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Interdisciplinary Projects in Biology and Chemistry

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Abstract: Since 1998, Thun High School has developed and implemented interdisciplinary, problem-based learning projects with the aim of preparing students for the successful completion of their Matura thesis. These projects have been integrated into the specialised subjects biology-chemistry course. To date, 11 large-scale projects and a number of smaller projects have been created. As well as teaching subject-specific content, these projects also develop interdisciplinary skills such as: self-organised learning; using scientific publication formats; conducting literature research; organised collaboration; and the preparation for the oral Matura examination. Each class completes at least three of these projects in the core biology-chemistry course. As teachers, we increasingly withdraw from instruction and guidance, thereby giving students more responsibility for the success of the project. This article presents the didactic concept using a concrete example and provides links to further information and insights into our various projects. Additionally, student feedback is presented, as well as the challenges and opportunities of interdisciplinary teaching.

Keywords: High school · Interdisciplinary · Matura thesis

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Thomas Hari is a chemistry teacher at Thun High School. He studied biochemistry at the University of Bern. He completed his PhD in Biochemistry and Molecular Biology at the Faculty of Medicine. He then completed his training at the University of Teacher Education in Bern. In his lessons, he repeatedly emphasises the importance of interdisciplinary collaboration with other subjects.

1. Introduction

The idea for these teaching units emerged with the introduction of the Matura thesis at Bernese high schools 1998. The intention was that all students at our high school would complete preliminary projects to gradually introduce them to the skills needed to independently develop and self-organize a larger project, such as the Matura thesis. This was intended to guide students 'into freedom' and prepare them for the Matura thesis itself. As the teaching staff could not be persuaded to implement the project comprehensively, it was limited to our specialised subjects of biology and chemistry (BC) and, to a lesser extent, the core subjects of biology and chemistry.

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Our students complete three projects during their high school education, between G2 and G4. Each project is based on a phenomenon that needs to be examined and explained. This structure corresponds to 'problem-based learning' (PBL), as used in medical studies at the University of Bern. We received advice on this PBL-style structure from Barbara Stadelmann and Banu Yürüker, both responsible for medical studies at the University of Bern.[1,2] We received further encouragement and input at a continuing professional development course at the 'Pädagogische Hochschule Bern', led by Peter Labudde and Peter Heiniger. This course focused on assessment models and project work in interdisciplinary teaching. The arch model was discussed, as later described in detail by higher education didactician Manfred Künzel (see Fig. 1).[3]

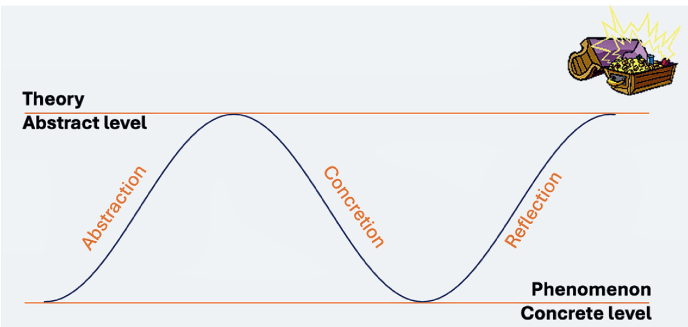

Fig. 1. **Arc model**, while regular lessons often only cover part of the arc, PBL-style teaching aims to develop a theory based on a phenomenon (*abstraction*). This theory is then used to process the relevant phenomenon in more concrete terms (*concretion*), before being embedded in the theory (*reflection*). This final stage is a central component of any research project and thus adds to one's personal knowledge base (*treasure chest*). To find suitable, curriculum-compatible interdisciplinary project topics, we attended each other's lessons throughout all three grade levels of a class in 2003 to 2006.

This formed the basis for our interdisciplinary collaboration, which has continued to develop and extend to other courses, such as facultative, supplementary, and basic courses, particularly those from the MINT report, as well as the format of our Matura examination in the focus subject BC. Further information and insights into our interdisciplinary collaboration can be found at:

https://sites.google.com/gymthun.ch/mint/startseite

https://sites.google.com/gymthun.ch/brunnerhari/einleitung

2. Example of a First Project

2.1 *Phenomenon*

Several branches of *Elodea canadensis* (waterweed) are immersed in a colourless, reduced indigo carmine solution and exposed to a strong light source. The process of photosynthesis releases oxygen, which oxidises the indigo carmine and turns the solution blue (Fig. 2). This experiment is demonstrated live to the students. If the experiment fails (which can happen if the Elodea is not active enough), a time-lapse film of the experiment is shown instead.

2.2 *Task of the Students*

The students must now work in groups of four to five people to formulate the learning objectives they need to achieve in order to gain a sound understanding of the phenomenon and be able to explain it as specifically as possible. The following questions will help them:

Fig. 2. **Elodea turns blue**, with the help of photosynthesis, the Elodea plant oxidises a reduced yellow indigo carmine solution, turning it blue. The corresponding film can be viewed here: https://youtu.be/5vj0J8ho8z8.

- What do we already know from class?
- What do we need to learn more about?
- What is still completely unknown?

After the lesson, we will help the groups to answer these questions and provide them with a reading list and practical instructions to help them develop the relevant theory and carry out practical exercises designed to reveal specific aspects of the phenomenon (abstraction in the arc model; see Fig. 1).

In this example, groups receive practical instructions and a reading list for their project on the following topics:

- Azo dyes.
- Phthalic dyes.
- Synthesis of phenylpolyenals.
- Dyes as a linear box with the corresponding excitation energies (The wave mechanical atomic model will be familiar from lessons).
- Recording spectra with the corresponding dyes.
- Presence of light reaction and Calvin cycle.
- Anatomy of chloroplasts.
- Properties of sunlight.
- Photosynthesis pigments (chlorophyll and carotenoids).
- Light absorption and excitation in photosynthetic pigments.
- Energy carrier molecules (ATP and NADPH).
- Reactants, products, and process of the light reaction.
- Reactants and products of the Calvin cycle.

The students then work independently, either in the laboratory or on the theory.

The scope is deliberately chosen so that not everyone in the group can do everything. Students must therefore teach each other the material they have learned at group meetings and present the results of the practical exercises. Ideally, as part of this process, they should explain and clarify the original phenomenon (concretisation in the arc model, see Fig. 1). We teachers participate in these group meetings, intervening only if the discussion takes an incorrect technical direction. Otherwise, the groups organise themselves independently and carry out the assigned work according to their own plan.

The groups must then write a report that explains the phenomenon and link it to the theory they have learned (reflection in the arc model, see Fig. 1). Once the reports have been corrected and returned, all students must individually take a 10–15 minute oral exam. The questions are identical within a group. The oral exam also serves to familiarise and prepare students for the oral Matura exam.

2.3 *Time Management and the Role of Teachers*

A project typically runs for around four weeks. During this time, students can attend all the chemistry and biology lessons relating to the project. This equates to 24–26 lessons in total. During the four-week period, students can organise their time as they wish. They can also work on projects alongside their lessons, in consultation with their teachers.

Both teachers are present at all lessons (team teaching), as far as the timetable allows. Otherwise, students are free to seek our help. This can be done in person or by email. Students receive only as much support as is necessary. This means that we only answer specific questions or provide hints as to where they can find the answers themselves. During the group meetings, if we notice that students are getting bogged down in thematic details, we will guide them back on track.

2.4 *Differences in the Second and Third Project*

The second and third projects are structured similarly but with another interdisciplinary topic. For the second project in G3, we only provide the groups with laboratory instructions. They must obtain the relevant literature themselves. We only assist with the formulation of learning objectives if necessary. For the third project in G4, students are only given a specific phenomenon to explain, along with questions for small-scale investigations (practical work). They must develop or search for the methods themselves. We will only help if questions or problems arise.

Students should always work with other group members on the three projects if possible. This is because later on, they will not always be able to choose their colleagues, whether in a job or during their studies.

2.5 *Assessment – Grades*

Each of the three projects has a different end product: the first project involves writing a report, the second involves giving a presentation, and the third involves creating a poster and a website. Group grades are given for each of these. The assessment criteria in our Matura thesis guide applies to the report and presentation. Posters are assessed according to the ETH guidelines for poster presentations.[4]

This group grade counts for 50%, while the oral test (see Chapter 1) counts as an individual grade, also counting for 50%.

The development process is assessed based on participation in group meetings. After every meeting, all students receive a 'fulfilled' or 'not fulfilled' rating. A student is considered to have fulfilled the requirement if they contribute relevantly to the discussion. Two 'passes' result in the student receiving half a grade credit on top of the previously determined overall grade. Two 'fails' result in a half-grade deduction. One 'pass' and one 'fail' mean that the overall grade is determined by the group work and the oral test.

3. Other Interdisciplinary Projects

Throughout our collaboration, we have developed a wide variety of projects. This has given us the opportunity to carry out different sequences of projects in successive years.

Further information and examples of student work on these topics can be found at:

https://sites.google.com/gymthun.ch/brunnerhari/einleitung/gemeinsame-arbeiten/pbl-projekte-im-schwerpunktfach

Alternatively, you can access them *via* the QR code (Fig. 3).

- Alcohol synthesis and degradation.
- Macromolecule synthesis and degradation.
- Biochemical detection methods.
- Elodea turns blue.
- Galvanis' wriggling frog legs.
- GFP+.
- Greek meal.
- Nitrogen cycle.
- Snake venom.
- Wood.
- Equilibria in biology and chemistry.

Fig. 3. Further information on interdisciplinary projects.

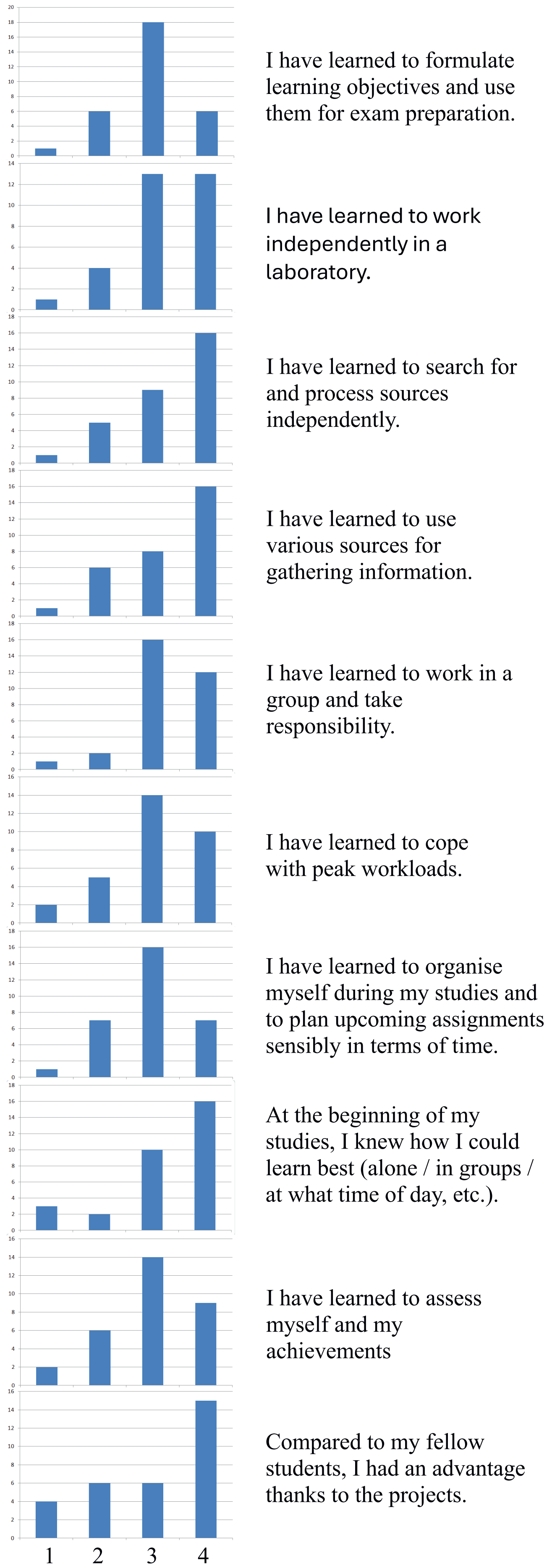

Fig. 4. **Feedback of former students**, possible answers were 'does not apply at all' (1), 'does not apply' (2), 'applies' (3) and 'applies completely' (4); y-axis: number of students.

4. Student Feedback

Regarding self-organised learning, it should be noted that most students found the balance between independent and guided learning to be appropriate. Several students also mentioned that their independence had increased as a result. Furthermore, many felt that these projects had prepared them well for university. Interestingly, many respondents said that the oral exam should definitely be kept. Students felt that it prepared them well for the oral Matura exam.

We also collected feedback from former students who are now at university and had completed these projects with us (see Fig. 4). The response rate was 50%.

Most students (23 people) estimate that they understood the theory from the projects just as well as they would have done with other teaching methods. Five people feel that they learnt more, and two feel that they learnt less. One person did not provide any information on this.

5. Conclusions

Interdisciplinary teaching poses a number of challenges for teachers, school administrators, and education authorities.

- Subject-based thinking must be partially abandoned.
- There is additional work to be done.
- Additional effort should be rewarded, but not all cantons or schools are equally willing to offer interdisciplinary teaching or fully remunerate teachers for team teaching.
- People must be willing to work together (teachers are usually lone workers).
- Ideas for feasible projects are needed. Tip: experience has shown that AI can help here, as demonstrated by one example.
- The necessary timetable and room planning can be problematic.

On the other hand, interdisciplinary teaching offers benefits that should not be underestimated.

- While current teachers have 'grown up' within the boundaries of their own subjects, students learn to focus on phenomena and problems rather than individual disciplines. They take this new perspective with them into further education or the professional world.
- This interdisciplinarity is undoubtedly one of the central requirements for explaining phenomena of all kinds, developing innovations, and solving global challenges such as food production, medicine, environmental and climate protection.
- We also repeatedly observe how interdisciplinary collaboration leads to mutual enrichment and great motivation. Last but not least, this cooperation strengthens human cohesion across disciplinary boundaries.

In this sense, we would like to recommend our interdisciplinary approach as a model for others to follow.

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[3] M. Künzel, 'Projekte und Maturarbeiten', [Online]. Available: https://drive.google.com/file/d/0B4x9amCQ0aD3TW9GZjRPR0E2VzA/view?resourcekey=0-BIp2z20mSQTegaA5-GscUA. [accessed on August 15, 2025].

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