"Creativity + Construction"
as part of the orientation program MINT^{grün}

L. Rademacher
Student Assistant in Creativity and Construction
Technische Universität Berlin
Berlin, Germany
E-mail: lisarademacher@gmx.net

C. Schröder
Research Assistant
Technische Universität Berlin
Berlin, Germany
E-mail: schroede@math.tu-berlin.de

Keywords: project laboratories, researched based learning, orientation studying, new focuses of engineering

INTRODUCTION

Since 2012 the Technische Universität Berlin offers a special one year orientation program called MINT^{grün} (in English: STEM^{green}). It is designed for young people, who just left school and don't know which direction to choose now. The target of MINT^{grün} is to show them, particularly young women, the countless possibilities of a future in sciences, technology, engineering and mathematics. The students have the advantage to try a lot of subjects, so they can figure out what these topics are actually about. Additionally we perform alternative ways of teaching by hands-on experience in the MINT^{grün} laboratories with terms like robotic, construction, environmental research, programming and mathematics. The basic idea in the MINT^{grün} labs is research based learning. Thereby we expect the students to get a better insight in different academic careers. [1]
In the course "Creativity & Construction" (C&C) – one of the MINT^{grün} labs – the students have to create real mechanical machines. After collecting ideas, what machines could be possible the student decides for one to build it in groups. The specialness of C&C is, that the students learn the facts and subject matters while they need it to complete their machines.

1 BRIEF OVERVIEW OF MINT^{grün} (in English: STEM^{green})

1.1 The Need of Orientation

After leaving school lots of young people feel a lack of orientation. They are expected to choose what to do for the next years of their life. This causes a lot of pressure and makes the decision even harder. That is one of the reasons why we offer an

orientation program at TU Berlin, to show those who are thinking about an academic future the countless possibilities of sciences, technology, engineering and mathematics.

1.2 The Structure of MINT^{grün}

MINT^{grün} takes two semesters and consists of obligate courses such as “Scientific Window” and an “Orientation Course” as well as facultative courses such as basic lectures and the MINT^{grün} laboratories. It is considered as a full time study program.

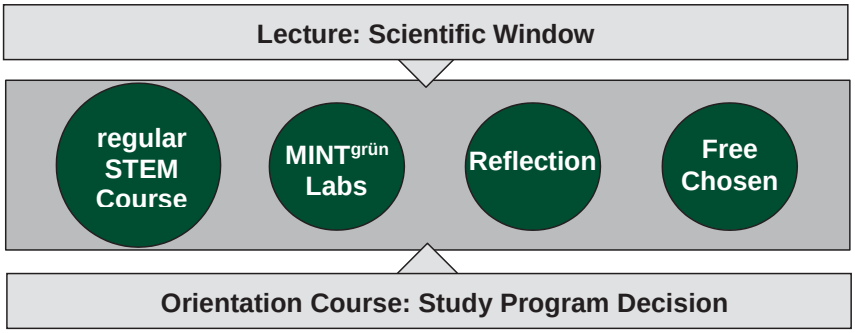

Fig. 1. Structure of the orientation program MINT^{grün}

The Orientation Course contains different ways of how to orientate, also how to use time or make decisions. By taking part at the basic lectures at different universities the students have the advantage to try a lot of subjects, so they can figure out what these topics are actually about. This is important because a lot of students can't decide about their future, due to the fact that they just have blurry ideas of the exact fields of work in academic topics. This is also why we offer the Scientific Window where students can talk to different people working in economics or academics. Thereby we expect the students to get a better insight in different academic jobs.

2 RESEARCH BASED LEARNING

MINT^{grün} offers special labs representing different topics. The different laboratories deal with subjects like robotic, construction, environmental research, programming and mathematics. Because of the newness of these labs there is still no standardized schema among them and there is also some try-and-error left.
The basic idea in the MINT^{grün} labs is research based learning. Besides it positive effects [2] we anticipate a better orientation progress by the experiences the students are expected to gain during the participation in MINT^{grün}. Research based learning offers to experience course contents independently, creatively and explorative instead of abstractly and academic. Normally academic studies begin with “dry” basic theory and reaches interesting topics in the later semesters. This approach often screens students out, even if they are actually interested and competent enough to fit in. This is often sensed as the main problem in STEM based degree programs.
That’s why we chose explorative learning as main concept in the labs.
In the laboratories students have to invent robots, mechanical machines, write programs and perform chemical experiments. This amount of independent working and responsibility within their beginning of studies distinguish a lot from old-established academic teaching practice. Although the other labs have the same basic idea of teaching the following text will just refer to “Creativity + Construction” (C+C) because every lab is a bit different from the others. The specialness of C+C is that the students are learning the facts and subject matters step by step while they need this knowledge to work further on their apparatuses. In this way it is more interesting for them and the meaning of single challenges are easier to understand and to master, when they refer to their projects. Learning-by-doing is also a good way to

convince people, who are in doubt about an academic future, because they're afraid of lacking mathematical talents. That's why we appreciate its role in the orientation progress. The knowledge we want to impart hereby is about engineering, construction, scientific work, manual labor, individual problem solving (also kludges), independent working and acting with schedules, competing ideas and fellow students.

3 THE ARRANGEMENT OF C+C

Our guiding principle is: 'If you can invent it, you can build it'. The C+C lab has to be equal to the course "Engineering Design1" offered by the TU Berlin because it can be charged as it. But "Engineering Design1" only teaches the planning part of inventing. The students there have to design an engine conforming to standards. At the end of the semester they have to submit a technical drawing and the calculations of their engine also they have to pass an exam. This concept lacks the changes and arising problems which occur during the construction process. Our goal is to make all the different phases of engineering accessible. That means choosing a project, planning and organizing in groups, doing researches, acquiring techniques, communicate and evaluate results and of course handling failures. In C+C each group has to fulfill three big tasks: complete the design of a mechanical machine and the documentation of the engineering process, fabricate an associated engineering detail drawing and finally build the engine by hand. These tasks shall make the process of development perceptible and provide us a better foundation for grading the students.
In the end of the work progress there shall not be only the experience and documentation but also the touchable product. By that we want to make the challenge of technical design more attractive.
Our course takes four hours every week, lasts 14 weeks in a semester, contains up to 30 seats and is credited with 6 ECTS. Most of the working shall be done as homework outside the attendance time. We split the semester into three big sections. These are marked by deadlines referring to the phases of developing and production. The working progress of the students is not as clearly separated as the sections are due to the different progress of the groups.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Invention					Engineering				Construction				
Submissions		Idea, sketches, basic principle, schedule			Estimations / calculations, part list				Technical drawing, documentation				Final machine, documentation, reflection of problems and changings	Evaluation and reflection
lectureship	→ Lectures about: Construction, components, mechanic					→ Lectures about: CAD-Programs, technical drawing → Workshop briefing → Excursion to DIY-Store				→ Only consultation hours				
Presentations			intern					intern					End of term presentations of all laboratories, extern	

Table 1. Order of the course C+C

3.1 Invention Period

The first section of the semester is for developing ideas. In the beginning we collect suggestions what machines could be possible or interesting to be build. Then the students join their favorite engine idea and found groups by that. So we can make sure that the students did not just found groups by choosing their friends but also by choosing the project which interest them the most. We implemented this approach to increase the bond between students and their project. After a brief time they have to submit a small paper containing their overall approach. In the upcoming weeks they have a lot of theory lessons. We try to avoid traditional teacher-centered teaching in this period but we also cannot skip imparting them elementary knowledge about gears, statics, technical standards and how to engineer. To pursue the strategy of research based teaching we also simulate constructing processes and talk about self-assessment and do practical exercises. After two weeks and at the end of this period the students have to submit their first papers, so we can get a detailed overview of what they are planning about and guide them, when they try to build castles in the air.

3.2 Engineering Period

The second period is concerned with defining the machine. The classes are about materials, CAD programs, how to craft and create engineering drawings. It contains an excursion to a crafting/DIY store for getting the materials while we offer reserved assistance. We figured out that a lot of students never made the experience to fully plan a material purchase because some of them never built something complex on their own before. Letting them do the purchase on their own is showing them the importance of a detailed and complete part list. Preparing the practical work the students also receive an instruction for working in a work shop. We work together with the workshop of the faculty of architecture of TU Berlin. Here the students can craft (sawing, drilling, polishing etc.) and can use the machines with the help and control of the employees working there. This period is very different from the first one, because a lot of plans they had have to change due to the frame conditions (e.g. available material and machinery) they have for crafting. The know-how they earn by modifying their projects is something they wouldn't have earned in the "Engineering Design 1" classes. Also handling the given boundary conditions is a very important ability for an engineer. It is not teachable by others because it concerns to practical and empirical experience they have to earn by themselves. Access to the work shop also offers the possibility to ask the shop employees who are used to construct in a totally different way. The supervisors there often have more simple or elegant ideas how to solve a specific problem because they are also a lot better in finding makeshifts. The dialogue with the shop employees is a special service in our concept of teaching. The phase ends with the submission deadline of the second paper, which contains the engineering detail drawing of their engine. The machine they have to build in the third period shall be build according to these plans.

3.3 Construction Period And End Of Semester

The third period is only about the construction itself. In this period there are no weekly meetings but consultation-hours to handle the upcoming issues which are similar to the problems from the second phase. The last paper they have to turn over has to contain a report of their results. It is especially about what changed during their whole working process and the evolving differences between drawing and the final machine. Also it should list the reasons for the changes or more precisely the upcoming problems they had and their solutions (executed and/or suggested if there were not enough capabilities or they ran out of resources). The last gathering in the

semester is used to evaluate the course and discuss about useful or necessary modifications of C+C. In the last week of the semester there is also a presentation where all the labs take part at. This is a great opportunity for the students to see what other labs did during the semester and if their machines, robots or programs are showing the same effort as they invested in their own projects. It has shown that unsuccessful and unfinished work was taken with interest and understanding among the groups which indicates a productive handling with failures and not just frustration. Due to the fact that a lot of students underestimate the time effort projects often stay unfinished. The comparison with the other groups shows the huge amount of work the students have accomplished and is suitable to raise the students' self-esteem which is of value for the orientation progress.

Once a year the TU Berlin hosts a public relation event ('Long Night Of Science') which presents the full range of activities and research projects the university offers. The students can take part there voluntarily to present their works representing MINT^{grün}. Every year some of the students use this opportunity.

4 PROBLEMS WITH RESEARCHED BASED LEARNING

Although explorative learning is a new opportunity, we figured out some problems with this concept and we still are trying to manage these.

4.1 Control

We are assuming the students to work independently. Most of the work shall be done outside the lecture time. But a lot of the students come directly from school and are not used to work without a permanent control. That's why we established up to five homework essays (mostly documentations, list of parts, drawings and calculations) the students have to turn over within the semester. The subdivided three phases shall also help to overview the amount of work. Also it forces the students to keep up with the schedule due to the fact that every working group shows problems staying in time. On the one hand these hand-overs produce enough stress to stay up with the schedule on the other hand they limit the free working progress.

4.2 Grading

Estimating and grading the work the students did is difficult within the laboratories. We grade the protocols, the presentations and the project results. The papers we receive from the students are a necessary fundament for grading the results, which is important because their work shall be chargeable (as a substitute for "Engineering Design 1"). So they don't have to do this course again if they decide to continue studying in STEM based courses. To make their work comparable we limit the ideas to single topics like clocks, household-helpers, etc. The grades they receive are just partially expressive because most of the learning effects of C+C such as acting with upcoming problems are not gradable at all. Grading research based learning is generally problematic [2].

4.3 Communication And Asking For Guidance

To increase the intern dialogue we did insert presentations (<5 minutes) about their state of affairs and their actual problems. Oftentimes these presentations were followed by heated debates about possible solutions on which everyone departed. Although these debates where a raving success, the dialogue often stopped soon. This increases the stagnation of the working progress. In the next semester we want to offer a Facebook platform to improve the intern communication among the groups. To increase the dialogue with the teachers we will set up supervised working rooms

apart the workshops so they can ask for guidance easier. The success of the new facilities depends on their voluntary visits.

4.4 Group Dynamics, Stability And Gender

Working in groups shows problems we have less influence on. Aside the variation of quality among the working groups, inside the groups students often take different roles like being workaholic or dragged along by the rest of the group [3]. Because we cannot regulate these dynamics we request the students to pay attention on it by themselves. A lot of the students pull themselves back because they have a low perceived self-effectiveness [4]. This concerns mostly female students because they are often afflicted to gender prejudices. We try to negate their gender perceptions by convincing them about their engineering skills and talents as well as our lot female teachers acting as confident and good examples.
Mostly the team spirit creates company and promotes conversation and orientation. But some of the students vanish over the year because they decided not to finish C+C or sometimes MINT^{grün} completely. In every semester we got the problem that some groups were restricted because of missing members.

5 RESULTS

Even if there are still some problems to solve, the laboratories and MINT^{grün} are very successful. The number of MINT^{grün} students was increasing from 77 in the first year, to 177 in the second year and up to 325 in the actual third year. The amount of women grows from 22% up to 34% in the same time -within C+C we have a fluctuating percentage of women from 29% to 33% in the beginning of the course and due to the leaving of students during the semester 29% to 43% in the end. In the last two years we could help a lot of students to choose their future mostly in STEM (up to 75%) or other areas of study (about 20%) but also outside academic contexts. That's what the challenge of MINT^{grün} is about.

REFERENCES

[1] Raue, C., Schröder, C. (2014), Das Orientierungsstudium MINT^{grün}: flankierter Systemübertritt von Schule zu Hochschule, *Zeitschrift für Hochschulentwicklung*, Vol. 9, No. 5, pp. 179–199.

[2] Huber, L. (2013), ‘Why researched based learning is necessary and possible’, Re-searched based learning during the study. Actual concepts and experiences, L. Huber, J. Hellmer & F. Schneider, Bielefeld: Universitäts-Verlag Webler, pp. 9-35.

[3] Bednarz, S., Schmidt, E., Otte, B., Lippe-Heinrich, A., Döring (2008), ‘Working process orientated and gendersensitive IT-education‘, I. & Sprenger, T. Bielefeld: Bertelsmann, p. 49.

[4] Kosuch, R. (2010), ‘Perceived self-efficacy and genderimpulses for STEM focused didactic’, Gender and MINT Solutions for teaching, job and study, Dorothea Kröll, Kassel: kassel university press, pp. 12-36.