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Summary

The Ö1 project is working on the scientific reconstruction of the central results of CATALIGHT for school and society. For this purpose, didactic guidelines are conceptualized in a first step on the basis of literature and surveys (Figure 1). Thereby, the necessary core concepts as well as more advanced, in-depth concepts will be systematically categorized and used for the development of a didactic guidelines for teaching. The questionnaire study will identify the potential of the topic as well as possible obstacles for the transfer into the school on the part of the teachers.

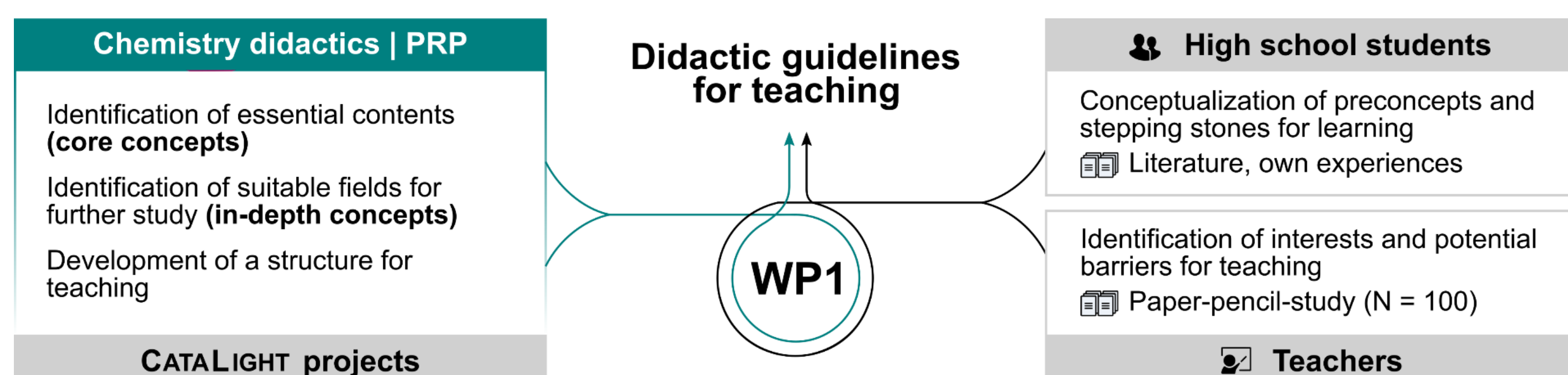


Figure 1: Development of didactic guidelines from literature and questionnaires.

The problem of equipping schools with quantitative measuring instruments is already well known. To counter this problem, a photometer and a hydrogen sensor are being developed within the project for the low-cost measuring station LabPi [1]. These will serve as one of the bases for the development of teaching units and model experiments. The experiments will be designed and coordinated in close cooperation with the other subprojects of the research network. The created materials will be tested and evaluated in partner schools and in the own summer school. The dissemination of the materials takes place on a larger scale, among other things through the training of teachers in the regional teacher training center and the freely accessible provision of the materials. A reduced overview of the process can be found in Figure 2.



Figure 2: Overview of the research design towards the conception of two school lessons.

Tracing Photochemical Reactions with a Digital Low-Cost Photometer [2]

Optical tracking of photochemical reactions offers the potential to provide students with both qualitative and quantitative feedback. Therefore, an initial experimental setup is presented below in which the hydrogenation of a photosensitizer (PS) is on the one hand tracked with the developed photometer and on the other hand induced by illumination within it. For this purpose, a system known from research is used in which illumination with light in the presence of the sacrificial electron donor triethylamine (TEA) $[(\text{tbbpy})_2\text{Ru}^{\text{II}}(\text{dppz})\text{Cl}_2]^+$ (PS) and structurally related systems accumulate two electrons and protons, i.e. hydrogen, at the dppz ligand by proton-coupled electron transfer (PCET) (Figure 3).

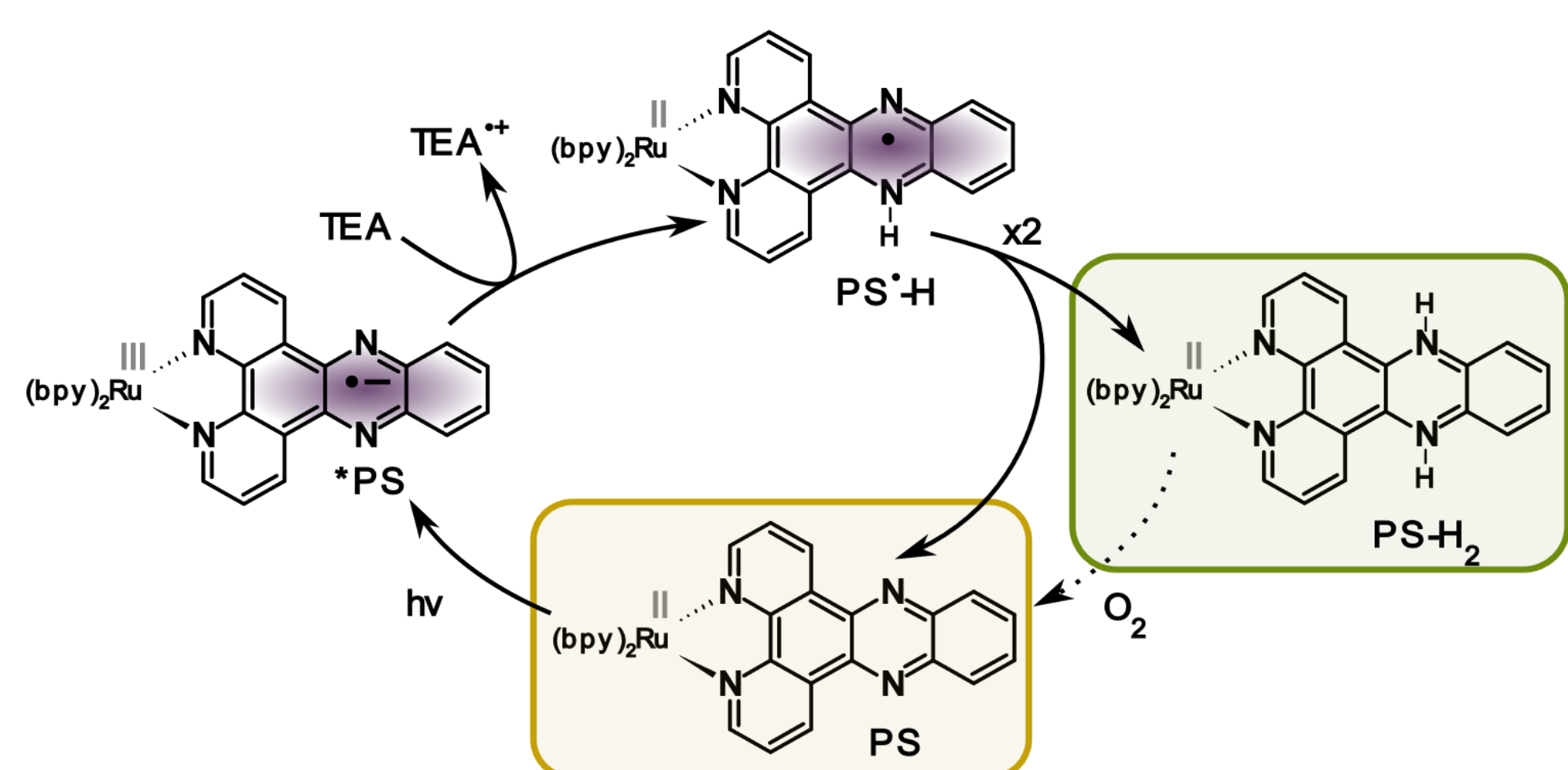


Figure 3: Mechanism of the light-driven hydrogenation of $[(\text{tbbpy})_2\text{Ru}^{\text{II}}(\text{dppz})\text{Cl}_2]^+$ PS (yellow), forming PS-H₂ (green) via *PS and PS-H. For the sake of clarity, the chloride anions are not shown.

A first simplification of the experimental set-up was tested for use in school. A minimal amount of the chromophore (PS) is placed in a UV-transparent plastic cuvette and successively 0.5 mL dem. Water, 2 mL acetonitrile (ACN) and 0.5 mL triethylamine (TEA) are added. The measurement and irradiation is performed in the LabPi photometer developed within the project (Figure 8, left side) and is carried out in an interval of 9x60 seconds of illumination of the sample by UV-LED ($\lambda_{\text{max}} = 392 \text{ nm}$) and recording of the readings after 10 seconds of irradiation by the red LED ($\lambda_{\text{max}} = 632 \text{ nm}$). The absorption coefficient is determined from the transmission at 392 nm in the solvent mixture alone and with the complex (20 μM) before illumination (Figure 4). Compared to the recording of the reaction course with the research spectrometer, the values recorded by the LabPi are lower. However, this is due to the cost factor as well as the changed reaction conditions, under oxygen exclusion vs. oxygen atmosphere. The experiment has shown that the students can be provided with a device that is suitable to follow the experiment and the reaction course.

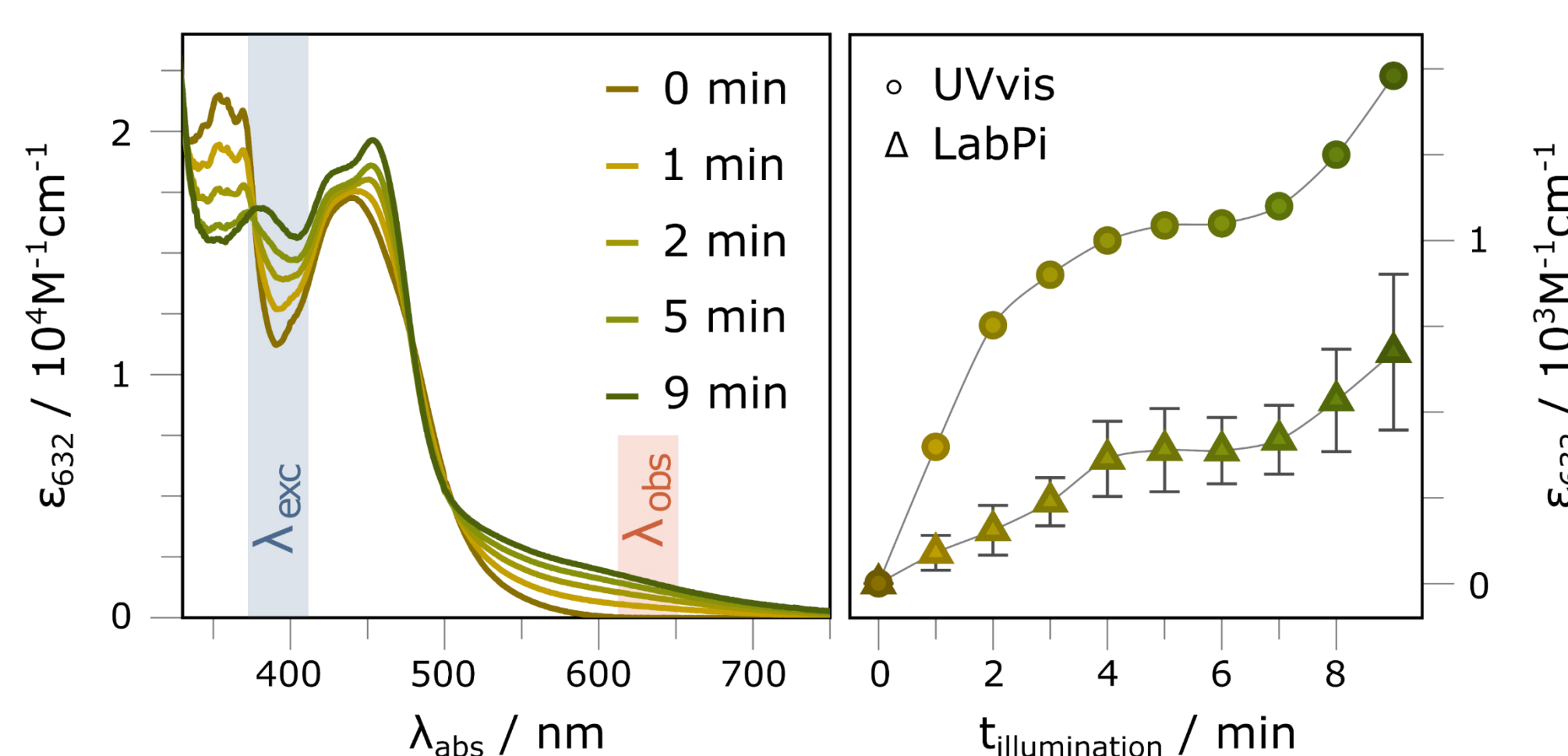


Figure 4: Left: Monitoring of the light-driven formation of PS-H₂ (green) from PS (yellow, 20 μM) upon LED-illumination at 455 nm (5 mW) in the presence of 1.0 M triethylamine by means of UVvis absorption spectroscopy. Right: Increase of absorption at 632 nm in the course of the photoreaction corresponding to the data as shown on the left side and collected using the LabPi (LED-illumination at 392 nm, c(PS) = 20 μM , c(TEA) = 1.2 M).

Tracing a Hydrogen Evolution Reaction with Sunlight for School Chemistry Education [3,4]

The process that takes place for the transfer of knowledge into the school is summarized under didactic reconstruction. This is necessary because, due to the high degree of specialization, current (basic) research is usually very demanding and difficult for learners to understand. Especially in understanding light, there are inaccurate biases or misconceptions on the part of learners that need to be considered. An overview of the decisions made towards the system available to learners is shown for the following experiment in Figure 5.

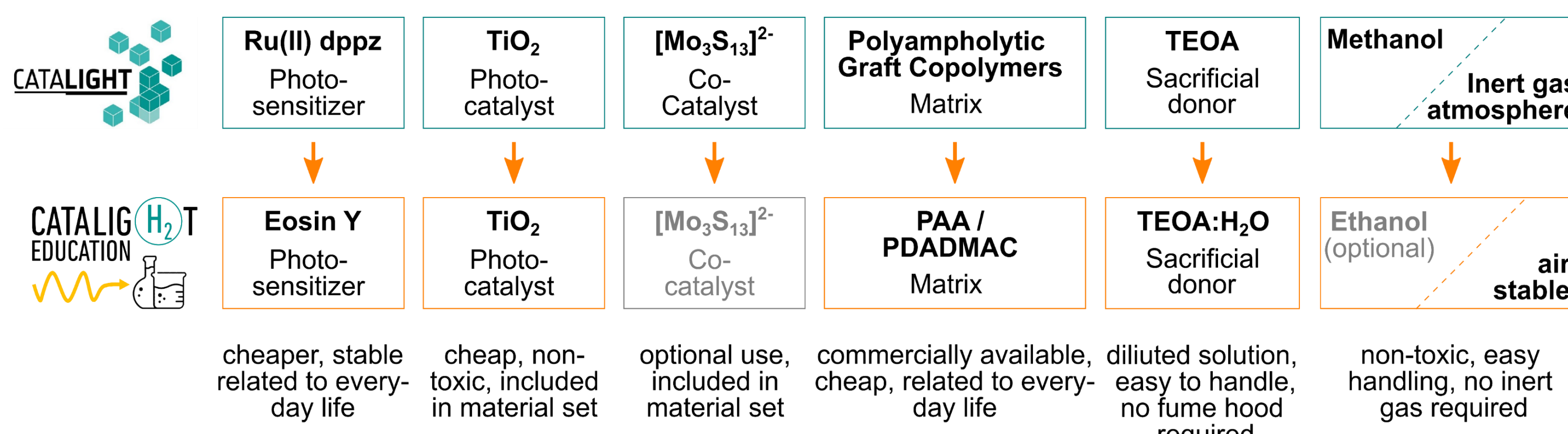


Figure 5: Development of a simple system for photocatalytic water splitting for student laboratories. The changes from the system used for CATALIGHT Education are highlighted in orange.

The photocatalytically active system developed in this process consists of three essential components. Here, the nanoparticles of the catalyst TiO_2 (CAT) alone are capable of photocatalytic hydrogen evolution when irradiated with UV light, serving as both light collector and catalyst [5]. In order to shift the required light energy into the visible range and thus extend the use of the solar spectrum, TiO_2 is supplied with the necessary electrons by the use of a suitable photosensitizer eosin Y (PS). Thus, the excited PS enables the transfer of electrons from the sacrificial electron donor triethanolamine (TEOA), which provides the electrons needed for the reduction of protons to molecular hydrogen, to the CAT, which in turn can reduce protons to molecular hydrogen (Figure 6).

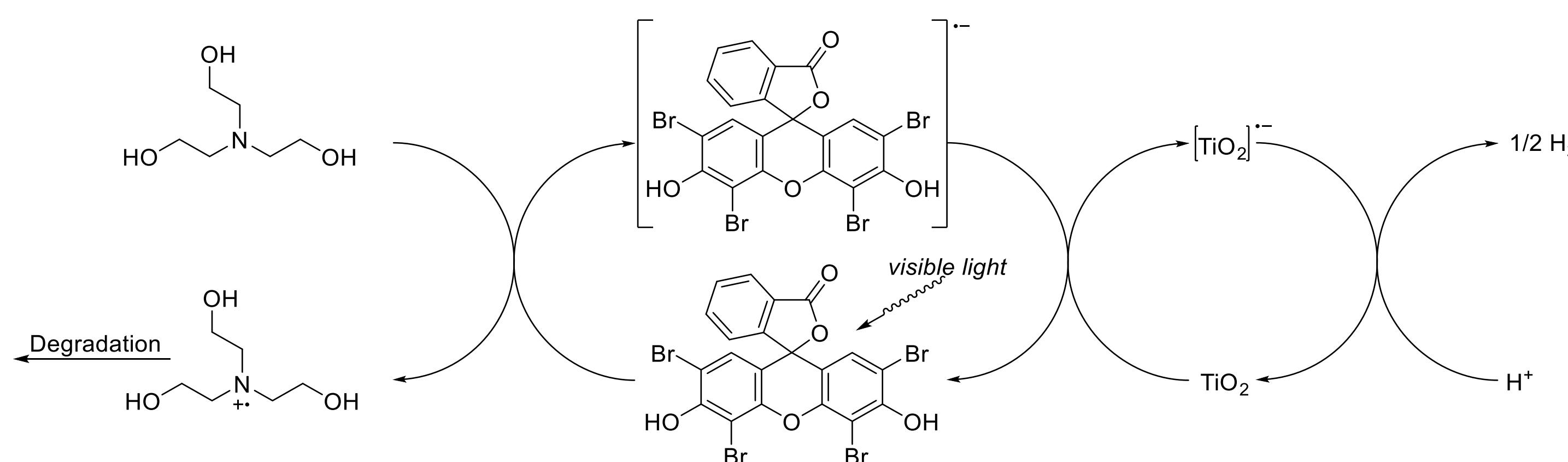


Figure 6: Reaction scheme for visible light-induced hydrogen evolution catalysis using TEOA as sacrificial electron donor, eosin Y as photosensitizer and TiO_2 as catalyst.

This system is supported by the use of a polymer matrix. A combination of commercially available polymers that form polyampholytic complexes was used to mimic the unique stabilizing properties of a custom graft copolymer found in the literature. In this regard, numerous reports utilize the ability of poly(acrylic acid) ("PAA") and poly(diallyldimethylammonium chloride) ("PDADMAC") to form pH- and ionic strength-dependent complexes in solution [6]. With this polyelectrolyte combination, we target a suitable soft matrix to perform photocatalytic studies. In initial investigations with the developed low-cost hydrogen sensor of the LabPi system (Figure 8), an increased hydrogen evolution could be measured in the system with the polymer matrix compared to the system without polymer (Figure 7).

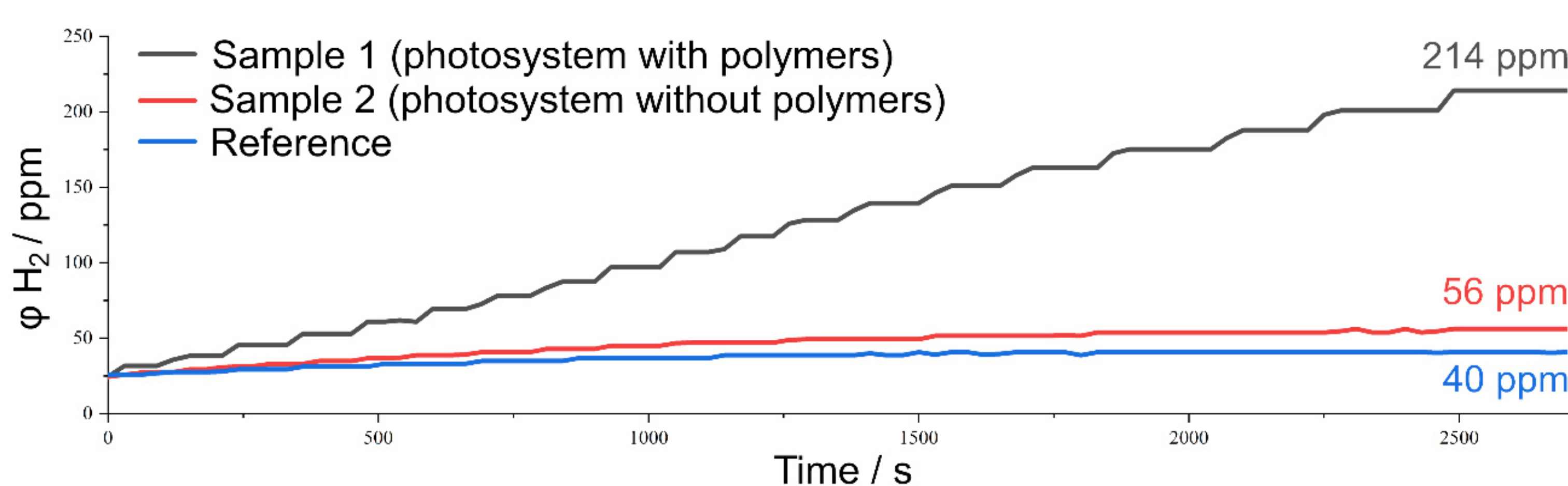


Figure 7: Comparison of hydrogen measurement by the low-cost LabPi sensor from a sample with and without polymer matrix. Sample 2: c(eosin Y) = 0.17 μM , c(TiO_2) = 0.66 μM , c(TEOA) = 667 μM . (A). Sample 1: sample 2 + c(PAA) = 1.33 μM , c(PDADMAC) = 1.86 μM . Reference: Sample 2 without TiO_2 .

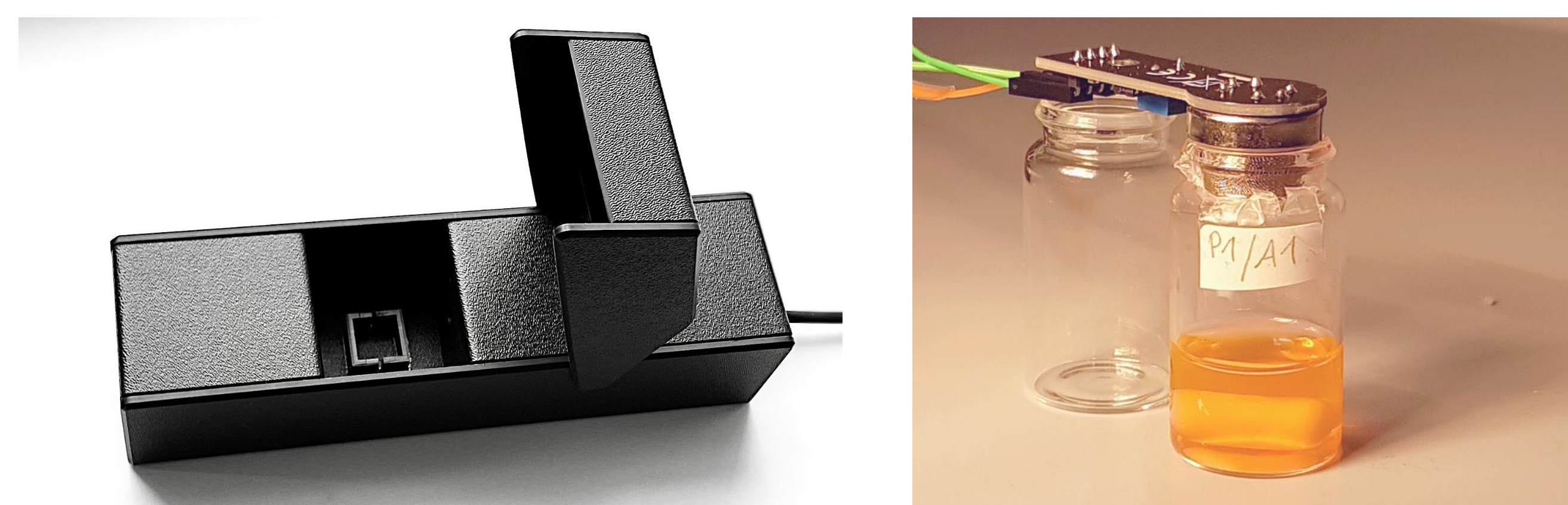


Figure 8: Left: Image of the LabPi photometer with open measuring chamber and view of the holder for the cuvette. Right: Image of the prototype of the hydrogen sensor for the LabPi system.

References

- [1] Wejner, M., Wilke, T. (2022). LabPi: A Digital Measuring Station for STEM Education 4.0. J. Chem. Educ. [2] M. Petersen, C. Müller, M. Wejner, S. Rau, B. Dietzek-Ivanšić, T. Wilke in International Conference Proceedings. New Perspectives in Science Education 11th Edition. Hybrid Event, 17-18 March 2022 (Hrsg.: Pixel), Filodiritto Publisher, Bologna, 2022, S. 110–115. [3] M. Petersen, P. Worliczek, J. B. Max, A. Nabiyan, M. Wejner, J. Eichhorn, C. Streb, F. H. Schacher, T. Wilke, WJCE 2021, 9, 190. [4] M. Petersen, J. Eichhorn, F. H. Schacher, T. Wilke in International Conference Proceedings. New Perspectives in Science Education 11th Edition. Hybrid Event, 17-18 March 2022 (Hrsg.: Pixel), Filodiritto Publisher, Bologna, 2022, S. 73–79. [5] Bakbolat, B., et al. (2020). Recent Developments of TiO_2 -Based Photocatalysis in the Hydrogen Evolution and Photodegradation: A Review. Nanomaterials (Basel, Switzerland) 10/9. [6] Alonso, T., et al. (2013). Study of the multilayer assembly and complex formation of poly(diallyldimethylammonium chloride) (PDADMAC) and poly(acrylic acid) (PAA) as a function of pH. Soft Matter 9/6, 1920–1928.