Social and Ecological Responsibility within Engineering Education. A Modular Student-Driven Course Design that is Implemented at Seven German Universities.

Dr.-Ing. André Baier[1]

[1]Institute of Machinery Systems and Systems Technology, Technische Universität Berlin, Germany

andre.baier@tu-berlin.de

Abstract

The Blue Engineering Course is a student-initiated course design that addresses the social and ecological responsibility of engineering. Its student-driven character is achieved through a set of over 150 building blocks, these are well-documented teaching/learning units which are freely available online. The course consists of three parts so that the students gradually acquire the competences to co-conduct and co-develop the course: 1) Students get to know high quality building blocks conducted by a lecturer/student tutors; 2) Students conduct existing building blocks; 3) Students develop new building blocks, conduct them and document them for future use.

The design of the Blue Engineering Course has been implemented at Technische Universität Berlin since 2011. Here, over 100 students participated in 18 consecutive semesters. The course design is also successfully adapted and implemented at six other universities in Germany. In total, four exemplary implementations are presented and than analyzed with regard to the transferability and success factors of it implementation.

1 Educational Design of the Blue Engineering Course

1.1 Genesis of the Blue Engineering Course

The student initiative Blue Engineering - Engineers with Social and Ecological Responsibility, commonly shortened to Blue Engineering was the starting point for the design and conduction of a student-driven course at Technische Universität Berlin. A group of students clearly saw the need for a course that covers the social and ecological responsibility of engineers (Baier 2012). However, in 2009 the university was not offering any particular course on this topic, thus they decided to create a course on their own. So, they set off to design a course that they would like to attend themselves. Since engineering education is dominated by ex-cathedra lectures and summative assessments at the end of a semester, they disregarded any teacher-centered form of education. Instead, they opted for a student-centered approach, so that engineering students actively engage in unveiling the complex interdependencies of their social, political, ecological and economic surroundings. It is important that the participants themselves do this analysis so

that they start to grasp their personal responsibility as well as the collective responsibility of engineers (Baier and Pongratz 2013). This also requires that the participants would learn to consider the different values, interests and needs from a global perspective as well as within one class(room) (Pongratz and Baier 2015). The student group further called for a course design which encourages democratic decision-making and the corresponding action to not only solve, but also to define problems within the course itself as well as outside of the classroom. By designing the Blue Engineering Course in such a way, it has become not only a student-driven course with respect to its genesis (Baier 2013), but also in regard to its implementation as the participants acquire valuable competences to co-create their environment.

1.2 Building Blocks - Well-Documented Teaching/Learning Units

Key element of this student-driven design is the concept of building blocks, that is 15 to 90 minute long teaching/learning units. Each building block must provide an appropriate set of methods to enable any generally interested group with a maximum of 25 persons to acquire a certain insight into the ecological and social dimensions of technology. In order to reach this goal, building blocks are self-contained teaching/learning units that cover one specific topic and that provide different methods that engage the participants in co-conducting a lesson more or less by themselves. Therefore, the person conducting the building block does not function as an expert that simply conveys knowledge but as a facilitator that organizes a complex group process.

The over 150 existing building blocks cover a broad range of topics within the field of social and ecological engineering. Some of these building blocks help to thoroughly analyze single technologies, e.g. fracking, preimplantation diagnostics, while others address the general effects of technology on society or nature. There are a number of building blocks which address the individual sphere, e.g. food and living preferences, while other building blocks address the global sphere, e.g. agricultural industry, capitalism, climate change. Several building blocks particularly address the work-life of engineers and the concept of work in general.

Along with the wide variety of topics, every single building block uses a specific set of teaching formats such as case studies, storytelling and station learning. Most building blocks, however, rely on a specific adaptation and new combination of known methods, e.g. learning cascades, court trials and educational games.

Building blocks generally consist of a well-documented, easy-to-use manual that provides all relevant information about the specific content, respective sources, external partners and clear methodological instructions along with a timetable. They provide clear instructions to facilitate the respective building block as well as compact background information, that consider multiple perspectives. All existing building blocks are published under a Creative Commons License (2009), which allows the use of these building blocks if the derived work is licensed with the same license and if attribution is given. The building blocks are publicly available on the Blue Engineering website (2018). Most of the building blocks are in German, however an initiative has been taken to translate a core set into English.

Typically one or two building blocks are conducted in each lesson of the Blue Engineering Course. The following two sections present the course design and its implementation in order to provide an overview how building blocks are used in the course.

1.3 Course Design of the Blue Engineering Course

Generally speaking, the Blue Engineering Course can be divided into three parts. This division ensures a step by step process where the students gradually take over more and more responsibility in conducting their course and in developing the Blue Engineering Course for future generations of students.

The first part of the Blue Engineering Course consists of a fixed set of core building blocks that are conducted every semester. This first part of the course is entirely conducted by the lecturer/student tutors and covers four to six building blocks. The basic idea of this phase is to let the students familiarize themselves with the educational concept as they most likely have not yet participated in a similar course during their education. Consequently, the first weeks of the course are mostly about giving them the space to get to know each other as well as to explore the different opinions and values present in the group. This is done in order to unveil different perspectives on various topics and to help the participants to value these perspectives as an asset in order to take proper action as an individual and within a group.

In the second part of the Blue Engineering Course, the participants are supposed to keep this general setup once they take over by conducting existing building blocks and preparing their semester projects. Here, groups of three to six students conduct an existing building block to about 20 to 25 fellow students. By doing this, the students experience first hand how it is to conduct a demanding teaching/learning unit on a specific topic that makes use of a broad set of methods in order to create a meaningful learning environment. Here, they gain the competence to conduct a demanding and complex teaching/learning unit for others.

The third part of the Blue Engineering Course builds upon the first two parts. Parallel to the first two parts of the course, the students use their experiences in order to create new building blocks that they will conduct and document during the third and last part of the Blue Engineering Course. Here, the students gain the competences necessary to develop a demanding building block on their own and conduct it to their fellow students. This building block is then documented so that others may use it in the future.

1.4 Assessment of the Students

For a successful completion, the students have to fulfil three assignments: 1) keeping of a learning journal; 2) conduction of an existing building block to their fellow students; 3) the semester projects consists of the conduction and documentation of a new building block.

The learning journal and the conduction of an existing building block each make up 25 % of the final grade and are each assessed through five criteria. The semester project makes up the other 50 % of the final grade and are assessed through ten assessment criteria.

The conduction of an existing building block and the semester project set a strong focus on collective action as they are done by small groups of three to six students. The keeping of a learning journal throughout the whole course is the only individual assessment that takes place and for that, every student is responsible for him_herself.

2 Implementation and Evaluation of the Blue Engineering Course at Technische Universität Berlin

2.1 Overview of the Course Setup at Technische Universität Berlin

The Blue Engineering Course at Technische Universität Berlin is offered by the Chair of Machinery Systems Design. Responsible for the course is the head of chair Prof. Dr.-Ing. Henning Meyer. The course is coordinated by a person holding one half lecturer position who mostly coaches and supervises the student tutors. The course itself is conducted by three student tutors with a total of 120 monthly hours.

The *Blue Engineering* Course has a capacity of 75 students in total. The students are typically split up into three rooms, so that there is a maximum of 25 students in each room and one assigned responsible student tutor. The lessons 1, 3, 7, 10 and 14 are (partially) conducted with all 75 students in one room by all three student tutors together.

The course is credited with 6 ECTS points and a total of four course hours per week. A semester typically spans 14 weeks.

The *Blue Engineering* Course started as a compulsory elective course in three master study programs: Mechanical Engineering, Industrial Engineering and Computational Engineering Science. As of winter semester 2017/2018 the *Blue Engineering* Course is established as a compulsory elective in the bachelor programs of Mechanical Engineering, Industrial Engineering, Computational Engineering Science, Transport Systems Engineering, Sustainable Management and a STEM Orientation Study Program. Every other student may take this course as an elective in order to receive credit points or participate without a final assessment.

2.2 Course Plan of the Blue Engineering Course at Technische Universität Berlin

The following Table 1 gives an exemplary course plan for the Blue Engineering Course. The three parts of the course, discussed in the previous section, are highlighted.

Table 1: Exemplary Course Plan of the Blue Engineering Course

Week/ Lesson	Room - A	Room - B	Room - C
Conducted by Tutors			
1	Introduction all in room A		
2	Plastics - common start for all in room A including knowledge chest Plastics - Role Play		

3	Topic- and Group Finding as well as TINS-D Constellation all in room A		
4	Technology as Problem-Solver!?	Responsibility and Ethical Codes	The Productivist Worldview
5	The Productivist Worldview	Technology as Problem-Solver!?	Responsibility and Ethical Codes
6	Responsibility and Ethical Codes	The Productivist Worldview	Technology as Problem-Solver!?
Building Blocks Conducted Solely by Students and Created by former Students			
7	Work, Society and Labour Unions all in room A including external expert		
8	Global Village 25 Questions by Frisch	Automation vs. Good Jobs CO2 Usage	Climate Trial Phoneblocks
9	Microplastics Peak Everything	Democratization of Work Greenwashing	Blue Stories Prisoner's Dilemma
10	Gender, Diversity and Technology common start for all in room A including external expert		
	Anti-Discrimination Exercise	Anti-Discrimination Exercise	Anti-Discrimination Exercise
Newly Building Block Created and Conducted Solely by Students			
11	2 Student's Building Blocks	2 Student's Building Blocks	2 Student's Building Blocks
12	2 Student's Building Blocks	2 Student's Building Blocks	2 Student's Building Blocks
13	2 Student's Building Blocks	2 Student's Building Blocks	2 Student's Building Blocks
14	Final Lesson with Market of all Newly Created Building Blocks in Room A		

2.3 Evaluation of the Blue Engineering Course at Technische Universität Berlin

The descriptive statistical analysis of the participants of the Blue Engineering Course shows that the number of participants has continually risen (Baier 2018). In total, 831 students passed the exam across the 14 semesters from winter semester 2011/2012 until summer semester 2018. The course attracted

students from a broad range of study programs which generated an interdisciplinary working atmosphere. Roughly one quarter of the participants studied mechanical engineering and roughly one quarter studied industrial engineering. The remaining half of the students had a background in 44 different study programs. About 55 % of the students were enrolled in a master's program and roughly 40 % were enrolled in a bachelor's program.

A qualitative evaluation (Baier 2018) shows that each of the 12 learning outcomes on module level is addressed through a broad range of learning activities and learning assessments. Accordingly, the students are required to use the 12 sub-competences of Gestaltungskompetenz (Haan 2006; 2010) not only at one single instant during the course but they are required to demonstrate the use of these 12 sub-competences in many instances. This finding is further underlined through a comprehensive quantitative evaluation (Baier 2017; 2018) which covered five semesters in total. It consisted of a triangulation for three selected core building blocks and a comparative self-assessment of the student's perceived competences.

3 Exemplary Implementation at Three Other Universities in Germany

The concept of the Blue Engineering Course is taken up at six other universities in Germany: TU Dresden, TU Hamburg, HTW Berlin, TH Köln, HS Düsseldorf and HS Ruhrwest. Three exemplary implementation will be presented here. In two cases, students took the initiative to establish their own local adaptation of the Blue Engineering Course at their university.

3.1 Technische Universität Hamburg

The Blue Engineering Course at Technische Universität Hamburg-Harburg runs continuously since winter semester 2012/2013. There it is offered as a 2 point ECTS block course in the free elective area for all study programs. Bachelor students attend a block course on two weekends, while master students start with a kick-off event and conduct themselves a series of evening events. The two courses are conducted entirely by student tutors. Formally responsible for the course is a former member of the student group who initiated the course. She is now working as a lecturer.

3.2 Hochschule Düsseldorf

Since 2016, a Blue Engineering Course has been offered at Hochschule Düsseldorf as a 5 point ECTS course in the compulsory elective area of several bachelor study programs. The course takes place every week in the first half of a semester and concludes with a weekend block in the middle of the semester. A local professor initiated the course by inviting the course's lecturer of Technische Universität Berlin as visiting lecturer. In one six day block Blue Engineering Course the participants gained the competence to conduct the course on their own in the future. Three participants then served as student tutors for the following courses (Kramer et al. 2019).

3.3 Hochschule für Technik und Wirtschaft Berlin

Starting in winter semester 2018/2019, the Blue Engineering Course is offered in the "general scientific area" that is included in all study programs at Hochschule für Technik und Wirtschaft Berlin. The course is credited as a 5 point ECTS course. The course is conducted every other week for four hours across the

whole semester. The course is run by a student tutor of the course at Technische Universität Berlin in the position of a visiting lecturer. The objective of the course is to empower the students to offer their own Blue Engineering Course next semester.

4 Analysis of the Implementation of the Blue Engineering Course Design

4.1 Transferability to Other Contexts

The adaptation and implementation of the course to a curriculum of one's own university is usually not a problem, as the modular concept of the course allows it to be adapted easily. All in all, the four different implementations in total show that the design can be flexibly adapted to the respective conditions of a university and that its implementation might lead to a continuous incorporation of social and ecological responsibility within the engineering education. The various people involved in the Blue Engineering Courses also conducted numerous one day to six day workshops at other universities, such as TU Delft, Aalborg University and Sharif University of Technology Tehran. In addition, the building blocks are highly flexible and may be used in any educational setting where the role of technology within society needs to be addressed in an interactive manner.

4.2 Success factors and Challenges Encountered

The most important prerequisite for the establishment of the Blue Engineering Course are committed students who not only initially designed the course, but who later on took the responsibility as student tutors to conduct the course themselves. Over the course of 14 semesters, several generations of student tutors passed on their expert knowledge of conducting the course. The demanding work as a tutor, offering a complex, interactive course independently, also allows the tutor to acquire skills that would otherwise hardly be taught during their studies.

The implementation at another university may follow the example of Hochschule Düsseldorf. Here, the future tutors first participated in a Blue Engineering Course offered at their university and three of them wanted to offer the course themselves in the next semesters. In the first semesters of the implementation, the course was accompanied by a lecturer from Technische Universität Berlin. This support always took place in the background, so that the tutors were able to offer a course independently from the first week onwards. Over the course of two semesters, this professional and didactic support was continuously reduced, so that the tutors had to assume more and more responsibility for the implementation and familiarisation of new tutors.

In any case, a professor is needed who takes formal responsibility for a course which is largely conducted by students. More so, the professor needs to stand in for the course, within the faculty and needs to take care of the anchoring of a module description as well as providing the resources for student tutors. This patronage is decisive for establishing the course at a university.

The resources available for course support are not only the well-developed building blocks, but also an inter-university network of volunteers who are committed to the further development and maintenance of the course beyond their own course participation.

References

Baier, André. 2012. "Projektwerkstatt Blue Engineering." In *Der Systemblick Auf Innovation*, edited by Michael Decker, Armin Grunwald, and Martin Knapp. Nomos: 381–386.

Baier, André. 2013. "Student-Driven Courses on the Social and Ecological Responsibilities of Engineers." *Science and Engineering Ethics* 19 (4). Springer: 1469–72.

Baier, André. 2017. "Evaluation of a Stand-Alone Course on Sustainability and Engineering through Student Comparative Self-Assessment based on Learning Outcomes." In *Proceedings of the 45th SEFI Annual Conference, Angra do Heroísmo, Portugal*.

Baier, André. 2018. *Education for Sustainable Development within the Engineering Sciences. Design of Learning Outcomes and a Subsequent Course Evaluation*. Dissertation. Technische Universität Berlin. doi:10.14279/depositonce-8844

Baier, André, and Sabine Pongratz. 2013. "Collectively and Critically Reflecting on Technology and Society." In *Proceedings of the 41st SEFI Annual Conference, Leuven, Belgium*: 16–20.

Blue Engineering. 2018. Website of the Blue Engineering Project. http://www.blue-engineering.org

Creative Commons. 2009. "Creative Commons. Attribution-ShareAlike 3.0 Unported." https://creativecommons.org/licenses/by-sa/3.0/ - Last Access 2018-05-28.

Haan, Gerhard de. 2006. "The BLK 21 Programme in Germany: A 'Gestaltungskompetenz'-Based Model for Education for Sustainable Development." *Environmental Education Research* 12 (1). Taylor & Francis: 19–32.

———. 2010. "The Development of ESD-Related Competencies in Supportive Institutional Frameworks." *International Review of Education* 56 (2-3). Springer: 315–28.

Kramer, Tim; Igor Lerner; Patrick Sacher; Matthias Neef and André Baier. 2019. Forthcoming. Blue Engineering - Was ist das und wie gelingt die Implementierung and (m)einer Hochschule? in: 13. Ingenieurpädagogische Regionaltagung: *Diversität und Kulturelle Vielfalt - differenzieren, individualisieren - oder integrieren? Wege zu technischer Bildung.* IPW Verlag. 2019.

Pongratz, Sabine und André Baier. 2015. "Encouraging Engineering Students to Question Technological Solutions for Complex Ecological and Social Problems." In *Integrating Sustainability Thinking in Science and Engineering Curricula,* edited by Filho, Walter et al. Springer: 375-86. doi:10.1007/978-3-319-09474-8_27