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The Biomedicine Project Course: Promoting Young Scientists at School and University

Note

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1. Introduction

This article presents a cooperation project between science and schools, which aims to provide high-achieving students with initial research experience at university and at the same time to encourage these students to take up medical or scientific courses of study. This is linked to the university's perspective of being able to attract potentially outstanding young scientists, especially in biomedical research. Thus, the project offers a win-win effect for all parties involved from school and university (Irmer, 2012). Feedback from an online survey of participating project students illustrates that even high demands can be motivating for students if the offer meets the students' interest and leads to experiences of self-efficacy. This article is intended to encourage the search for such opportunities for cooperation between schools and universities and to focus more strongly on their importance in generating young scientists.

2. Project background

Science thrives on researchers who, with their special curiosity, produce new insights into our world. However, curiosity alone is not enough; researchers need special skills such as problem-solving competence, creativity, but also stamina. In the field of medical research, the problem is that too few students are interested in the research perspective. One of the reasons for this is assumed to be an insufficient basic education in science (von Dülmen et al. 2006). For this reason, a cooperation project between school and university was established to stimulate interest in research among high scholl students at an early stage.

The cooperation existed for 5 years between the Hospital of the University of Duisburg-Essen and the Gymnasium Essen-Werden (grammar school). A teaching subject so-called "project course" was established at the school, which was integrated into the Research Training Group 2098 Biomedicine of the Acid Sphingo-myelinase/Acid Ceramidase System funded by the German Research Foundation (DFG). The Research Training Group consisted of 11 research projects of the University of Duisburg-Essen. In addition to the research groups in Essen, there was also cooperation with Cornell University in New York (USA). The medical and scientific research focus of the program includes a wide range of medical fields from tumor research, bacterial and viral infections, and cardiovascular diseases, all of which are related to the metabolism of specific membrane systems, the sphingolipids. The importance of the biochemical reactions of sphingolipids are very diverse, e.g. they have an influence on signal transduction in cell-cell communication (Henry, Ziobro, Becker, Kolesnick & Gulbins, 2013). The field of sphingolipids is thus very complex and represents a highly specialized area of basic medical and scientific research. The purpose of establishing the Research Training Group was to attract motivated and high-performing young researchers to this branch of research and to promote them within the framework of qualification programs such as dissertations. The goal of the Research Training Group, to promote young scientists, was also transferred to high school students in grade 11 (aged 16 to 18 years) in this project. The integration of the students into the graduate program is justified by the need to strengthen science at school, especially with the aim of training and inspiring competent school leavers with university qualifications for science and medicine (cf. van Ackeren et al. 2007). Figure 1 shows an overview of the institutions involved.

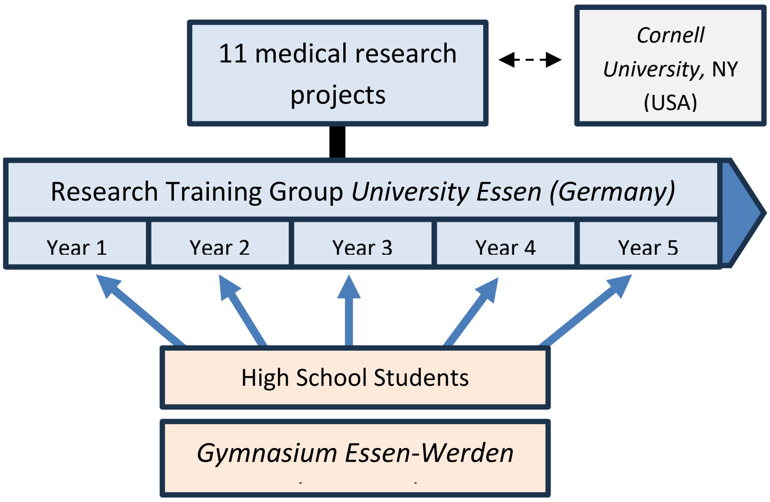

Figure 1. Overview institutions

A research training group is a temporary program at a university to promote young scientists. As a rule, university graduates can earn their doctorate or postdocs can further their qualifications here. High school students are at a grammar school and still must achieve their final qualification (in Germany: "Abitur"), which entitles them to study at a university.

The school curriculum provides for the establishment of so-called project courses, in which cooperation between university and school is possible, but rarely realized in practice (Ministerium für Schule und Weiterbildung des Landes Nordrhein-Westfalen, 2013). In this cooperation to the graduate college, the students were enabled to work scientifically on their own research projects. The subject didactic perspective of science thereby pursued the goal of awakening enthusiasm for research and making science tangible, thus shaping the project course as a concrete undertaking in the didactic concept of Nature of Science (Ertl, 2010; Heering & Kremer, 2018). By directly participating in the science enterprise, students should not only acquire (subject-) scientific knowledge, working and research methods, but they should also experience and participate in the provisionality of medical, scientific knowledge, the scientific discourse around findings, and the social embeddedness, e.g., by interacting with the other people in the research units. This constitutes a complex space of experience in which outstanding interests and abilities can crystallize.

3. Project implementation

The content-related demands and the time frame of the project posed a particular challenge for the students, who had to be prepared to work on their own research projects in a flexible, disciplined and highly committed manner. This can be seen from the fact that some students took advantage of the university's offer and worked full days in the lab on weekends. In view of the expected high demands, participation in the project course was restricted by nomination of the students. The nomination was based on two criteria, firstly on the subject allocation of a science profile and secondly on the recommendation of teaching subject teachers of the students. The science profile was characterized in particular by the focus (advanced course), so in of the total N= 60 participating students 55% had an advanced course in biology, 27% an advanced course in chemistry and 18% an advanced course in physics. The gender distribution was relatively balanced, with 55% girls and 45% boys.

The students' subject assignments were able to support project participation, for example through the subject of biology, since the basics of cytology are covered here in the curriculum. This also applied to the subject of chemistry, as the introductions to reaction kinetics, chemical equilibrium and organic chemistry had been helpful. However, it seemed more important to have a basic interest and understanding of science, as well as a willingness to perform in order to participate in the project course. Therefore, the students were required to work through the learning content of the university events mostly independently, while the school supervision mainly took on a supporting function.

4. School support of the project course

The school preparation for the technical context of the project course was implemented by a short intensive course on biological-chemical basics. Further support was provided primarily at the organizational level of the events and in the form of methodological and technical support, insofar as this was possible for the teachers. The further methodological and technical support consisted mainly of the documentation and presentation of the research results, as well as a didactic reduction or reconstruction in the case of content-related queries on the part of the students.

5. University support of the project course

For the most part, the project was implemented by the university or the staff of the graduate college. In the first half of the project course, a weekly seminar was set up in the winter semester, which included a weekly alternating laboratory practice part. In the second half of the semester, there were individually supervised project groups and thus a more flexible implementation in terms of time in the various research groups.

In the seminar, scientific basics and research methods were taught exclusively for the students by university lecturers, while in the following week the working methods were applied practically in the laboratory. The practical units took place in small groups, which were supervised by scientific staff. Supervision consisted of instruction in subject-specific methods, on the one hand, but also in helping students transfer theory into concrete, practical application. Typical event sequences were, for example:

- Week 1 Seminar: Proteins - Week 2 Practical: Proteins
- Week 1 Seminar: Cell Death and Cell Proliferation - Week 2 Practical: Cell Death & Cell Proliferation

In particular, learning and work assignments in the internship part corresponded to the requirements in medical school, as the following excerpt shows (Figure 2).

> Proteins
>
> a.) Deparaffinize histological sections (prepare lung, liver 25x sections), stain with H&E stain, view in small microscope. In addition, prepare 10 sections, cover and view in a microscope (100x).
>
> b.) View in confocal microscope fluorescence staining.
>
> c.) Prepare and develop western blots of experiment I. To do this, prepare the membranes and shorten all incubation and washing steps.

Figure 2. Work order example

In addition, there were additional offers with further qualification measures within the Research Training Group, in which the students could freely participate. These included further guest lectures by scientists, conferences, workshops, etc. If necessary, students could be released from regular classes at school to participate in these offerings, in the spirit of the revolving door model (Renzulli, Reis & Smith, 1981; Greiten 2016).

In the second phase, the students worked on their own research project in close cooperation with the researchers from the Research Training Group. Here, the students were to apply the expertise they had gained in the first phase. An important goal was to document and present the research results. Within the framework of the graduate college, the students were to present their projects and discuss them scientifically at scientific symposia with other researchers. These symposia took place annually at different institutes, e.g. at Cornell University in New York, at the Institute of Virology at the University of Würzburg, at the University Hospital of the Goethe University in Frankfurt am Main and at the University Hospital of the University of Duisburg-Essen. Here, the students' contributions were integrated into the conference programs of the scientific symposia and treated equally with all other contributions. The language of presentation was always English.

As an example, the following working titles shows those of students' research projects:

- „Optimization of intracellular signal transduction ways of the acid ceramidase“
- „Role of sphingolipids in viral infections“
- „Staphylococcus aureus α-toxin disrupts endothelial tight junctions via acid sphingomyelinase, ceramide and stress-activated protein kinases“
- „Regulation of neuronal stem cell proliferation in the hippocampus by endothelial ceramide“

6. Evaluation of the project

A systematic evaluation of the program objectives mentioned at the beginning would have required accompanying scientific research, but this was not planned for this project. Nevertheless, an online survey of the participating students from the first four project course years was conducted at the end of the funding phase. These cohorts were no longer students at the time of the survey. The last course cohort was severely impacted due to the Covid-19 pandemic at the end, so no survey of this group was conducted. An anonymous online questionnaire containing closed and open-ended question formats was used to survey the previous cohorts. The closed-ended questions relate to the project course itself, the medical science research perspective, and the students' current or future career perspectives.

7. Results

Of the students invited to participate in the survey N=48, there are N=15 responses, which corresponds to a response rate of 31%. The responses are relatively evenly distributed across the four grades, regardless of how long ago the former students had graduated from high school. Figure 3 shows the closed questions related to the project course. The participants had to choose one answer option each.

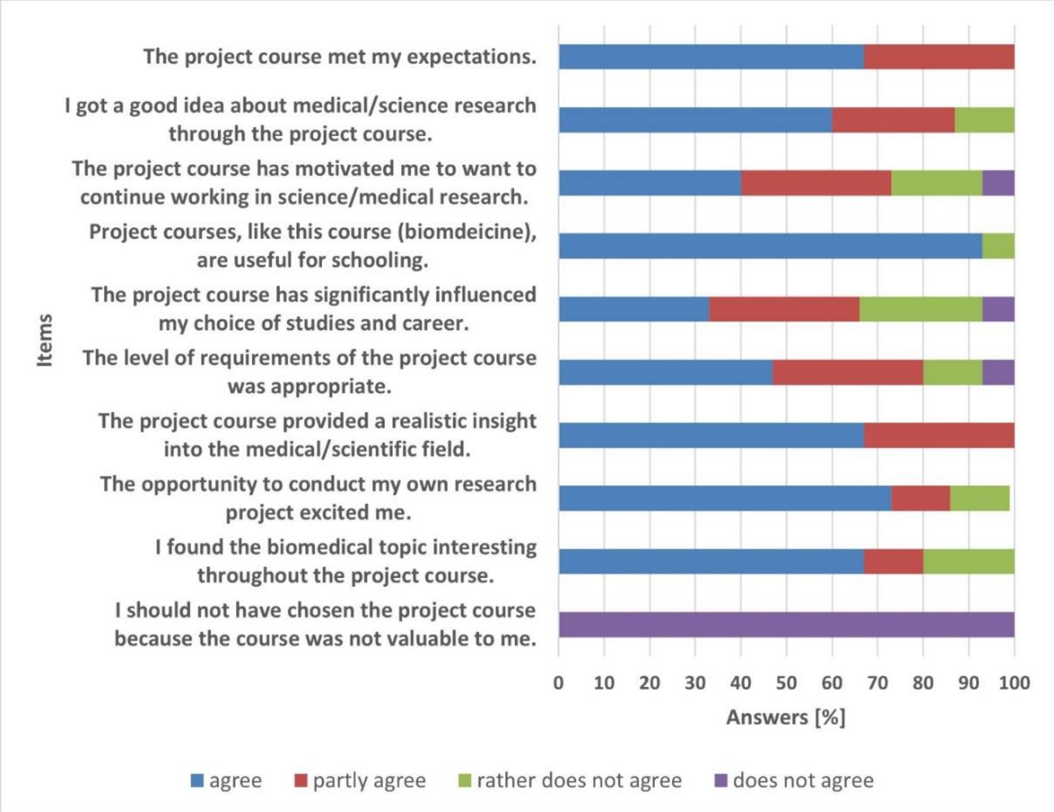

Figure 3. Results of the questionnaire (closed question form)

Most students estimate the level of requirements as appropriate (47%) and 33% gave partial agreement. The feedback without agreement is not further differentiated as to whether the requirements are assessed as too high or too low. There is a similar assessment regarding the expectations for the project course. Almost all students agree with the statement that the project course seems to be useful for their school education. These positive tendencies can also be found in the feedback on medical-scientific research. All questions regarding scientific and medical research show an overwhelming agreement of the students. This concerns the topic, the insight and the presentation about research as well as the possibility to do own research projects. Nevertheless, the project course was not able to motivate all students for a further activity perspective in research (agreement 40%). Not all of the students surveyed have started medical or scientific studies after graduation or have plans to do so. Including those who did not start studying directly after school, the proportion in favor of studies in the science or medicine outweighs those who prefer another field of study, as Figure 4 illustrates.

Items After graduating from high school, I ...	Number of mentions
... started studying directly - but not natural science or medicine.	5
... started studying directly - science or medicine.	7
... started vocational training (e.g. apprenticeship) - not in the scientific/medical field.	1
... started vocational training - in the scientific/medical field.	0
... something else than the above-mentioned options done.	1
… did not start studying directly after graduating from high school. But later I planned to study (but not medicine or science).	0
… did not start studying directly after graduating from high school. But later I planned to study medicine or science.	3

Figure 4. Orientations to study

The two open questions focus on the one hand on the aspect of what particularly impressed the students in the project course, and on the other hand on the possibility of a free commentary. The following statements illustrate the positive feedback:

“I was particularly impressed by ...

- ... being allowed to do research myself.”
- ... to take on responsibility to get to know the working world.”
- ... to gain professional experience.“
- ... the research, the process, the insight into the University Hospital Essen.”
- ... the possibility to gain special experiences already during the school career.”

"Participating in this project course was a valuable experience that I wouldn't miss. Although the required level of expertise was very high, especially for students without an advanced biology course, but I am convinced that this "throwing in at the deep end" has made me better able to deal with comparable situations in my studies. The course not only advanced me professionally, but also methodically and really broadened my horizons for my studies. I am therefore glad that this course has given me the opportunity to think beyond the normal school day."

Some of the students' research projects were able to produce fundamental scientific findings, so that publications in scientific journals could be realized. An overview of peer-reviewed publications with students in the authorship can be found in the following Figure 5.

Gulbins, A.*, Grassmé, H., Hoehn, R., Wilker, B., Soddemann, M., Kohnen, M., Edwards, M. J., Kornhuber, J. M. & Gulbins, E., (2016). Regulation of Neuronal Stem Cell Proliferation in the Hippocampus by Endothelial Ceramide. *Cell Physiol Biochem*; 39: 790-801. https://doi.org/10.1159/000447789.

Gulbins, A.*, Grassmé, H., Hoehn, R., M., Kohnen, M., Edwards, M. J., Kornhuber, J. M. & Gulbins, E., (2016). Role of Janus-Kinases in Major Depressive Disorder. *Neurosignals*; 24:71-80. https://doi.org/10.1159/000442613

Becker, A. K., Fahsel, B.*, Kemper, H.*, Mayeres, J.*, Li, C., Wilker, B., Keitsch, S., Soddemann, M., Sehl, C., Kohnen, M., Edwards, M. J., Grassmé, H., Caldwell,C. C., Seitz, A., Fraunholz, M. & Gulbins, E., (2018). Staphylococcus aureusAlpha-Toxin Disrupts Endothelial-CellTight Junctions via Acid Sphingomyelinase and Ceramide. *Infection and Immunity*; Volume 86, Issue 1.

Baduva, K.*, Büchter, L.*, Kreyenkamp, K.*, Westphal, L.*, Wilker, B., Kohnen, M., Schuchman, E.H., Edwards, M. J., Becker, K. A., Gulbins, E. & Carpinteiro, A., (2019). Signalling Effects Induced by Acid Ceramidase in Human Epithelial Or Leukemic Cell Lines. *Cell Physiol Biochem*; 52:1092-1102. https://doi.org/10.33594/000000074.

Bergermann,T.*, Born, L.*, Ferguson, F.*, Latkovic, P.*, Scheul, A.*, Sonnenschein, N.*, Leanza, L., Keitsch, S., Sehl, C., Wilker, B., Edwards, M. J., Zorattie,M., Paradisi, C., Kohnen, M., Szabob, I., Becker, A. K. & Carpinteiroc, A., (2019). Inhibition of PI-3-K and AKT Amplifies Kv1.3 Inhibitor-Induced Death of Human T Leukemia Cells. Cell Physiol Biochem; 53(S1):1-10. https://doi.org/10.33594/000000187

Figure 5. Publications with student participation (students)*

Some of the projects took part in the German "Jugend forscht" competition, where some students were able to successfully present their work in a different context and in front of a jury.

8. Discussion and conclusion

The goal of the cooperation project between university and school to motivate and promote scientific, research-oriented young talent already at school, as described at the beginning, can only be evaluated in a tendential way based on the rather explorative survey. However, the feedback shows that large parts of the students are interested in medical and scientific research and decide on a corresponding course of study. The decisive factor at this point could be that students were given the opportunity to participate in a real, authentic research context and that this was associated with a positive self-efficacy experience. This includes that the challenges were not only on the professional, but also on (cf. Bergmüller, 2019 the social, communicative level. Comparable experiences have been shown, for example, in the Göttingen experimental laboratory XLAB (Neher 2012).

The fact that the requirements were largely perceived as appropriate by the students suggests that the potentials of the students were correctly assessed when they were nominated. The research results and their documentation illustrate the learning successes in the subject area and in the area of experimental and scientific working methods (cf. Henke, 2007).

Overall, the cooperation project between science and school in the form of this project course appears to be a measure that promotes young talent and can result in benefits for both science and research. For students with outstanding potential, this project arrangement seems to represent a suitable enrichment (cf. Schüttler & Hausmann 2019), in which they can pursue interest-driven study and career perspectives and achieve special achievements. Despite the methodological limitations and the small, non-representative sample, this feedback shows an overall positive evaluation of the project by the students. For the future, more comprehensive accompanying research for this project would be desirable.

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