Transfer from science to school: Didactic reconstruction of a liposome photoreactor

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1. Introduction

Photochemical reactions provide a vast array of potential applications and demonstrate remarkable versatility in their utilization. Along with advancing these potentials in science, it is crucial to make sure that the knowledge acquired is accessible and comprehensible to the public. One method of achieving such knowledge transfer is pursued in the CRC CataLight. Within this network, various findings are being transferred to schools within the framework of the Educational Transfer Research Model through close collaborations between chemistry and chemistry education. In this setting, a series of experiments was designed where the photochemical conversion of NADH to NAD^+ can be significantly accelerated by enclosing the system within liposomes [1].

2. Model of Educational Transfer Research

The model describes the didactic reconstruction of a subject for (school) chemistry education. For this purpose, chemistry and chemistry didactic groups work closely together and complement each other with their respective competences. At the beginning, literature analyses and surveys are carried out to transform the knowledge structure of the subject into a structure for teaching this content (**Conceptualisation**). In the next step, model experiments and teaching materials are designed based on these findings in a cyclical process of *Conception* ‣ *Testing* ‣ *Evaluation* ‣ *Optimisation* (**Development**). In the last step, the results are made available to school as OER and scientific communities (**Dissemination**).

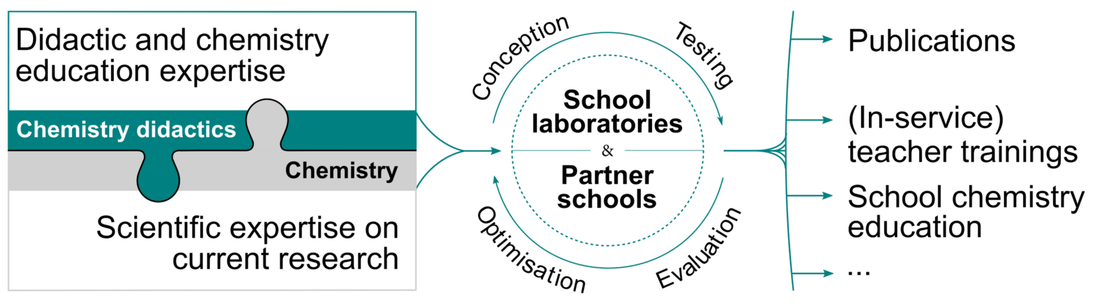

Fig. 1: Process of the Model of Educational Transfer Research

3. Scientific Background

In a study [2], a reaction concept was presented, where the light-driven conversion of NADH to NAD^+ was investigated. A ruthenium-based complex was used as a photosensitiser, which forms singlet oxygen after light irradiation for the oxidation of NADH (Fig. 2).

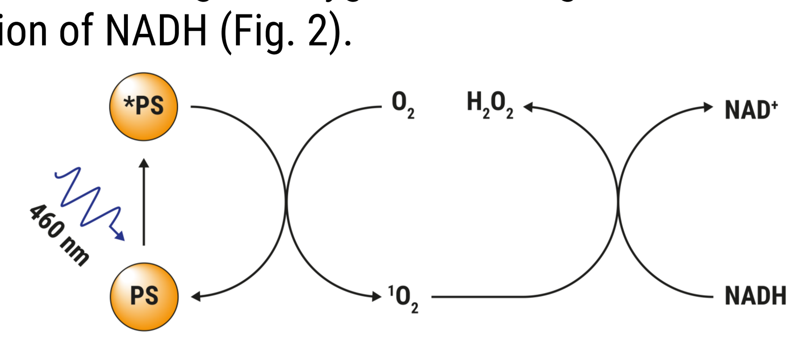

Fig. 2: Schematic representation of the oxidation of NADH to NAD^+ by a photosensitiser (PS).

The photochemically formed singlet oxygen is very short-lived in aqueous media and must meet an NADH molecule in this time window to enable a reaction. By compartmentalising photosensitiser and NADH in a vesicle, whereby a membrane of a lipid bilayer encloses an aqueous compartment and thus forms a kind of nanoreactor (Fig. 3), an acceleration of the reaction rate by a factor of 21 was achieved compared to classical reaction conditions (bulk). This can be explained by spatial proximity and is particularly helpful for light-driven reactions with short-lived light absorbers and those reactions in which short-lived reactive intermediate species are active.

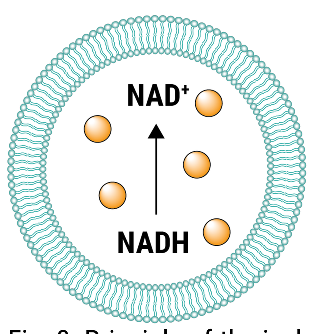

Fig. 3: Principle of the inclusion of the photosystem in liposomes.

4. Didactic Reconstruction

In the reconstruction of the scientific system, it is divided into its individual components, and each is examined for its suitability for the school. Necessary considerations include areas such as: hazardous materials, availability of materials, difficulty of implementation, possible methods of analysis, costs, etc.. Through this process, piece by piece, an attempt is made to recreate the system for the school (Fig. 4) while maintaining the effect. In Fig. 5, this process can be traced from the scientific system (blue) to an initial simplification by replacing the liposome components (green) to the final system in which the photosensitiser is replaced (purple).

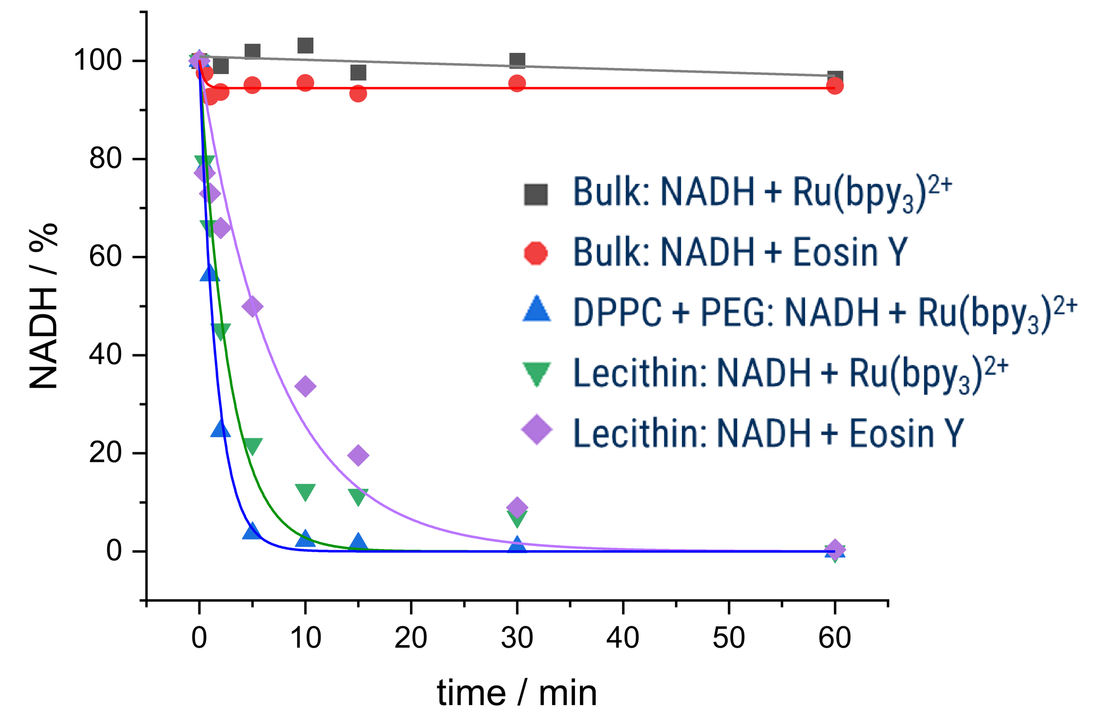

Fig. 5: Percentage degradation of NADH over time. The compilation of the measured values can be traced in [1].

CataLight	**DPPC + 14:0 PEG 2000 PE** Liposome building	**Rutheniumcomplex** Photosensitizer	**NADH** Function as model substrate	**Tracking with UV/VIS** Analysis method	**Photoreactor as light source**	**Demanding and elaborate synthesis**
	↓	↓	↓	↓	↓	↓
CatalighT Education	**Lecithin from egg** Liposome building	**Eosin Y** Photosensitizer	**NADH** Function as model substrate	**Qualitative tracking** Analysis method	**Flashlight as light source**	**Simplification of the formation of liposomes**
	Cheaper and can be easily obtained	Cheaper and found in many schools	Light stable and well detectable via UV/VIS or fluorescence	Reduction of the experiment to a visual observation	Possibility to operate the reaction with flashlight with similar efficiency	Simplification of the experimental procedure with preservation of the effect

Fig. 4: Summary of the didactic reductions made from the research to the school system.

5. School Experiment

The experiment based on the reconstruction is examined with undergraduate pupils for its suitability in school. Since, in addition to the complex topic of photochemistry, column chromatography is also used, it is important to relieve the learning process in some places. Here, the change to eosin Y proves to be particularly helpful since the collection of the fraction in column chromatography. It does not have to take place under UV light as in the scientific system since it can be followed under ambient light (Fig. 6). The method itself was introduced by additional materials and did not pose a major challenge for the students (Fig. 8, left).

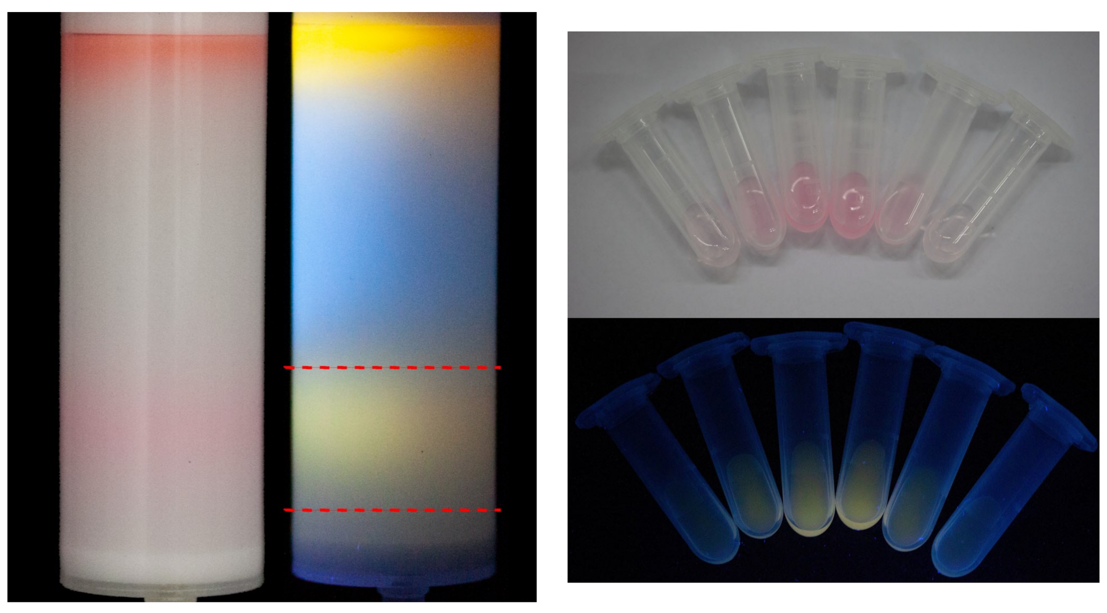

Fig. 6: Left: Used column under ambient light (left) and UV (right) In the marked area the produced liposomes can be recognised by the fluorescence of NADHs or eosin Y fluorescence. Right: Collected fractions after the column in ambient light (top) and during irradiation with the UV lamp (bottom).

The subsequent illumination for the actual photochemical reaction was performed with a flashlight. Due to the simultaneous decomposition of the eosin Y, the students can recognise the end of the reaction without using a UV lamp and subsequently check the solution for the fluorescence of the NADH (Fig. 7).

On the one hand, initial feedback in a pre/post-test design shows tendencies that the students can understand and explain the basic principle of the inclusion of a photochemical reaction through the experiment and the tasks provided. On the other hand, obstacles are still to be found in the general understanding of photochemical reactions, which was, however, to be expected with this extra-curricular topic. We intend to address this challenge in the future through the planned additional experiments.

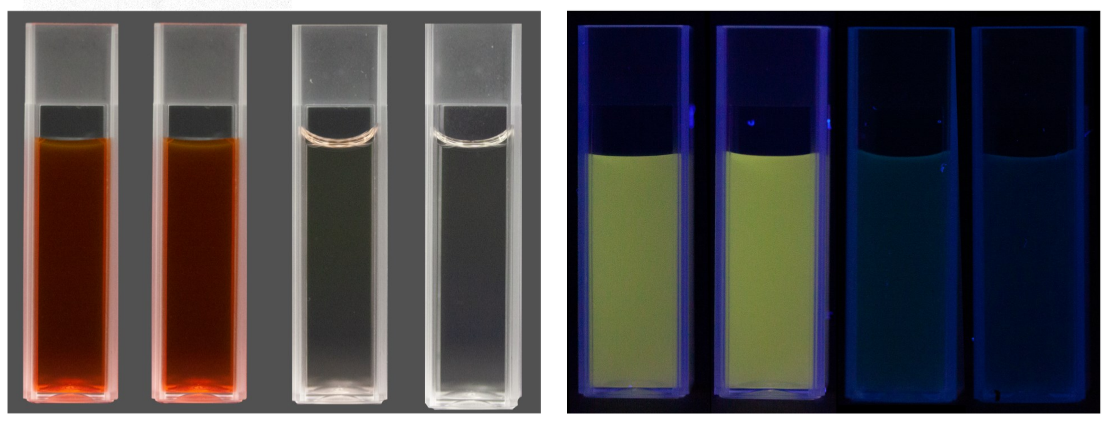

Fig. 7: Photo under ambient light (left) and UV-light (right) of eosin Y (c=0.56 mM) and NADH (c=56 mM) in the liposome nanoreactor after 0, 15, 30 and 60 min while irradiation with a flashlight.

6. Dissemination

In addition to scientific publication, the sustainable dissemination of findings into teaching practice is part of our research. This is done primarily by transferring the findings through student laboratories or directly to the teachers in schools. Fig. 8 briefly summarises some of these possibilities. Left: Pupil carrying out the experiment in the school laboratory. Top right: Provision of essential chemicals, expensive materials and lesson documents (OER) for direct application at the school. Bottom right: Providing general information about the project at education fairs.

Fig. 8: Summary of the different possibilities of dissemination.

References

[1] Petersen, M., Nau, R. E. P., Pannwitz, A., Wilke, T. (2023). Weniger ist mehr: ein leistungsfähiger Photoreaktor auf der Nanometer-Skala. CHEMKON. [2] Nau, R. E. P., Bösking, J., Pannwitz, A. (2022). Compartmentalization Accelerates Photosensitized NADH to NAD+ Conversion. ChemPhotoChem, e202200158.
Figure 2, 3, 4, 5, 6, 7 were taken and adapted from reference [1]

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