A Model of Inclusive Chemistry Teaching – Three Steps Towards Inclusive Education

Joachim Kranz, Rüdiger Tiemann
Humboldt-Universität zu Berlin, Chemistry Education Lab, Germany

Abstract

The acquisition of scientific knowledge through problem solving offers the possibility to consider different requirements for inclusive chemistry lessons. We will present and discuss, based on empirical data, a theoretical model that differentiates between low achievers and high performers and, in addition to domain-specific characteristics, considers general criteria for good teaching. The architecture of the "model for inclusive chemistry teaching" (MiC) is designed in a way that teachers can follow the path to inclusive teaching in a fixed, guided sequence of 3 steps. As part of the evaluation of our model for inclusive chemistry teaching (MiC), a learning environment on the topic of "fire & flame" was designed and evaluated [1]. The learning environment includes real experiments, an interactive Multitouch Learning Book and a paper-based workbook. The teaching unit was quantitatively tested (N = 165) with school students at the age of 12 and 13 years from different school types. Questionnaires and video recordings were used to record the perceived fit of the teaching offer with the individual performance of students, supplemented by questionnaires and observation forms from teachers. The results regarding the pre-post analysis showed positive, significant changes for the students' self-assessment regarding the "fire and flame" content knowledge (high school N = 51, primary school (N = 43), comprehensive school (N = 71), 23 items, Expertise pre: α = 0.927, post: α = 0.846, p <.001). We showed that even students with a low interest in natural sciences answered all tasks in the knowledge test at a very high level.

Keywords: *Inclusive Education, Model of inclusive chemistry teaching, Multitouch Learning Book*

1. Introduction

School Education is undergoing a rapid change. Inclusion and education are new and nation-wide accepted framework conditions which demand basic competences in the realisation of an inclusive, digital world in school from teachers [1]. The principle of equal participation of all people in all areas of life goes back to the Salamanca Declaration in 1994, which became legally binding in Germany in 2009 through the ratification of the UN Disability Rights Convention [2,3]. The link between inclusion and digitalisation was formulated by the Conference of Ministers for Education (KMK) in the strategy for "Education in the Digital World" [4] and thus elevated to a new fundamental principle of the German school landscape. The paradigm shifts for teaching from exclusive to inclusive and from analogue to digital are usually considered on their own, but the inclusion process can only be optimized by combining both aspects [5].

The acquisition of scientific knowledge through problem solving offers the possibility to consider different requirements for inclusive chemistry lessons. The theoretical model [6,7,8,9,10] points at lower achievers and higher performers and, in addition to domain-specific characteristics, considers general criteria for good teaching.

2. Model of inclusive teaching

The architecture of the "**m**odel for **i**nclusive **c**hemistry" (MiC) is designed in a way, that teachers can derive concrete, planning-guiding assistance from it. MiC is characterised by three levels: The lowest level is determined by the state through the curricula and their subject-specific requirements. The second level is looking at the individual, taking decisions after diagnoses, which, in addition to the didactic reduction, concern the various approaches.

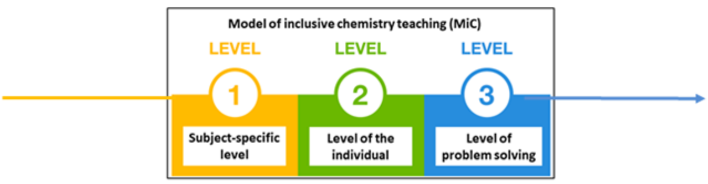

Fig. 1: Three steps of MiC

The third level concerns the decisions regarding the selection and the way of formulating the problem. These levels can be gone through step by step.

Level 1 – level of subject-specific educational goals

The objectives, competences and standards as well as the subject areas and contents were formulated in the curricula. The teachers can select subject areas and contents and make further subject-related preliminary decisions. These introductory statements on level 1 also apply predominantly to traditional teaching. For inclusive teaching, two further premises are style-forming: joint work on the common subject and an open teaching approach.

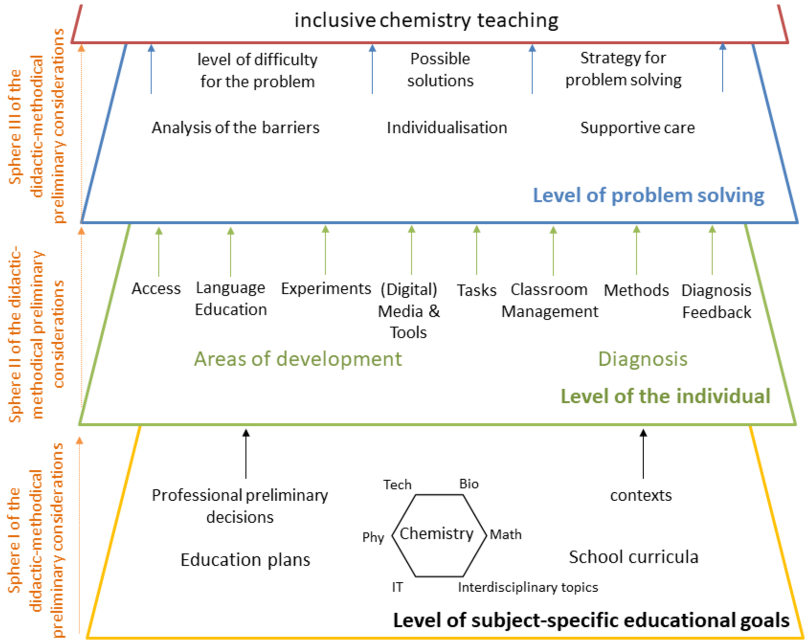

Fig. 2: MiC-Levels

Level 2 – level of the individual

A stronger focus on the individuality of learners in lesson planning is one of the key points of school inclusion and the MiC approach, which is reflected in the 2nd level. The diagnosis of learners in lesson planning includes an analysis of the individual learning status and progress by the teacher, but it goes far beyond this. The other characteristics of the learners, i.e. physical limitations, learning speed, haptic or intellectual learning types, must also be assessed [11]. Diagnosis and feedback also play a role in the implementation of lessons, because it is the teacher's task to keep an eye on the progress of the current acquisition of competences [12]. The “encounter phase” of the lesson can lead to an individual motivation boost for all students through different approaches. Points of contact that involve all senses, including aesthetic or tension-inducing ones, are a characteristic of inclusive teaching. Digital media can support the aforementioned aspects at the level of the individual, e.g. by enabling self-evaluation through learning games and surveys, by deepening and clarifying models and model experiments. Chemistry as an experimental subject requires sophisticated, proactive classroom management in terms of accessibility to the subject rooms, equipment, chemicals and learning aids, as well as an adapted hazard potential [13].

Level 3 – level of problem solving

The high degree of support of the problem-solving process [14], that is necessary in inclusive chemistry lessons, requires an intensive engagement with the formulation and the degree of difficulty of the problem. Due to the traditional problem solving theory, the ability of abstract thinking is often a reason for success or failure. In traditional teaching, the analysis of a problem’s difficulty and the subsequent problem-solving process is rather the exception, but in inclusive teaching it is a fundamental condition for anticipating possible barriers and obstacles on the part of the students, and thus a necessary prerequisite for the conception of learning aids and further support measures. Under the premise of open teaching, it is also important for the teacher to generate problems, that allow multiple solutions and different problem solving strategies.

3. Transfer of the MiC into an inclusive learning environment

As part of the evaluation of a model for inclusive chemistry teaching (MiC), a learning environment on the topic of “fire & flame” was designed [15]. The orchestration of the learning environment with real experiments, an interactive Multitouch Learning Book [16] – a dynamic, web-based platform that allows the instructor to combine e.g. texts, videos or learning games –, and a paper-based “researcher” booklet leads to a realistic design. It takes into account research-based design features for problem solving, motivational aspects, self-regulated learning with digital media, the sequence and type of experiments, and the use of prompts.

Multitouch Learning Books – a forward-looking digital tool on the way to inclusive teaching

Multitouch Learning Books offer the opportunity for new learning formats. Thus, in addition to individualizing learning paths, linear and branched procedures can be designed. Furthermore, learning paths can be supported by assessment or diagnostic tasks, learning games and specific assistance. Multitouch Learning Books are therefore a forward-looking digital building block on the way to inclusive teaching [16].

Many experiments in chemistry lessons require a heat source and as such the gas burner is an indispensable piece of laboratory and working equipment, that all students should be familiar with in the sense of a broad understanding of inclusion up to the intermediate school leaving certificate.

Fig. 3: Multitouch Learning Book with a selection of the icons used, some of them interactive, with QR code (link to the textbook)

In the media-supported learning environment with the interactive Multitouch Learning Book, attention is paid to a balance between instruction and construction. The experiments are suitable to support both, less gifted and highly gifted students, according to their ability, and to initiate corresponding increases in competence.

Fig. 4 illustrates the pronounced interactivity of the digital Multitouch Learning Book for “fire & flame”. The vertical arrows pointing up and down show the clickable icons that provide individual learning pathways. Navigation runs via arrows and icons, the clickable icons lead to different information, animations, video clips and tutorials. They serve to explain and deepen problems, problem-solving strategies and contexts.

The widgets with playfully designed exercises for self-assessment contain feedback on the solution of the tasks with hints on the errors that occurred. The tips work either as individual learning aids or, in the case of more demanding experiments, as staged learning aids.

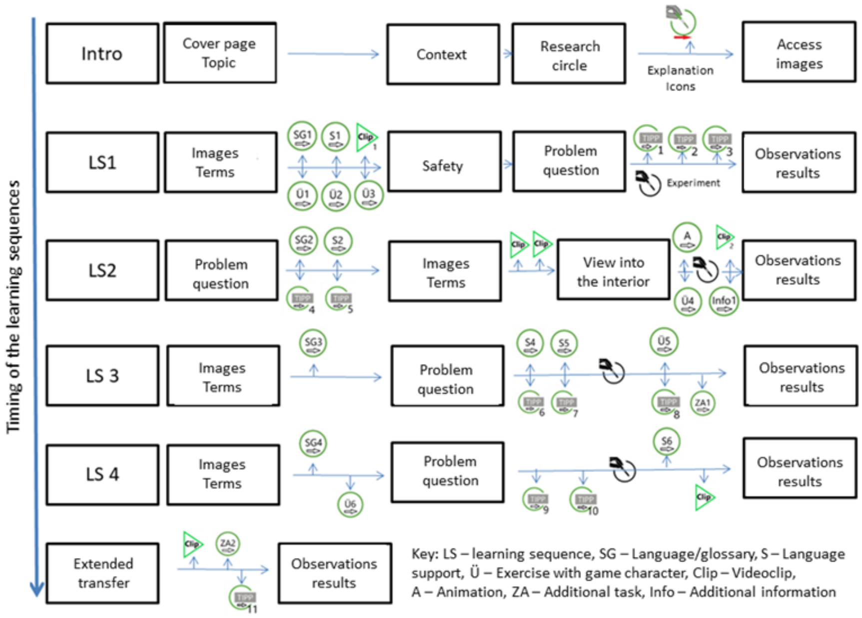

Fig. 4: Interactive parts of the Fire & Flame Multitouch Learning Book.

4. Results of the evaluation

The teaching unit was quantitatively tested with 7 classes (N = 165) of the grades 6 and 7 (age 12-13). Situational questionnaires and fisheye 360^0-video recordings were used to record the perceived fit of the teaching offer with the individual performance of students, supplemented by questionnaires for teachers. The results regarding the pre-post surveys showed positive, significant changes for the students' self-assessment regarding the fire and flame knowledge (high school N = 51, primary school (N = 43), integrated secondary school ISS (N = 71), 23 items, Expertise pre: $\alpha = 0.927$, post: $\alpha = 0.846$, $p < .001$). We showed that even students with a low interest in natural sciences answered all tasks in the knowledge test at a very high level.

154 out of 165 students passed the competence test. Of the 10 tasks of the competency test, an average of 8.5 were solved (M = 8.51, SD = 1.57), so the pass rate can be classified as very high. This rate decreases from high school students to primary school students to ISS students. The differences are significant ($p = .003$). The effect size shows a medium effect $\eta^2 = 0.0679$.

On average, the students performed 8.42 clicks out of 37 possible clickables in the Multitouch Learning Book. The number of clicks reached the highest score for the ISS students. They realized a mean of 8.95 clicks out of a possible 37 (M = 8.95, SD = 3.53). The use of the clickables did not differ significantly for the different types of schools (high school, ISS, primary school), i.e. the interactive offer is accepted comparably well in the sum of the clicks.

The Multitouch Learning Book appeals equally to girls and boys. Both genders show no significant differences in the self-assessment of domain specific knowledge, the use of the interactive digital medium and in the competence test. Video tutorials are used equally across all school types. In contrast, the other interactive offers are used in a school-specific way: Learners from integrated secondary schools make greater use of the learning and language aids, high school students are interested in the additional offers and information, and primary school students increasingly click on the exercises with gaming character. The respective school-specific differences are significant. In an extreme group analysis, it could be demonstrated that students who frequently used the tips - especially those from the integrated secondary school - were able to produce glass products, a stirring rod made of glass, of comparable quality to students who produced the product without using the tips.

5. Conclusion and Goals

With regard to the teachers' assessment of the suitability of the interactive textbook for inclusion, it can be stated that the entirety of the investigated inclusive aspects of the learning environment and especially of the Multitouch Learning Book were positively assessed.
The results as a whole show the potential of the Multitouch Learning Book as a platform for inclusive learning environments, and at the same time the successful transfer of the MiC into a practical, inclusive learning environment could be demonstrated. It could be shown that the three steps of the MiC approach are manageable and practically implementable.
Considering the largely identical strategies of knowledge acquisition in the subjects of biology and physics, an extension of the model for inclusive chemistry teaching (MiC) into a **m**odel of **i**nclusive **s**cience **t**eaching (MiST) could be envisaged.

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