

The Impact of Cooperative Learning Scenarios on the Applied Mathematics Education of Geomatics Students

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Abstract

Geomatics students need a profound knowledge in mathematics to master their studies and to be prepared for their life as an engineer. The best way to realise this necessity is to apply the mathematical methods and techniques in scientifically sound projects. We offer summer camps in Spain, to work in international student teams on surveying projects in archaeological sites in Spain. The students apply laser-scanning, photogrammetry and other high tech surveying methods. The resulting data must be assessed, evaluated and visualized using the methods learned before. Because of the scientific relevance of the results, the students are highly motivated.

Cooperative Learning (CL) as a learning or teaching strategy is a part of Civic Education and successfully applied at schools and universities. The idea is that students of different levels of ability learn and act together in a group to achieve a common goal and improve thereby their understanding of a subject.

We show that the categories of CL can be used to describe our projects and help to improve the learning and teaching processes.

Introduction

The challenge of our bachelor and master degree programs is to achieve a professional qualification and employability of graduates at all levels. They have to face a global world with complex tasks and should be prepared for lifelong learning. In addition to having profound knowledge in their chosen field they must be able to apply this to new and unknown fields often in collaboration with scientists with a different cultural and scientific background.

It is practically impossible to teach every fact that could possibly be used in the future life of an engineer. The best way to overcome this problem is to provide a thorough education in maths and natural sciences such as physics.

From this point of view it is a lucky coincidence that there is a strong demand in the field of Archaeology for the skills our students are taught. In collaboration with colleagues from Spain we can define projects at archaeological sites or excavations, where Spanish and German students from Geomatics and Archaeology can share and exchange their knowledge and achieve scientifically important results.

The aim of these projects is to impart knowledge in new technologies, practical skills and the consolidation of the theory and the mathematical background of treating subjects like Practical Geodesy, Photogrammetry, Geodetical Networks and Engineering Geodesy.

In the following we briefly discuss the mathematical implications of terrestrial laser-scanning. The learning theoretical background of our projects can be described by the concept of the “Cooperative Learning Scenario”. We introduce this concept in a dedicated section and then show how it applies to our projects.

The Maths behind Terrestrial Laser-Scanning

The main task for a Geomatics engineer (called surveyor in former times) is to determine the coordinates of points and objects in space. They use a (laser-) optical device called “total station” to measure angles and distances to and between single distinct points of the objects. Using this technique objects are represented by a (small) set of typical points e.g. of corners or the rooftops of buildings. In terrestrial laser-scanners (TLS) this idea is enhanced. This device sends out laser beams in a certain direction which are then reflected by the object. Measuring e.g. the light travel-time, the distance can be determined. Together with the direction, this gives the coordinates of the reflection point in the system of the scanner. Rotating the device and using mirrors the direction can change automatically so that it is possible to measure thousands of points per second. Figure 1. shows schematically the result.

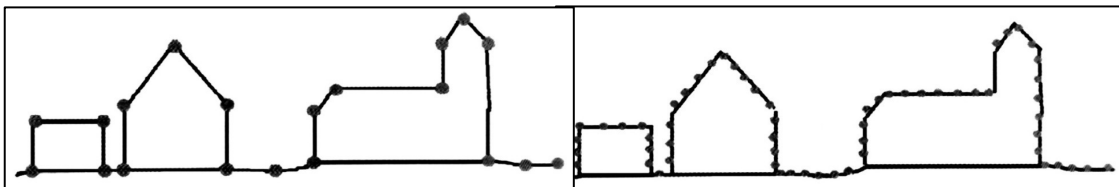


Figure 1: (a) Typical points of buildings as measured by a total station.

Figure 1: (b) Grid of points of buildings as measured by a TLS.

To look into any corner of an object and to have a full 3d-view it must be scanned from different positions. For this purpose marks or targets are laid out and scanned and must be recognized in any scan to join the data to a common coordinate system. Additionally, the marks are measured by total stations together with known points of the surroundings to embed the data into a global coordinate system. The result is a 3d-point cloud. Normally, it must be thinned out and smoothed. Connecting the points to triangles yields a surface which can be coloured or textured to get a realistic model of the object.

The first step of this measurement is the preparation and the planning as, for example, shown in Figure 2. Besides the technical skills to set up the equipment the student must have a genuine understanding of the geometrical concepts. One problem is to distribute the marks so that they do not lie in a line or on a plane or that the triangles built by the

marks and the scanners do not have too small angles. The achieved accuracy of the scans would be bad if these conditions are not fulfilled and the student would realize this at home. Thus, a student must know everything about *points, lines, planes*, their mutual intersections and *triangles* in the sense of pure and *analytical geometry*. To enhance the accuracy there are normally more points and marks used than absolutely necessary. Mathematically, this leads to *overdetermined linear systems*. The student must know how to solve linear systems in the determined and overdetermined case using the *Gaussian elimination* and the *least squares* method with a background in *multivariate calculus*.

The next step is performing the measurements which are normally no problem if the preparation was done well. First data analysis is done in the field so that large errors can be avoided or measurements can be repeated.

The data must be evaluated at home. In this phase, which can take up to ten times more time than the measurements, software packages are used to make a model from the data. The student needs a lot of experience and cannot use the software as a black-box. The marks must be identified in each scan to combine the data. The raw data sets can be quite big and one needs a good understanding of the *statistics* to smooth and thin them out. Making surfaces from the point clouds is not a standard task. The software offers some possibilities but sometimes it must be helped manually. For special data sets new methods must be tried out. For this purpose students must know about graphical algorithms as *Delaunay-triangulation* or its *Voronoi* representation. Sometimes even spline- or *NURBS*-surfaces do the trick or software must be developed to detect and fit certain geometrical shapes. Mathematically, this leads to a *linearization of systems of multivariate equations* which leads in this case to an *eigenvalue* problem.

To summarize: preparing, performing and evaluating laser-scanning is a task which needs a lot of engineering mathematics as background. Besides geometrical concepts of surveying, linear algebra, multivariate calculus and statistics is needed in some depth to achieve reliable results.

Aspects of learning theory

Cooperative Learning (CL) as a learning or teaching strategy is a part of Civic Education and successfully applied at schools and universities [3]. The idea is that students of different levels of ability learn and act together in a group to achieve a common goal and thereby improve their understanding of a subject.

Usually, this is a strategy for a teacher who carefully designs the lessons and activities for teams in a classroom to teach a dedicated subject. However, our well-prepared projects, applying geodetical concepts to Archaeology in small international student teams, seem to fit the categories of CL quite well.

The students learn, practise and apply complex scientific and technical skills. Besides the pure fact-oriented view, we achieve benefits including: higher self-esteem and academic achievement, an increase in level of reasoning and development of social skills and skills in oral communication and some more [2].

To insure that CL, and therefore its benefits really occur, five conditions must be fulfilled [1]:

1. **Positive interdependence** (sink or swim together)
In our projects small student teams receive clearly defined tasks in surveying or scanning parts of archaeological sites. Since the groups are working on real and not on toy-science, the contribution of each member becomes important. Their work must be done very carefully, because its quality is mostly assessed later, with no chance for repetition.
2. **Face-to-Face interaction** (promote each other's success)
Although instructors are available, the teams are mostly working on their own. Advanced students must teach the other (often foreign) team members in a chosen common language. Subjects, learned in the past, must be recapitulated, discussed and successfully applied.
3. **Individual and group accountability** (no hitchhiking! no social loafing)
As stated in condition one, the quality of the results of the work is important per se and often also important for the future work (thesis) of some group members. The group tasks are connected, so that the results are important for other groups. These constraints lead to self-control of the group with a positive effect on the engagement of the members.
4. **Interpersonal and small group skills**
The students learn-by-doing to act inside a team. Since there are different levels of ability, we find an interchanging structure of teaching and learning. This leads to a respected (changing) hierarchy inside the group, founded by knowledge, ability or choice. The international composition of the groups helps to overcome prejudices against foreign nations or races.
5. **Group processing**
The data are often pre-processed after work and the quality becomes obvious. Discussing the results and planning the next activities leads to a reflection and improvement of the roles of each group member.

CL summary

Obviously, CL is a suitable framework in which our student projects can be discussed from an educational point of view. Since the learning theoretical background is quite evolved, we can use the categories to reflect the success (or even sometimes the failure) of the projects. CL makes clear that interdisciplinary science cannot only be learned from books but also has to do with the interaction of human beings.

Description of the projects

Primarily, the HafenCity University Hamburg and the Polytechnic University Madrid exchanged lecturers through the European Education Program ERASMUS. After two years of cooperation, they started working in 2006 with the first common project (BARRIOS et al, 2008), two diploma thesis about the data acquisition and 3D Modelling of a castle in Villavellid, North Spain (Figure 3).



Figure 2: (left) *Preparation of a laser-scanning of an archaeological excavation in Mara, Spain.*

Figure 3: (right) *Villavellid castle, Spain*

Each student, one from each university, works first together in Madrid and later in Hamburg on the calculation, processing and creation of the 3D model of the castle. After its completion, each student elaborates his own work in different theses with different priorities.

After the good experiences and results of the initial project, both universities agreed to organize a Summer Camp to be carried out every year. The first summer camp in 2007 took place in Atapuerca, Burgos and Hellín (MAS et al. 2008a,b). Sixteen students together with four lecturers from Hamburg and Madrid attended this project. The second summer camp (2008) took place in Atapuerca, Burgos and Mara (Calatayud). Twenty students together with seven lecturers from Hamburg, Madrid and the United States attended this project. The third summer camp (2009) took place in Mara (Calatayud), where twelve students attended the project together with four lecturers from Hamburg and Madrid. The next camp starts in July in Logroño.

Each project starts with a meeting of all attendees and traditionally with a conference about “The Physical Geography of Spain”, specially designed for the foreign students, and also with a presentation of the projects. Upon arrival on the site, the students begin with a tour, conducted by the local researchers, through the excavations and a presentation of the work to be undertaken.

After the visit, the students have to organize themselves and to form working groups or teams to perform the various tasks (Figure 4a). The teams develop a working strategy to dispatch the tasks which they present to all participants. The lecturers and scientists serve as consultants in this part of the project in order to remove possible ambiguities.

Once the strategy has been set up for the project, the students begin with the data acquisition (Figure 4b). Here, they are instructed in the use of the instruments by students with these skills (Figure 5a).



Figure 4: (a) Tour through the excavation, Marà, Spain. (b) Data acquisition with three teams

In the evening, the backup of the day's work has to be done through specially prepared computers.



Figure 5: (a) Instruction by students in laser-scanning. (b) Evening presentation

After partial completion of work (usually after two days) new teams can be formed. These groups will begin to document, evaluate and update the results. Occasionally detected errors or gaps are immediately communicated to the measuring groups, so that the work can be complemented and fully completed. Additionally, evening presentations of a high scientific standard are presented by the lecturers and scientists of the participating universities and guests from research institutes or industries (Figure 5b). At the end of the project the teams present their results (as they are) to the plenum of all other teams and instructors and open a panel discussion about the projects and the positive and negative experiences.

Conclusions

We introduced the theoretical framework of Cooperative Learning and showed that it applies to our concept of geomatic archaeological projects which we presented in some

detail. Of course, we did not consider CL as an end in itself but propose to use the concept with some care to increase the success of the projects.

We point out that not only the geodesic and mathematical subjects should be practised and dealt with here. We seek the transfer of technology to other sciences, as in our particular case, archaeology. It is important to the whole process of learning and experimentation.

Other features of this cooperation are:

- Provides the possibility for the students to work in a field of science which, until now, was not in direct contact with Geomatics.
- Increases the collaboration between students from several countries in Europe and opens the understanding and perception of these.
- Opens the possibility to carry out attractive and practice oriented Bachelor and Master Theses.
- Solves problems using new technologies such as laser-scanning, GPS, GIS, fringe projection.
- Allows one to delve deeper into the history and culture of other countries and opens the horizon for free thinking.
- These kinds of projects opened the cooperation with researchers from different countries, such as Spain, USA, Germany and other countries.

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[1] www.co-operation.org/

[2] edtech.kennesaw.edu/intech/cooperativelearning.htm

[3] clte.asu.edu/active/clinhighed.pdf