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Elective Lessons in the Online Upper School Campus Pilot Project: Context-based Approaches to the Atom

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ABSTRACT. Our aim is to demonstrate how an online high school campus can open up new, practical paths within Waldorf education in response to current social challenges and central scientific questions. We focus on the example of a hybrid elective course in grade 11 that we developed and tested, offering context-based approaches to understanding the atom in the subjects of physics and chemistry. We describe the experiences we made with the course and conclude with some considerations for further development.

Keywords: Online high school campus, hybrid teaching, atom, context-based, Waldorf school curriculum

Introduction

At the beginning of 2022, the *+3 magazine* of the *Süddeutsche Zeitung* asked its readers what improvements schools needed. Invited to outline visions, the following article was included in the online discussion for issue 84 from February 25, 2022 (Sommer 2022):

> „**The best for everyone**
>
> The school of tomorrow needs a new Enlightenment. Young people develop themselves there by learning to value their cultural heritage as well as their multi-facetted grounding in Nature. They have the courage to use their minds in a dialogical way. They experience themselves as an embodied subject that is Nature as well as a being surrounded by Nature. They encounter the new with an empathetic as well as analytical eye.
>
> For a new Enlightenment, the school of tomorrow needs time for expeditions, designed and led by excellent teachers. Universities or think tanks provide them with the freedom to develop pioneering prototypes. They unfold their new perspectives once a week – live, but online; post-Corona, they have the necessary skills. Students join in according to their interests, connecting from a wide variety of schools and cities. Their teachers accompany them as they work through and follow up on the shared stimulations. Questions are mirrored back and taken up again the following week.
>
> Why all this effort? Tomorrow's adults need new contexts today, through which they can enrich and supplement tried-and-true school and examination materials: How are existence and life intertwined? Are atoms the building blocks of Nature or elements of a description? Is pluralistic realism conceivable? What is it like to be human, and what does it mean?"

A first pilot project

The vision outlined here – not a scientific text, but a contribution to a discussion – is formulated with sharp contours and presented in a self-confident style. We took hold of the vision during the 2023/2024 school year and developed and implemented a pilot program based on it. The thematic focus was the question of whether atoms are building blocks of Nature or elements of a description. For the science curriculum of Waldorf schools, this represents a challenge as well as an opportunity.

In the following, we will specify the chosen task in the context of the upper secondary curriculum, present our first implementation of an online upper secondary campus, discuss the experiences we have made with it and end with an overview of our current thinking about how the project can be further developed.

Curricular tension in regard to the atom

Phenomenological approaches play a central role in science lessons at Waldorf schools. This applies both to the phenomenological teaching approaches of main lesson teaching (Rohde 2003; Sommer 2023) and the phenomenological approach in the acquisition of scientific knowledge (Østergaard, Dahlin & Hugo 2008).

In German Waldorf schools, the atom is one of the central chemistry and physics topics in grade 11 (it may have already been mentioned as a concept in previous years). In recent years, the science curriculum of Waldorf schools has been further developed and differentiated through numerous dissertation and research projects. Nevertheless, for many teachers the teaching approach to understanding the atom remains unsatisfactory.

On the one hand, there is the phenomenological approach, which dominates main lessons as a non-reductionist approach and was experienced as particularly motivating by learners in Austria, for example (Wallner-Paschon 2009; Salchegger, Wallner-Paschon & Bertsch 2021).

On the other hand, in many places the atom is introduced pragmatically and briefly in exam preparations and treated purely reductionistically. This approach has been discussed several times in recent years at the annual meetings of German-speaking Waldorf chemistry teachers. Experience has shown that learners initially find the approach abstract, but soon appreciate it for its explanatory power.

These two approaches were, and still are, often unconnected. Proposals to close this gap began early on. Even during Steiner‘s lifetime, there was the so-called „atomism controversy“ and Kolisko‘s attempt to develop a hypothesis-free chemistry. Rozumek (2012) provides a comprehensive overview of this. While a didactic bridge emerged to connect phenomenological approaches to electricity with the atom via the electron (Kühl 2018; Sommer 2020), the tension remained in many places. The teaching time required to traverse the bridge was simply not available.

We have therefore tried to resolve the tension by offering an elective course in the 11th grade (Sommer 2025; Rohde 2025). In a pilot project, we tested a hybrid teaching-learning format that can be offered across schools in an online upper secondary school campus. The courses were designed as a scientific and epistemological offering focused on common examination topics. In them, the atom was initially addressed as an element of a description and not directly as an instance of explanation.

There were several reasons behind the decision to offer elective lessons in the 11th grade, which should be taken into account when transferring our pilot project to other countries. In Germany, Waldorf pupils complete upper secondary school with the “Abitur” examination at the end of the 13th year. They therefore have one year longer than in most other countries. They have to complete three challenging written examinations set by the state from subjects they can choose. Using the subject of biology as an example, it has been shown that Waldorf pupils cope with the associated challenges without any special problems (Rohde 2022). In addition, there are school-internal oral examinations in other subjects chosen by the pupils. This means that final examinations in physics and chemistry are not compulsory. These subjects are also rarely chosen as examination subjects. And even if this is the case, the content from grade 11, although

it forms a basis for the Abitur examination, is of little direct relevance to it. In Germany, there is therefore a great deal of freedom in terms of content in these two subjects in grade 11.

Elective lessons have the advantage that the students thereby fulfill a school-prescribed course requirement. This means that they are not completely voluntarily present in such a course. At the same time, they can choose between several subjects, none of which are compulsory for the Abitur examinations. This allows them to follow their personal inclinations more closely. In our atom course, we observed that students basically interested in the subject had chosen to enroll.

In the following, we will present both the concept of the elective course and our initial experiences.

Online high school campus

Organization

The course „Context-based approaches to the atom“ was offered for half a year (two quarters) at a rate of two double lessons per week. The physics instruction took place in the first quarter under the direction of Wilfried Sommer at the Freie Waldorfschule Kassel. They were broadcast to Marburg and supervised there by a physics teacher. – During the planning phase, the simultaneous transfer to a third location was planned. However, the supervising teacher became unavailable, on short notice.

In the second quarter, the participants from the Freie Waldorfschule Marburg then experienced the chemistry courses in person under the guidance of Dirk Rohde and the participants from Kassel online. In Kassel, they were supervised on-site by Wilfried Sommer.

In both Marburg and Kassel, cameras with pre-programmed settings were used: in particular focused on the blackboard, the flipchart and the classroom screen, but also on selected positions of the experiment tables. Both teachers coordinated their preparation with the camera settings.

A high-quality microphone ensured that participants‘ contributions and questions were not only clearly understood in the classroom, but also at the broadcast location.

Another camera was directed at the learning groups in both Marburg and Kassel so that the learners in one place received an impression of the situation in the other.

Structure of the courses

Roughly speaking, the courses alternated between three phases:

- the presentation of content (lectures by the teacher, accompanied by blackboard notes or with reference to a presentation; demonstration experiments),
- the discussion phases (answering questions; discussion and development of content) and
- the phases of independent work (worksheets; main lesson book write-ups).

Depending on the content, individual phases lasted from a few minutes to half an hour. Most of the time, several of these cycles followed one another. The sequence of phases was not a rigid concept and was flexibly aligned to the content.

During phases of independent work, the microphones were switched off at both locations. This allowed the learners to ask the teacher on site directly and in a protected environment for support and, in particular, to shed light on aspects that they wanted to understand better in direct conversation.

In contrast, the contributions during the discussion phases were audible to all participants. In individual cases, the teachers on site had to remind the participants to articulate clearly in the direction of the microphone. In numerous discussion segments, the learners demonstrated an ability to refer directly to arguments that they had only heard through the broadcast. In particular, the learners at both locations quickly got used to

a technical language practice session, in the form of a short question-and-answer sequence at the beginning of the physics instruction.

The presentation of content had the character of a lecture. It proved very useful to record what was presented on the blackboard and to decide in class, depending on the content, whether the students should take notes directly or only make their own notes based on the blackboard notes during the independent work phase.

One of the participants was an immigrant and initially had little knowledge of German but very good knowledge of English. After consultation with both groups of learners, English was chosen as the language for the presentations for a while, but the learners were able to decide for themselves whether they wanted to ask questions in German or English. Most of them chose English.

The lessons in Kassel and Marburg did not overlap completely; on Wednesdays, a total of 70 minutes was available as common time and not 90 minutes as usual. On Fridays, Marburg was only able to set up one overlapping lesson of the planned double lesson, so that on this day in Kassel, the second part of the double lesson included longer individual work, which was left to the learners in Marburg as homework.

In general, the aim was to organize the phases of independent work in such a way that the learners had to do little or no homework, which could not be fully realized in Marburg for the reason mentioned above.

Networking with the main lessons

In physics, the elective course required prior knowledge of both electrostatics and electrodynamics. The content was arrived at through agreement between Kassel and Marburg.

As physics lessons in grade 11 are taught in blocks at both schools, the physics blocks took place before the start of the elective lessons.

In chemistry, it was not possible to schedule the chemistry main lessons before the start of the block lessons for all participants. For some learners, some content represented a repetition or new emphasis, while others encountered new content. This had to be taken into account when designing the courses.

Naturally, the topic „Context-based approaches to the atom“ appealed specifically to those interested in science. However, the Waldorf schools of Kassel and Marburg did not formulate any requirements that stipulated special talent or special achievements as a condition for participation. As a result, the level of achievement of the participants was spread across the usual range.

In Kassel, the learners were able to improve, but not worsen, their grade in physics through their results in elective lessons. The Marburg learning group was not graded. As this was a pilot project, which in principle could also fail, this ruled out any risk for the participants.

First experiences with the hybrid teaching-learning format

During the presentation of content, the teachers were faced with the challenge of keeping an eye on two learning groups, the „roomies“ and „zoomies“ (Heitmann, Michel 2022, p. 24 ff.). This was made much easier by a monitor that only showed the learning group of the other location via a separate Zoom access; the „zoomies“ were thus given a greater significance.

If worksheets were used in the phases of independent work that were coordinated in detail with the presentations and their notes on the board, the learners were able to work independently. Free or open work formats, e.g. writing up the presented material based on their own notes, did not prove successful, it represented an excessive demand in terms of content and motivation for many participants.

It was particularly appreciated, for example, when the supervising teacher in Kassel took notes himself – on a flipchart that stood to the left of the screen on which the lecture from Marburg was transmitted.

The students were thus able to experience how to compose a transcript directly from a presentation, which highlights not only the content but also its structure.

This training, which over time increasingly turned out to be an anticipation of university courses, proved its worth. Most of the students did not take the notes directly from the flipchart. Rather, they used them as a back-up for their own notebook work.

The „proximity bias" typical of hybrid settings – we prefer people close to us (Heitmann, Michel 2022, p. 33 f.) – was thus easier to handle, as teachers were active at both locations and positioned themselves with empathy in their respective teaching-learning format.

The initial concern that learners' differing prior knowledge could significantly influence the course of the lectures proved to be largely unfounded. In the presentation phases of the hybrid teaching-learning format used, even familiar content must be carefully activated cognitively or linked to an example, as some of the participants do not have the direct personal impression that would enable and legitimize greater situational action.

During discussion phases, it sometimes happened that teachers had to repeat and clarify a learner's contribution so as not to lose the online learning group. This form of so-called teacher echo is rightly frowned upon in face-to-face teaching, as it makes it attractive for learners not to listen to each other and not to relate to each other, but only to interact with the teacher. The negative effects of teacher feedback in face-to-face lessons were largely absent. Overall, however, it was rarely used thanks to the good microphones and the clear articulation of most learners.

Elisabeth Feigl (2022, p. 176) suggests using the SAMR model to reflect on whether „digital is not used additively, but integratively". „In this way, it can be recognized whether analogue media can simply be replaced by digital media (substitution - S), whether a moderate functional expansion can be achieved (augmentation - A) or whether the actual goal is reachable: that levels of modification (M) and redefinition (R) can be achieved".

As explained above, we have the impression that a specific and helpful modification is added to the substitution for the „Zoomies" when the supervising teacher writes his/her notes on the flipchart next to the screen and/or otherwise assists their learning group. Since the learning content is also conveyed in two ways through the dual support of both learning groups (simultaneously digital and analog by one teacher in each case), it can also be referred to as augmentation to a certain extent, as this increases the learners' opportunities for understanding.

In contrast to Axel Krommer and Philippe Wampfler (2021, p. 8 f.), we also do not start from the fundamental question of how learning and teaching should be structured in a culture of digitality. The hybrid teaching-learning format we have tested is intended as a tool, while Krommer and Wampfler argue that „media are not tools, but shape perceptions, communities and social action" and thus „the question of added value cannot be asked in a meaningful way": „Those who ask what digital media improve are starting from the understanding of learning and knowledge of the culture of book printing and are not comparing cultures, but tools".

Our further explanations will make it clear that we want to develop the teaching-learning format described as a tool for global learning.

Curricular decisions

About the leitmotif

The question of whether atoms are building blocks of nature or elements of a description cannot be answered with a yes or a no. It is a major question of natural philosophy in which the concepts of substance, causality and interaction play a central role. Kant regarded them as fundamental „concepts a priori" and, following Aristotle, referred to them as „categories" (Willaschek 2024, p. 303). This aspect alone quickly goes beyond the dimensions of school teaching and learning.

The question of what matter is, is also directly linked to the atom. Another important question is the extent to which the concept of the atom is linked to the understanding of the human being as an individual. And last but not least, the role of models in the natural sciences plays a central role. All these topics are extremely complex and only a few aspects can be dealt with adequately in an elective course.

Accordingly, we chose the title „Context-based approaches to the atom". We started from contexts which, after our didactic deconstruction and reconstruction, we considered suitable for dealing with questions of natural philosophy with the learners. Our didactic efforts focused on embedding reductionist positions on the atom in contexts that are not purely reductionist.

With such an approach, we hope to make a contribution to the discussion on what is currently being called for as a „new Enlightenment". This demand also represents such a comprehensive question that we merely wish to name it here as a framework for our own motivations, but not as a scientific program for our own work.

Physical aspects

The course of instruction in the subject of physics is set out in a separate publication (Sommer 2025) and will not be detailed here.

In a nutshell: the courses started with mechanical contexts, then addressed electrostatic contexts (field states as shape states of space without matter, charges as anchoring these shape states to matter) and then built a bridge to electrodynamic contexts. The end result was the localized electron as an object in electrostatic and electrodynamic contexts.

The descriptions of the individual contexts were based on concrete physical phenomena, which were developed in series of experiments wherever possible. The aim was then to illuminate them through thinking, from different directions. In this way, the learners were increasingly able to combine the concrete view of physical phenomena with symbolic forms.

In this learning process, it quickly became clear to what degree of formalization the participants were able to spell out symbolic forms and what mathematical level was achievable.

In the end, we ended up with linguistically condensed formulations, two of which will be reproduced here as examples to illustrate the character of the descriptive approach we chose.

- The concept of the atom integrates possible interaction processes with the environment into a local description approach, which stands in an additive context. To this end, electrodynamic and electrostatic perspectives are combined.
- The atom is a concept and a form of matter in which the binding energies of the electrons numerically indicate the interaction potential with the environment. At the same time, the possible interaction processes are linked to an additive-spatial descriptive approach.

The learners often described such formulations as „really fundamental" or „really philosophical" and thus distinguished them from „popular" approaches that they had encountered elsewhere.

Chemical aspects

In the subject of chemistry, the progress of the courses is also recorded in a separate publication (Rohde 2025) and is therefore not presented in detail here.

A quote from Hans Primas (see below) was handed out at the beginning, with the announcement that it would be discussed at the end on the basis of what had been covered in the chemistry section. The differences between the chemical and physical approach to matter were then briefly summarized. As a first prerequisite of the atomic concept, the importance of examining water with the help of precision scales and

using standardized, normalized measurements was worked out by means of experiments. The focus was on the concept of chemical elements and their reactions in constant and multiple proportions. The relationship between mass and volume was then discussed. This was followed by reactions in the redox series of metals, the resulting electrical voltage differences and their use in electrolytic experiments.

The discussion of Avogadro's theorem, the introduction to methods for determining Avogadro's number and the recourse to hydrogen then led to the localized proton in the context of water formation. The electron as a negative elementary charge, Rutherford's gold foil experiment and current orbital models showed the intersections with physics.

At the end, the above-mentioned Primas quote was discussed: „It is not correct to say that the material world is *made up* of electrons, protons, atoms and molecules. But it is quite correct to say: The molecular aspects of the material world can be *described* extremely well with the terms electron, proton, atom, molecule." (Primas 2004, p. 13) One key question was what it meant for the learners' thinking if they – in contrast to Primas – assumed that matter was made up of smallest building blocks. Another key question was what connection they saw between the concept of the atom and their self-image as an individual, as both words – atom and individual – refer to an indivisible entity. According to the learners, these discussions were fruitful and very thought-provoking.

Perspectives

Review with the participants

The participants' feedback related to both organizational and content-related aspects of the course itself. Many of the organizational aspects have been incorporated into the checklist found in the appendix to this document.

With regard to the content of the course, the students emphasized that supplementary materials were necessary in order to be able to fill any gaps caused by absences. The natural philosophical character of the course requires specific literature. – We will take this as an opportunity to create appropriate bilingual literature (German and English) (Rohde 2025; Sommer 2025).

We opted for a bilingual version in order to keep open the possibility of offering a corresponding course in English in an online upper secondary school campus across national borders in the future. Based on the reactions of our students, this would certainly meet with a positive response due to the international nature of teaching and learning at school. A course that takes place once a week seems realistic to us, partly in order to facilitate the necessary overlaps in the timetables of the participating schools.

Furthermore, the bilingual version of a book accompanying the course would be an attractive offer for gifted learners, as they could expand their language skills at the same time. For us, it would also be conceivable to add other elements, such as those proposed by Klaus Oehmann and Patrick Blumschein (2020, p. 200 ff.) for hybrid learning and teaching and discussed since the 2000s under the term „blended learning".

Finally, the participants particularly welcomed the fact that, after weeks of meeting digitally, the last teaching unit for all participants took place in person. This allowed everyone to see each other in person at least once. This could represent an interesting challenge for a transnational project, as it would result in longer trips, which in turn would be suitable for exciting follow-up activities.

The hybrid teaching-learning format thus served as the gateway to a specific form of global learning.

Shared interest among teachers and students

As mentioned above, the chemistry courses in Marburg took place in person and in Kassel online. The supervising teacher in Kassel, Wilfried Sommer, had a physics background and a solid, but not in-depth,

knowledge of chemistry. He took notes himself on a flipchart to the left of the screen on which the course from Marburg was broadcast.

By observing how these structured notes of „their" teacher matched the presentation by Dirk Rohde, the teacher in Marburg, the Kassel students not only had an example of university learning in front of them, but they also experienced how „their" teacher found an access to chemical content together with them and thus learned it himself. It was this shared interest of both the teacher and the students that was at the heart of classroom learning and shaped the learning atmosphere.

We see this shared interest as an important perspective when we think about the further design of an online upper secondary school campus: Couldn't teachers and students work together in elective classes to develop points of view that place school content in new contexts? In contexts that stimulate perspectives for a „new Enlightenment" or for socio-ecological transformation processes in the broadest sense? This would also be an innovative form of continuing education for teachers.

Should we share interest once a week in elective classes oriented towards the future? And at a time of day when participants from several time zones can come together at the same time?

We see the Waldorf school curriculum as having the potential to embed purely reductionist approaches, which dominate many examination formats, in contexts that are not approached in a purely reductionist way. In this way, we hope to work towards forming judgements dialogically.

Changing examination formats in the short term seems illusory to us. On the other hand, offering contexts that broaden the perspective through elective lessons seems realistic. For lessons on the atom, it is also conceivable to shorten the chemistry and physics main lessons in grade 11 slightly and offer an interdisciplinary atom main lesson in the one to two weeks gained as a result. As a hybrid lesson, this atom period would ideally take place before the Christmas vacations, which start at the same time everywhere, thus guaranteeing the necessary overlap of lesson times. For us, these are the first further steps that we would like to take. Please contact us if you are interested, we will be happy to share our experiences!

Appendix: Organizational checklist

- All teachers involved in any way in the project should be informed of all organizational consequences well in advance and these should be thoroughly discussed with them.
- The overlapping teaching times between the participating schools must be determined to the minute in advance.
- Foreseeable absence from lessons, e.g. due to school projects, must be communicated as far in advance as possible and work-arounds identified and planned.
- Each group of learners must be supervised by a competent professional. Sickness-related substitutions must be ensured.
- Elective lessons that fulfill student course requirements are strongly recommended, as the compulsory teaching load at upper secondary level is too high for entirely voluntary lessons. The content and level of requirements, including the necessary prior knowledge, must be described in detail to those interested in advance so that they can assess whether the course is suitable for them.
- The course requirements and the grading must be determined in advance with all responsible teachers and communicated to the learners.
- Sufficient time must be planned for all technical aspects of hybrid teaching. It is time-consuming in many respects to organize the necessary rooms, materials and technical requirements. In addition to demonstration experiments, opportunities for student experiments should also be planned.

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