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GEODETIC SURVEYING STUDIES FOR CIVIL ENGINEERING STUDENTS AT TALLINN UNIVERSITY OF TECHNOLOGY

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Abstract. Studies in the Tallinn University of Technology are based on a modular system, where geodetic surveying comprises a self-contained study module in the curricula of all civil engineering specialities. Due to geodetic surveying being taught to all first year students of civil engineering, it serves as a touchstone to test a student's suitability for an engineering specialism. Future civil engineers are taught basic geodetic measurements and how to use optical theodolite, levelling instrument and laser level. The paper gives an overview of geodetic surveying lectures, laboratory classes and field survey camp. Teaching and assessment are based on learning outcomes. Students who have passed the exam are allowed to participate in the summer field survey camp, the aim of which is consolidating the knowledge acquired throughout the year and practising teamwork.

Keywords: geodetic surveying, civil engineering students, learning outcomes, lectures, laboratory classes, field survey camp.

1. Introduction

Tallinn University of Technology (TUT), which was established in 1918, is the only university in Estonia that gives engineering education. According to its Mission Statement TUT undertakes international level fundamental and applied research and has potential for developing high-technology applications primarily for the civil engineering, information and communication technology, chemical and biotechnology, environmental technology, materials science and technology, economics, production technologies, machine and apparatus building industries.

Today TUT has over 14,000 students in its eight faculties and four colleges. Academic (teaching and research) staff and administrative staff amounts to approximately 2000, including 125 professors. The main language of tuition is Estonian, but courses are also taught in English and Russian.

The changes that took place in society about twenty years ago brought about reforms in study volumes, curricula and duration of studies. Course-based system was changed to subject-based. TUT, like the rest of Estonian higher education institutions (HEI), has adopted the ECTS (*European Credit Transfer and Accumulation System*). One ECTS credit point (ECP) equals to 26 hours of notional learning time. The adoption of ECTS aims at facilitating student mobility within Europe and assuring academic recognition internationally.

University studies are based on curricula that determine the aims, learning outcomes, nominal study period of the studies, subject lists with volumes and brief descriptions, specialisation options, etc. Curriculum design assumes that a student accrues 60 ECP within a year. Academic studies are divided into three stages:

- Bachelor's studies, 180 ECP, study period 3 years;
- Master's studies, 120 ECP, study period 2 years;
- Doctoral studies, 240 ECP, study period 4 years.

Civil engineering studies are an exception, as in 2002 five-year integrated studies (altogether 300 ECP) were reintroduced for this domain. This was due to the fact that according to the European Union requirements the profession of a civil engineer is attributed special liability. Thus we have integrated engineering studies, which means that for the two final years the curriculum allows for admission of Bachelors of adjacent specialities and graduates of institutions of professional higher education aspiring for a Master's degree. The engineering programme comprises of 10 terms, the last of which is allocated for writing the graduation thesis. Upon completion of the programme the student is awarded a Master's degree (MSc) and is eligible for doctoral studies.

TUT Civil Engineering Faculty consists of six departments – the Department of Structural Design, the Department of Building Production, the Department of Mechanics, the Department of Road Engineering, the Department of Environmental Engineering and the

Department of Logistics and Transport and the Centre of Engineering Graphics. The Civil Engineering Faculty prepares specialists for three main domains – civil and industrial engineering, environmental engineering and road engineering. These, in turn, are divided into three to four narrower specialisms. For instance, road engineering students can major in bridge engineering, road construction or geodesy.

All TUT curricula can be divided into five blocks: General Studies, Basic Studies, Core Studies, Special Studies and Free Choice Courses. General Studies provide students with essential knowledge in humanities (philosophy, law studies, foreign language, communication skills) and the fundamentals of economics, environmental protection and organisation of studies at the university. Basic Studies create a basis in exact sciences and general engineering knowledge. These studies include graphics, information technology, and various mathematics, chemistry and physics courses. Core Studies lay the foundation for Special Studies. In addition to the obligatory courses the module offers optional courses that enable students to start preparing for narrower specialisation later on. Special Studies provide students with in-depth knowledge of the field they major in. The Free Choice block enables students to take courses of interest either from the TUT or other HEI curricula. Additionally, the curriculum comprises industry training and preparing the graduation thesis.

The study blocks are in turn divided into modules, each of which consists of three to seven subjects. For instance, the Civil Engineering core studies are composed of Mechanics (23 ECP), Civil Engineering (22 + 18 ECP), Optional Courses (9 ECP) and Geodetic Surveying (7 ECP) modules.

The current paper seeks to convey the experience of teaching geodetic surveying to TUT civil engineering students. First, the aims of the Geodetic Surveying as a self-contained study module are explained, and, further on, its components are analysed in more detail. A brief summary concludes the paper.

2. Target group for the Geodetic Surveying studies

For the reader of this journal the subject “teaching geodetic surveying” can be understood as teaching a whole complex of subjects, e.g., for preparing geodetic specialists. Therefore, it needs to be emphasized that this paper is not intended to be as an introduction of the curriculum of geodesy major at the TUT. Instead, we will focus on geodetic surveying in a narrower sense – as one of the compulsory subjects in TUT’s Core Studies block. Given the level of complexity (or rather, “the level of simplicity”) of the study module, it could actually be named “Basics of surveying for Civil Engineers”, highlighting the fact that it is a considerably adapted and simplified version of “genuine geodesy”. In other words, the target group are those we do not expect to earn their living with the knowledge acquired during this study module. Rather the knowledge of the methods of acquiring and using of spatial data they obtain is meant to support the special studies of civil engineering. In addition to civil engineering students, the

course is obligatory for the second year geotechnology students of the Faculty of Power Engineering and first year earth sciences students of the Faculty of Science. Geodetic surveying is taught to approximately 200 students per academic year.

It is no secret that the dropout rate at TUT (as, presumably, at any other university of technology) is the highest during the first year of studies. The major touchstones for first-year students are physics and/or mathematics, but probably the role of the geodetic surveying studies in this “natural selection” process should not be underestimated either. This, unfortunately, means that some of the attention and tuition given to some of the students in laboratory classes will eventually (due to lack of formal output on the student’s part) prove to be resultless.

As geodetic surveying is one of the first subjects taught that is related to civil engineering courses, it is essential to gradually familiarise students with the subject and clarify its relationship to their specialism. Additionally, the differences between high-school and university tuition need to be explained to them, e.g., the necessity of the use of required standards and choice of units with appropriate precision.

3. The Geodetic Surveying Module

In Tallinn University of Technology we use outcome-based tuition, where the central role belongs to assessable learning outcomes the student is expected to achieve at the end of the studies. As the learning outcomes of the self-contained geodetic surveying courses students will have:

- acquired basic knowledge on depicting landscape and situation elements on topographic maps and plans;
- developed skills for determining positions of the landscape and artificial objects;
- been introduced to handling basic geodetic instruments and applying respective methods for acquiring spatial data;
- been given an overview of on-site geodetic works related to construction, maintenance and servicing of buildings/roads and their required accuracy.

Due to the academic year being divided into two terms, therefore the Geodetic Surveying I (lectures 12 academic hours + laboratory exercises 16 hours) is offered during the autumn term, and Geodetic Surveying II (lectures 20 academic hours + laboratory exercises 16 hours) is taught in the spring term. One week is allocated for homework (basic geodetic calculations and drawing tasks) and examination preparations. The academic year is rounded off by a field survey camp, which aims at consolidating the knowledge acquired throughout the year and practising teamwork, see Table 1.

The Geodetic Surveying Module is taught by the Chair of Geodesy of TUT Department of Road Engineering. Three to four lecturers are directly involved with this. Before giving a more in-depth description of the subjects taught, we will review the available study materials and equipment.

Table 1. Components of the Geodetic Surveying Module

Subject		ECP	Weekly hours	Term
Code	Title			
ETG0011	Geodetic Surveying I	2	1.5	1 (autumn)
ETG0012	Geodetic Surveying II	3	2	2 (spring)
ETG0013	Field Survey camp	2	–	3 (summer)
Total		7		

4. Study materials

As all the geodesy textbooks currently available in Estonian are both content- and volume-wise more suitable for preparing future geodesy specialists, a few years ago study materials for teaching geodetic surveying for non-geodesy majors were compiled at the TUT. The three brochures (altogether 270 pages) encompass practical guidance to laboratory exercises and field survey camp, for more details see Ellmann and Kala (2010, 2011a, 2011b). Due to a slightly broader scope, these make quite suitable textbooks as well.

It should be stated that modern students seem to fear textbooks. There is a tendency to consider textbooks too voluminous and incomprehensible; besides, students seem to lack the habit of reading and searching for information in books. Whereas the internet is widely used among students, lecture materials are made available prior to the lesson on the subject website. Students are advised to familiarise themselves with the materials in advance and also print them out to be able to take notes.

It should be noted that applying innovative methods in teaching, e.g., using short videos (e.g., on levelling, handling a theodolite, etc.) in lectures and laboratory classes not only enhances the efficiency of tuition but also increases students' cognitive need for knowledge. In the future, we plan to shoot short (7–8 minutes) digital study movies to introduce various fieldwork operations in class to provide prior understanding of the fieldwork.

5. Resources and equipment

Geodetic Surveying is a subject that would be difficult to acquire based only on theoretical knowledge. Thus resources and equipment have a significant impact on the study process. When choosing equipment, two main criteria were considered:

- geodetic instruments used in civil engineers' daily work;
- the cost of the equipment.

Typically Estonian civil engineers do not use high performance and high precision geodetic instruments (digital levels, *electronic total stations*, GPS receivers) in their daily work. Currently all the high performance or high precision on-site geodetic measurements (such as setting out of construction elements and axis, as built survey and deformation observations of main supporting structures) are outsourced to specialised surveying

companies. Major construction companies may have a geodetic survey unit who are equipped with relevant technology to perform required geodetic measurements. Thus civil engineers perform only basic/simpler geodetic works, e.g., alignment of construction elements or setting out auxiliary structures without any peculiar accuracy requirements, where optical theodolites, and optical and laser levels, and steel tapes can be safely used.

Considering the above, TUT civil engineering students use optical 30" theodolites FET500 and their older analogues 2T30 as well as precise optical levels GeoFennel No10-32 and their older analogues H-3 and HB-1 and optical squares. Also a laser level is used mainly for demonstration purposes. Instead of steel tapes, fibreglass tapes are used, as the former are too fragile to stand handling by students.

Next the aims and learning outcomes of the Geodetic Surveying Module will be discussed.

6. The aims and learning outcomes of the subjects

Learning outcomes reflect the knowledge, skills and attitudes acquired as a result of studying, the existence and acquisition level of which is certifiable and assessable. Learning outcomes reflect the expected threshold level of knowledge and skills. The aims of Geodetic Surveying I are to:

- give an overview of the principal geodetic calculation problems and their solutions;
- introduce basic geodetic instruments and their application in positioning of landscape objects, but also depicting objects on maps and plans.

The respective learning outcomes establish that the student has to be able to:

1. describe main fields of geodetic activities and their connections with other disciplines;
2. identify and draw topographic symbols;
3. solve the direct and inverse geodetic calculation problems;
4. handle the optical theodolite;
5. perform traverse data processing together with estimation of measurement errors.

The aims of Geodetic Surveying II are to:

- give an overview of tacheometric surveying and the aims and principles of geodetic heighting;
- introduce levelling instruments, methods and calculations;
- give an overview of geodetic surveying on construction sites and the necessary skills.

The respective learning outcomes establish that the student has to:

1. know the main methods of topographic surveying and mapping;
2. be able to handle the optical levelling instrument;
3. be able to carry out geometric and trigonometric levelling and perform the respective data processing;
4. be able to solve the principal geodetic surveying tasks on construction sites: area levelling, setting out buildings; calculating and setting out curves, route surveys, designing and drawing along-route profile and cross sections.

7. Geodetic Surveying lectures

The Geodetic Surveying Module subjects are taught in both Estonian as well as Russian in accordance with the language of tuition of the student. The lectures of Geodetic Surveying I and II are therefore held in the respective language for large audiences. Proceeding from the aims and expected learning outcomes of Geodetic Surveying I and II, the lectures cover the following topics:

1. **Autumn term:** Shape and size of the Earth. Coordinate systems. Orientation of lines. Geodetic control networks. Surveying methods and equipment. Processing of surveying results.
2. **Spring term:** Tacheometric survey, fieldwork, data processing, plan drawing. Aims and principles of geodetic heighting. Geometric levelling. Estonian National Vertical Control Network. Precision classes for levelling. Levelling instruments and levelling staffs. Processing levelling results. Area levelling. Route surveys, designing and drawing along-route profile and cross sections. Setting out on construction site. Area calculation.

In addition to knowledge transfer, the lecturer plays an important role in raising students' motivation. Students may be blessed with inherent abilities, they may be taught at well-equipped classrooms, but if they lack interest in the subject taught, tuition will be to no avail. Clearly, it is impossible to teach an unmotivated student.

University studies require working through vast amounts of material and many of the subjects are rather demanding. It is an advantage if students are interested in the specialism studied from the outset, because they have had some prior contact with it through work experience and want to replenish their knowledge; or they have respective experience or information gained from parents, relatives, acquaintances or literature. Unfortunately, many first-year students tend to lack motivation, which could be caused by the following factors:

- choice of HEI due to parental influence;
- starting HEI under peer influence;
- shock at the high demands on the prospective student's level of knowledge;
- disappointment with the chosen specialism;
- pursuit of a diploma solely to gain authority in one's social environment;
- habit to strive for good marks rather than knowledge.

While planning the teaching process, it has to be considered that motivation is neither a skill nor information; but it is a system of goals and intentions that enhances human functioning. It cannot be practised like handwriting or memorised like a multiplication table. Motivation can only be stimulated, increased or developed. Students' attendance of lectures cannot be a goal of its own - students should actively participate in the study process, i.e., there should be cognitive, behavioural and emotional engagement. The attempt to focus solely on knowledge acquisition could prove boring. Additionally, we cannot ignore the fact that the theoretical part of geodesy – applied mathematics – does not seem very attractive at first encounter compared to other subjects, e.g., chemistry, physics or literature. Many start to take an

interest in the subject only during the field survey camp, i.e., toward the end of the course. Interestingly, there have been cases of civil engineering students changing their initial major to geodesy after the field survey camp.

Proceeding from our observations, the following measures could be taken to enhance motivation:

1. explicit and well-illustrated explanations;
2. increased student involvement during lectures, and encouraging, even provoking, questions;
3. clarity of the grading system and increased frequency of assessment;
4. considering the preparation level of the audience;
5. offering illustrative material on how the subject relates to the students' specialism and potential problems that a civil engineer lacking the basics of geodetic surveying knowledge will face;
6. fair and benevolent attitude.

The best motivators are certainly an inquisitive mind and a desire to acquire a profession, but as an initial incentive aspiring for high grades and authority in the group would suffice. These will provide an adequate springboard for a desire for knowledge. Here we should not forget teacher's assessment of a student's work as a powerful motivation tool.

8. Laboratory classes and homework

Practical assignments are divided into individual and groupworks. Laboratory classes are held for 15-strong groups every two weeks. Prior to practical classes there is introduction for the entire or half-group, but the subsequent practical exercises are organised in small groups of 2 to 4 including both individual as well as cooperative assignments. In case of individual assignments groupwork involves mutual checking of results and also peer guidance, as the lecturer due to lack of time might have difficulty with identifying the student's problem instantly. As a rule, assignments are checked individually. For practising measurements there are cooperative assignments. In these classes, after having listened to the instructions from their lecturer, students perform the following tasks:

- Acquaintance with the optical theodolite, levelling instrument, optical square and laser level.
- Horizontal angle measurements with theodolite, testing a theodolite, laboratory simulation of tacheometric surveying.
- Laboratory simulation of levelling, testing and adjusting a levelling instrument.
- Acquaintance with modern geodetic instruments.

In April-May, if the weather permits, laboratory classes on levelling and tacheometric surveying are held outdoors. Geodetic Surveying I and II homework assignments are as follows: 1) map symbols and scales; 2) traverse calculations and adjustment; 3) tacheometric surveying and map drawing; 4) area levelling calculations and map drawing; 5) profiling a route together with levelling and calculation of the chainage and the elements of circular curves.

9. Examination

The Examination takes place at the end of the spring semester. The exam questions cover all the topics of both

the lectures and practicals of Geodetic Surveying I and II. The prerequisite for taking the examination is timely completion and submission of homework and laboratory assignments together with providing adequate explanations where necessary.

The examination is graded on a scale of 0–5. The examination is a written test and is divided into two major parts:

- answering thematic questions;
- solving calculation tasks.

Only insignificant inadequacies are allowed in answers. An unsatisfactory or considerably faulty answer (less than 50% of the expected volume and content) gives 0 points.

Answering a question or solving a task completely and flawlessly is awarded by the maximum points indicated on the task sheet. Calculation errors and incomplete answers result in a proportional decrease in points. The examination is considered a pass if both of the following conditions have been fulfilled:

- the answers to thematic questions score a minimum of 50% of the possible maximum, while none of the questions has been left completely unanswered;
- the answers to calculation tasks score a minimum of 50% of the possible maximum for calculation tasks.

In case these two conditions are fulfilled, the points scored will be summed to get the final examination mark.

10. Field survey camp

We assume that upon successfully passing the examination, the student should be prepared to the field survey camp, which has been allocated three full weeks. We consider the fieldwork the most important part of the Geodetic Surveying Module, as geodesy is an applied science, where application skills are of no less importance than theoretical knowledge. We expect sufficient consolidation of the theoretical knowledge during the field practise.

The aims of Geodetic Surveying fieldwork are:

- creation of conditions similar to real-life working environment;
- consolidation of various geodetic measurement methods acquired throughout the preceding academic year;
- demonstration of the significance of accuracy in documenting and visualising surveying data.

During the field survey camp each team (consisting of 5–8 students) will perform a set of geodetic works that comprise:

- Testing and, if necessary, adjusting of all instruments (theodolite, levelling instrument) and equipment (measuring tape, levelling staffs, optical square) to be used during the course of the camp.
- Carrying out tacheometric surveying of a 2 ha plot at a scale of 1:500 (accompanied with traverse and levelling line measurements/adjustments), calculations and map drawing.

- Precise levelling (at least 1 km, both forth and back) for determining heights of benchmarks.
- Route (at least 0.5 km, with 3 turning points) chainage and survey, setting out of the circular curves by three different methods, calculations and designing and producing profile and cross section drawings at a scale of 1:2000/1:200.
- Precise height determination of an inaccessible target using trigonometric levelling.
- Setting out of main construction axis.
- Common on-site engineering surveying tasks, e.g., setting out of pre-defined angles, distances, heights and coordinates; setting out of buildings and tilted surface; check a building for verticality, transfer of heights to the construction horizon, survey of the system of precipitation collectors and pipes, area levelling, etc.

During the fieldwork, optical theodolites and levels are used, which is intentional, as a civil engineer will obviously not need expensive high-precision geodetic instruments for routine tasks on the construction site. Geodesy students are introduced to usage of modern geodetic instruments during the course of Special Studies in later study years.

It should be noted that the added value of the field survey camp lies in testing and developing social skills of students. Apparently, for many students this is the first experience of teamwork where they have to achieve acceptance of their ideas and proposals amongst their own peers. For a future manager self-assertion skills are of considerable importance. 5 to 8-strong teams are formed for carrying out fieldwork tasks. Each team elects a team leader and his/her assistant.

Fieldworks are guided by four to five lecturers, each in charge of three to four teams. The lecturer gives short instructions for each task, referring to the respective theory part. Next, solutions are sought for in brief and relatively random group discussions that take place upon necessity and stimulate creativity in searching for different solutions. Thus, teamwork enhances cooperation and collaborative learning among the students and results in consolidated experience. At the end of the field survey camp the students are assessed either individually or in teams.

The expected learning outcomes of summer field survey camp establish that the student has to:

- be able to plan, organise and perform geodetic measurements both in separate stages of surveying as well as a complete process;
- be able to design geodetic measurement methods dependent on given requirements and conditions;
- be proficient in handling various geodetic instruments in conditions similar to actual construction site environment;
- have consolidated geodetic data processing and reporting skills.

11. Conclusions

A review on the Geodetic Surveying subjects taught at the Tallinn University of Technology for Civil Engineering students was given in this paper. Having performed

the required independent calculation/drawing practicals and laboratory tasks; demonstrated the theoretical knowledge as well as ability to apply these; and, finally, consolidated all knowledge and skills during the field survey camp; the student should be prepared for performing basic on-site construction surveying tasks.

A drawback here, however, is that the Geodetic Surveying subjects are taught during the first study-year, which leads to a suspicion that many students may have forgotten much of the material by the time they graduate from university.

Years ago, another specialised subject filled the gap – “The Basics of Construction Surveying for Civil Engineers”, which took a more detailed approach to on-site geodetic surveying (the volume of the current construction surveying course does not allow for this) and was taught in the third study year. That course provided a deeper insight into the relationship between construction and geodetic works, thus enabling the future operations manager to better plan the works with simultaneous revision of handling geodetic instruments. Today, this subject has been removed from the curriculum, as due to addition of various new subjects, curricula would otherwise get overloaded. The sole expectation is that young specialists will be introduced to the material uncovered during their studies at their workplace, in the framework of lifelong learning.

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