, we think it is necessary to clarify and resolve problems that prevent the implementation of inquiry-based learning in biology class lessons in the first place by establishing an empirically founded link between internal and external factors. Once the problems are named they can be tackled and thus the dissemination of inquiry-based learning might be improved.

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In order to better assign the literature according to our categories, we arranged the literature to the sections of the paper and the categories as given in table 1, respectively. Some articles may appear twice, when the research cover different categories simultaneously.

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