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Algae: The Green All-Rounder – An Interdisciplinary Teaching Unit for Middle School Students

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Abstract

The biological and chemical research focusing on algae in the last few years indicates their enormous potential as a new green alternative to mineral and fossil raw materials or as in the example by Groß or Yu, as bioreactors in the medical field, as well as for the visualization of tumours or metastases by using luciferase-catalysed luminescence. Besides the algae's great potential in different areas of our daily lives, they additionally offer great didactic potential for interdisciplinary science classes in which students have the opportunity to design experiments and evaluate different factors such as ideal living conditions or the use of algae as bioindicators for environmental influences such as nanoscale titanium dioxide.

We will present various possibilities for the utilization of different algae types in interdisciplinary science teaching. The aim is to foster the presence of the modern topic algae within the subjects Chemistry and Physics and subsequently focus on an interdisciplinary science approach. For this purpose, we are presenting a context-based, interdisciplinary science project enabling students to verify experimentally the production of oil in algae. Connections to classical scientific subjects such as Chemistry can be established by putting an emphasis on activities like the pH-based detection of the carbon dioxide consumption during photosynthesis. Moreover, the investigation of environmental influences fosters interdisciplinary competencies and allows students to learn more about current research efforts and the advantages of utilizing characteristic properties such as bioluminescence for the detection of tumours.

1. Introduction

For the planning of a lesson, different models can be utilized, varying in their goals, orientations, and methodologies. The model by Cook and Martinello includes five criteria for the selection of a topic regarding the significance and suitability for interdisciplinary science education (ISE): "Is the big idea true over space and time? (I), Does it broaden students' understanding of the world or what it means to be human? (II), Is the big idea interdisciplinary? (III), Does it relate to students' genuine interest? (IV) and Does it lead to student inquiry? (V)" [1]. The theme of algae allows to handle various major issues like climate change or the scarcity of resources as currently important topics (I). The second criteria can be considered by the sustainability in the use of nanoscale material. It expands the connected understanding of the students for the world and for the influence people have with their actions on the environment (II). The diversity of the topic and references to our daily lives are intended to interest the students (IV). By referring to current areas of application of algae, *e.g.* in medicine, the students are interested in a way such that they want acquire more detailed information independently and start their own investigations (V). Finally, Fig. 1 an excerpt for the multitude of possibilities of interdisciplinary connections, caused by the algae issue, is shown (III).

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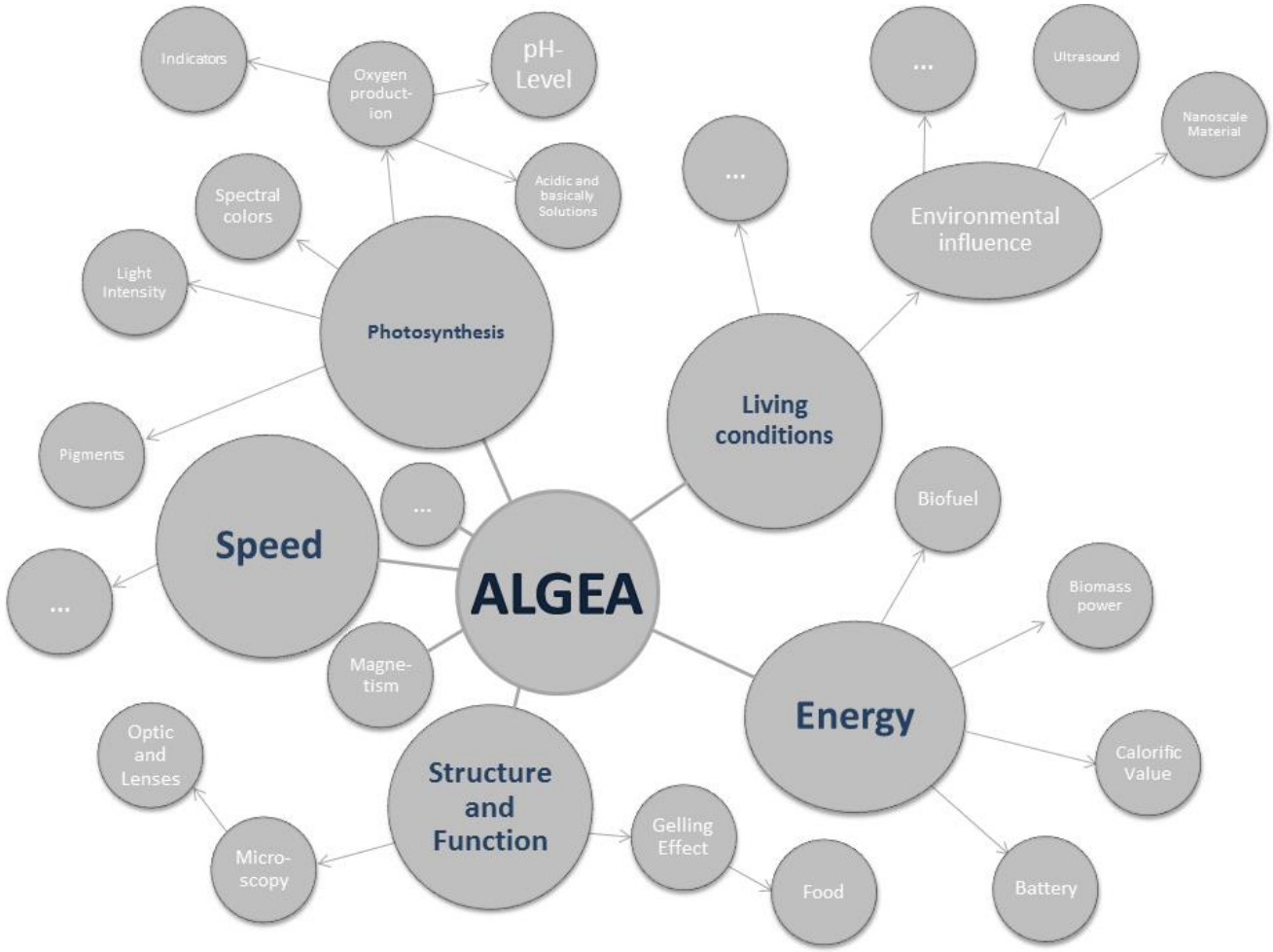

Fig. 1: Excerpt of a MindMap of the topic of algae in the interdisciplinary science education.

The relevance of an interdisciplinary thinking is reflected in the demand for it in daily life as well as in university-based research. In both areas, it is essential to link knowledge from various fields to understand and solve problems. It is also shown that science subjects are increasingly integrated to one single subject, irrespective of level or school type. An interdisciplinary approach is defined as “inquiries which critically draw upon two or more disciplines and which lead to an integration of disciplinary insight” [2]. Research by Frykholm and Glasson shows that interdisciplinary teaching promotes many competencies of PCK and CK such as communication skills and professional learning, as well as interlaced thinking [3], so that there will be a positive effect for each single discipline. Reasons are that topics are “less fragmented and more stimulating […] for learners” [3], [4], when compared to the subject-separated teaching, thus making it more harmonized with the learning structure of students. Other benefits of cross-curricular teaching are that ISE is often context-based and oriented to the daily life of the students [5], resulting in a higher self-confidence especially for girls [6]. Furthermore, the context-oriented in ISE classes can increase the interest and motivation for scientific subjects [7], [8]. Results by Labudde et al. show that the methodological diversity, such as group work, in ISE is higher than in subject-separated classes [9]. Studies have shown that this cooperative approach leads to higher test scores and passing rates for most respondents [10]. Below, a teaching concept about algae will be presented, which makes it possible to structure interdisciplinary teaching in a meaningful and irrelated way.

2. Background Information

Algae is a collective term for primitive water plants lacking roots, stems and leaves [11]. Most of them belong to the group of eukaryotes that can absorb water and carbon dioxide and convert it into oxygen and glucose. However, there are various algae which produce for example carrageen, alginate, lipids (e.g. *Botryococcus braunii*) or hydrogen, depending on external influences. The large diversity of algae can not only be seen in the various products of metabolism, but also in the field of morphology. Algae's dimensions range from microscopically small up to several meters, flagellated and aflagellated form as well as colony-forming and not colony-forming units. Further variety of algae is shown by part of the algae of the genera *Dinoflagellaten* with their stress-based luminescence (see Fig. 2). These algae can be used *e.g.* for the exemplary illustration of luciferase-based bioluminescence-imaging for tumour growth [12] and show students thus the relevance of algae in everyday life and the current research.

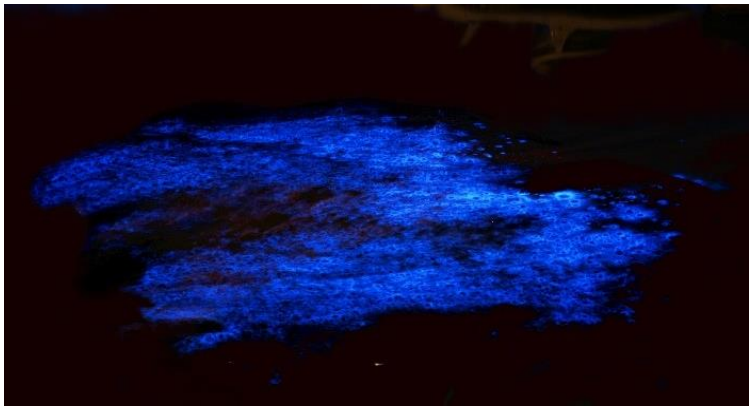

Fig. 2: Noctiluca scintillans. © Hans Hillewaert (CC-BY-SA 4.0)

To illustrate chloroplast-based photosynthesis in school experiments, the flagellous, unicellular, eukaryotic green algae *Chlamydomonas reinhardtii* with two anterior flagella is a suitable model system, it grows *e.g.* good in water with some light. However, algae of the types *Euglena gracilis* (flagellated and round or rod shaped), and *Micrasterias radiata* (colony-forming and aflagellated) are convenient to show the various morphologies in student experiments due to their different cell structures, furthermore both grow well under simple living conditions.

3. Using algae in an interdisciplinary teaching proposal

The introductory course for integrated teaching in grade 7 and 8, presented here, is intended to provide ideas, and give indications to increase the presence of the modern topic algae in the subjects of Chemistry and Physics in order to strengthen the interdisciplinary science approach. The design is based on the criteria of Stohlmann et al. for interdisciplinary teaching with focus on connections, using problem-based learning. Additionaly, it should be student centered and focus on big ideas, concepts or themes, integrated technology as well as showing real world and cultural relevancy [13]. In the presented teaching design, the students acquire various scientific competencies and skills, for example experimental skills and assessment competencies, by imparting PCK and CK from all three subjects (Physics, Biology, and Chemistry). The following table summarizes the general structure of the teaching unit as well as the corresponding learning objectives:

Lesson	Purpose
1. Morphology Lab	• gain familiarity with characteristic of algae (flagellates, shapes or colony-forming)
2. Living Condition Lab	• develop an experimental setting to examine the living conditions • name and point out the different influences (water, air, light and fertilizer) for plant growth
3. Photosynthesis in Algae Balls	• determine experimentally the photosynthesis • compare the different solution and interpret the results also related to the light intensity
4. Changing Colours	• know and can name different indicators
5. Acidic and Basically Solution Lab	• perform experiments with differently concentrated solution considering the pH-level • explain the correlation between colour changes and acidic/basically solution
6. pH-Level in Daily Life	• explain the necessity of pH-level examination in pools • test the pH-level with indicators
7. Who Swims in the Pool?	• use microscopy and field book to determine the living beings in a clouded pool solution
8. Cleaning up the Pool	• evaluate the effect of e.g. the titan dioxide on the algae • associated impact on the ecosystem
9. Look to the future and research	• describe the fluorescence of *Dinoflagellaten* triggered by stimuli • investigating other uses of algae

In addition to the CK, another focus is on conduction experiments to increase student activity and motivation. Therefore, the teaching unit starts with the microscopy of the morphology of algae (*Chlamydomonas reinhardtii*, *Euglena gracilis* and *Micrasterias radiata*), then the living conditions are examined [14] with the help of an experiment planned by students, which leads to the photosynthesis. In the study of photosynthesis, oil is detected next to oxygen as a metabolic product. The algae are placed under a microscope (1000 magnification) and students can observe oil bodies as accumulated bubbles [14]. Oxygen can be detected using algae balls and bicarbonate indicator the pH-level [14]. The dissociation equilibrium shifts due to the diffusion and conversion of carbon dioxide during photosynthesis, the concentration of the hydronium ions changes, a colour change can be detected by mere eye. At this point the terms of acidic and alkaline solution as well as the pH are introduced, which are already known mostly likely from the area of swimming pools or beauty products. Following, students test possibilities for pool cleaning by using salt, ultrasound, algae-free and nanoscale titan dioxide [14]. The destroyed cells can be interpreted with the expertise of the cell structure (at the beginning of the unit) and the diffusion (in the algae balls). In addition, this experiment is taken as an opportunity to promote the competencies of evaluation and sustainability by discussing the use of nanoscale materials *e.g.* in sunscreen. At the end the luminescent algae are examined [14], the reference to the application in medicine offers the possibility to deepen the knowledge about the potential of algae by literature search and lectures.

4. Summary and Outlook

Algae are already found in large areas of our lives (medicine, nutrition, and cosmetics), new applications, such as energy-carriers are currently tested on an industrial scale. The topic offers a multitude of possibilities to elaborate curricular content interdisciplinary and to organize it in a student- and context-oriented way as shown here. The next step should be to improve the cultivation of algae for school conditions and to work on the topic of energy as an example of the algae battery. Existing experiments have shown that the generation of energy from algae in form of a battery in laboratory scale is already possible. The aim is to develop a student experiment with low costs and to use it in school settings.

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