Evaluation of Innovative Teaching and Learning Projects in Engineering Education

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INTRODUCTION

The evaluation of lectures, exercise classes and tutorials[1] is gaining more and more importance in the university context due to quality aspects. This is especially true for *tu wimi* *plus* which is one among 8 project-lines that are funded by the German Federal Ministry of Education and Research (BMBF) to improve the quality of teaching and learning at TU Berlin. Mainly, this ought to be done by augmenting interdisciplinary and student-centred approaches. Currently, *tu wimi* *plus* provides support for 7 research and teaching assistants at thematically very different chairs (e.g. electrical engineering, mathematics or mechanics) on how to design and implement subject-specific teaching curricula in their respective fields. More concrete, they are responsible for the didactical (re-)conception of 9 innovative teaching and learning projects (TLPs) within which problem- and project-oriented or e-learning-supported teaching methods are applied more frequently.

Some of the most exigent questions – and also responsibilities – for the *tu wimi* *plus*-team are to ascertain how didactically innovative teaching and learning projects should be evaluated and how they are perceived by students compared to ex-cathedra teaching. Addressing these issues, we developed a questionnaire which pursues to be in alignment with the learning objectives of the respective lectures. In addition, it focuses on the self-evaluation of the learning activities students perform in class rather than concentrating on their satisfaction with the lectures.

Hence, this paper will explain the underlying considerations and objectives to evolve into this – for TU Berlin fairly new – evaluation design. The integral concept of the questionnaire, including the process of development, its quality criteria and distinct sections or constructs respectively will be outlined as well. Moreover, the first

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[1]In the German higher education system, the following structure prevails: In general, lectures are accompanied by an exercise class and/or tutorials. Usually, lectures are delivered by professors. Exercise classes that provide the basis for deepening the understanding of the subject and for addressing questions in larger groups are executed by (research and) teaching assistants. Tutorials as an extra possibility to practice – e.g. mathematics in smaller groups – are held by student tutors.

preliminary findings of a pilot survey conducted in 4 teaching projects during the winter term 2013/2014 will be described and analysed.

Finally, this contributions ties on to our previous considerations presented in Leuven 2013 and will not only engage in the approach of *tu wimi plus*, but also explain how *tu wimi plus* could possibly enlarge the focus of quality control within the context of TU Berlin´s quality management.

1   GENERAL CONSIDERATIONS

1.1 Status Quo

As one of the biggest technical universities in Germany, Technical University (TU) Berlin is facing particular challenges in its engineering education due to its size. Despite the necessity to accommodate more than 30 000 students in nearly 100 degree programmes, about 300 full-time professors and 2500 (research and) teaching assistants assigned to 7 faculties [1] need to assure that quality teaching and large student numbers are not contradictory terms. This is especially true for the highly frequented lectures of the basic STEM-courses, delivered during the freshman year. At times, these involve up to 1000 students – or even more – and are all too often critical to study success [2]. Now, the question is: how can this be assured?

In order to tackle the problems of considerably high drop out-rates during the first year and of declining attractiveness of engineering curricula accordingly, our corresponding study reform, which will be outlined first (see also 1.2), mainly concentrates on interactive teaching and learning methods [2]. And – of course – one of the most important means of quality assurance is the evaluation of degree programmes in general and their courses in particular, which will be illustrated second (see also 1.4).

1.2 The Study Reform Project

The federally funded study reform project at TU Berlin forms the framework for the activities of *tu wimi plus* which is one among 8 rather diverse project-lines, determined to establish a new teaching and learning culture at TU Berlin. The success of the study reform is forwarded by the creation of an interactive teaching and learning environment, which fosters learning activities, by the improvement of study conditions in general and the quality of teaching and learning in particular [2], [3]. 4 project-lines including *tu wimi plus* are located at the Centre for Scientific Continuing Education and Cooperation (ZEWK), which is a central unit that is in charge of all scientific continuing education measures [13].

tu wimi plus comprises both quantitative measures, such as the preliminary increase of teaching staff, and qualitative measures, for example offering support for teaching staff in terms of counselling, assistance or continuing education and qualification. In order to provide didactically qualified staff, 7 additional (research and) teaching assistants (change agents) have been hired for *tu wimi plus* in especially challenging fields of our university [2]. They do not only focus on the improvement of their own teaching competencies and their long-term work as disseminators of good teaching practices within their own institutes, but develop also innovative teaching curricula within the frame of teaching projects, which they apply directly in their own subject-specific teaching [14]. Even though *tu wimi plus* and the other 7 project-lines are state-aided, it needs to be stressed that additional activities to improve the quality of teaching at TU Berlin are continuously pursued and expand constantly [13].

1.3 Innovative Teaching and Learning Projects

We will now get to the core of this paper and have a closer look at the innovative teaching and learning projects (TLPs) that are meant to be evaluated. Currently, *tu wimi plus* provides support for the (re-)conception and realization of 9 TLPs which are located at thematically very different chairs and differ significantly in their characteristics: 3 TLPs are hosted by the chair in "continuum mechanics and material theory" and 1 TLP each by the chairs in "aircraft and light-weight construction" and "construction informatics". All three chairs have reworked and developed their course offers by adapting the teaching aids to the latest didactical standards, also fostering digital learning. 2 TLPs are operated and organized by the chairs in "micro-technology" and in "thermodynamics and thermal process engineering". Whereas the first has come up with a completely new study module focusing on e-mobility, the latter is in the very act of establishing a process technology laboratory. Another 2 TLPs

are "Mathematics for Engineers: Analysis I", executed by the "Service Institute of Mathematics", located at the chair in "modelling, simulation and optimization in natural and engineering sciences", and "Foundations of Electrical Engineering" (GLET), carried out by the chair in "light engineering" [2], [4]. Although there is no definition so far that experts commonly have agreed upon, our understanding of didactic innovativeness comprises the main innovative learning principles in terms of a.) the learning approach: both problem- and project-based or context-oriented, b.) the contents approach: inter-disciplinary or exemplary learning, and c.) the social approach: team-oriented or participant-directed learning [5].

1.4. Quality Management

Part of the major project tasks is to search for suitable evaluation methods. Our efforts at the ZEWK to evaluate the innovative TLPs of *tu wimi ^{plus}* by means of a manageable pilot study could be seen as an additional idea to widen quality control within the university context. At TU Berlin, the quality management system is centrally anchored and executed by the department of Strategic (University) Controlling [6]. As one of its core competences in terms of quality assurance is to support faculties and distinct organizational units in evaluations, we leveraged this expert knowledge by entering into a productive dialogue when we started the process of redesigning the questionnaire (see also 3.1.).

2 EVALUATION OF INNOVATIVE TEACHING AND LEARNING PROJECTS

2.1 Objectives

So far, all faculties have been using a particular questionnaire to evaluate their lectures, exercise classes or tutorials which includes an obligatory set of introductory meta-variables – e.g. the name of the study programme or the number of completed terms – that the distinct faculties had previously agreed upon. In addition to this basic stock of items, the faculties have decided to select the most appropriate categories for their evaluations from a pool of relevant items. Some examples for evaluation categories to be chosen are the range of topics covered during the course, the course structure, the quality of the professor´s (or other teaching staff´s) teaching, the adequate use of media or the overall assessment of the perceived quality of the course. Taking into account the nature of these categories, it becomes quite clear that this questionnaire focuses very much on the degree of the students´ contentment with the course rather than concentrating on the extent and nature of the (teaching and learning) activities which are ought to be performed in class. In addition, our university offers such a wide range of courses that not every single one of them can be evaluated during every turn. Thus, lectures usually get assessed only every second or third term by the evaluation team.

Against the background of the given situation at our university, we had to ask ourselves the following crucial questions: What does teaching staff do to foster activating teaching and learning? And how are the teaching staff´s activities perceived and implemented by students?"

Considering these questions, we primarily had to become clear about our objectives: *First*, our questionnaire needed to be designed in a way that raised the awareness of both students and teaching staff for the innovative character of the TLPs in general and for the desired teaching and learning activities in particular. Thus, we were eager to develop a questionnaire which focuses on the students´ activities they are ought to perform in class rather than on their satisfaction with the respective lectures. *Second*, the questionnaire should match the learning objectives of the lectures. *Third,* we wanted to track the results of our TLPs every semester (and not only every second or third) in order to have a solid documentary of the progress made during the run of our project-line *tu wimi ^{plus}*, also providing us with data when we start to prepare for the following tender.

2.2 Questionnaire Adaptation

In order to ensure the quality of our TLPs, we decided to implement an evaluation which is mainly activity-based, matches the learning objectives of the course and is intended to be executed every semester. It became quite clear that the previously stated objectives could only be met if the previously used questionnaire as an important means of quality assessment had to be altered and adapted to match the previously stated needs. To reach this goal, we combined categories of the hitherto existing questionnaire, which were still considered to be useful, with altered elements – now, this encompasses categories and singular items – of the "National Student Survey of Student Engagement" (NSSE)-questionnaire (see also 3.2.).

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2.3 Advantages of NSSE

We found the NSSE-survey particularly interesting and suitable for our purposes as it assesses the extent to which students engage in educational practices that are associated with considerably high levels of learning and development [7]. Among the five categories that are included in the NSSE-questionnaire we were especially inspired by the first category which highlights participation in many educational activities (see also 3.3.). Adapting some elements of the NSSE-survey according to our teaching situation and including these newly designed items into the questionnaire, provided us with the rare opportunity to take up a competence-based perspective and to gain valuable insights into the students´ activities: What do the students´ activities look like? Which kind of activities do they perform in class and between? With regard to our innovative TLPs, generating answers to these questions is particularly important as they are essential building blocks for the continuous improvement of teaching and learning. More concrete, we could try to derive an "activity profile" of the students which means to identify favourite and frequently performed tasks and integrate this knowledge into our teaching and learning concept.

3   QUESTIONNAIRE DESIGN
3.1   Development Process

When we started to redesign the questionnaire during the summer term 2013, we got fully engaged in an iterative process with several feedback loops of different parties to guarantee the best possible outcome. Our team consisted of the project head of Strategic (University) Controlling and one of her members of staff, one expert of the evaluation team of Strategic (University) Controlling, also responsible for the electronic evaluation system, the 7 research and teaching assistants and the project leader, the coordinator and the student tutor of *tu wimi* [plus]*.*

First of all, the items of the NSSE-survey that were considered to be most relevant to assess the students´ activities and the quality of the TLPs were identified by the research and teaching assistants. Then, the task force agreed upon a set of particularly interesting categories and items from the previously existing and the NSSE-questionnaire, but also considering potential questions from two other questionnaires that were dealing with the topic. Afterwards, the preliminary questionnaire was electronically programed. Hence, this procedure was followed by another round of intensive discussion and feedback. The latter again provided valuable insights for the improvement for the preliminary draft, which got once more electronically altered and converted into a "pretest-questionnaire". During the summer term 2013, a pretest was conducted that served to evaluate 3 among 9 TLPs; 54 questionnaires were returned and their results analysed. The participating research and teaching assistants had been instructed beforehand to get feedback from their students right after collecting the forms, e.g. about the clarity of the questions or the scales. The feedback received from the students was also included in the design of the questionnaire, single items were discussed, rephrased and newly programmed.

Finally, this version was used to execute a pilot survey in 4 among 9 TLPs during the winter term 2013/2014. This time the students´ feedback after completion was more positive which led us to the conclusion that the clarity of the questions had increased. We generated 236 returns that have been summarized, analysed and interpreted. The results were also communicated to the participating chairs to foster discussion and identify further improvement potentials. What made this process so successful has been the joint effort and involvement of all relevant parties to the subject and it still continues.

3.2   Quality Criteria

As described in the previous section, we followed Bortz and Döring [8] who recommend to take advantage of already existing questionnaires on the topic, but to check them and their constructs thoroughly. The mere modification of the sequence of questions or of whole scales can already alter the quality criteria of objectivity, reliability and validity [9].[2]

We used explorative factor analysis, a method from multivariate statistics, to test whether our scales showed underlying latent dimensions or factor structures accordingly. Data processing was done

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[2] A comprehensive overview about all necessary considerations about questionnaire design is beyond the scope of this paper. Please consider references [8] and [10] for further details.

computer- based via SPSS 2.0 after exporting the data from Evasys, the automated evaluation system of TU Berlin. When doing so, the data was double checked by our student tutor, using statistical and descriptive values [11].

To assure quality, we also examined the nature of our questions critically. As closed questions do not only improve objectivity, but also alleviate data analyses, interpretation – time-consuming and cost-intense coding and categorization doesn´t need to be done – and the completion of the questionnaire, most of our questions are closed [11]. However, we also included four free text fields where students can provide valuable feedback for the improvement of the lectures, of the teaching staff or of their own learning process. Another important aspect is the length of the questionnaire. With a total length of 3 pages (including more than 1 page of space for free text) we found a good compromise between increased reliability or internal consistency accordingly and feasibility. On the one hand, the more the number of items increases that describe a particular feature, the more precise the test results get. On the other hand, the longer the questionnaire the more the willingness of the students decreases to work on the items appropriately [10]. In addition, the objective of the conducted pretest was to identify items that did not meet the requirements of the design. It was conducted in July 2013 in the lecture rooms of 3 innovative TLPs, which matches an ad hoc-sample and was introduced by the respective research and teaching assistants who stayed in the room to answer questions. It took approx. 10 minutes and addressed students of construction engineering, physical engineering science and aerospace engineering [11]. As all TLPs shall be evaluated prospectively, we herewith have laid the foundation for a longitudinal analysis.

3.3   Included Constructs

With regards to content, our newly constructed and standardized questionnaire consists of diverse constructs that picture the following themes:

- Structural characteristics of the studies of the respective student
- Competencies of the teaching staff
- Students´ learning activities
- Overall evaluation of the course

Considering the above mentioned objectives, we have mainly focused on the competencies of the teaching staff and the students´ learning activities; the latter has been inspired by the NSSE-questionnaire. However, both constructs share the commonality of a four-level bipolar Likert-scale for answering options – ranging from "applies fully" to "does not apply at all" – and therefore preventing neutral answering possibilities in the middle, which are statistically chosen most frequently [12].

Following our goal to sensitize both teaching staff and students for their own performance in class, the construct "competencies of the teaching staff" involves the following set of items:

The lecturer/teaching staff…
- …precisely explained the goals and requirements of the course.
- …imparted the content in a structured manner.
- …gave me valuable hints for self-study or exam preparation.
- …gave me feedback about my performance.
- …gave me the opportunity to ask critical questions.
- …motivated me to participate actively in the course.

The students´ perspective, which gives them the chance to reflect upon their own behaviour and activity during the lectures, comprises the following items:

During the course, …
- …I worked on technical questions and tasks in learning groups.
- …I participated actively in group work.
- …I solved project tasks independently.
- …I solved technical problems the solution of which were not given.
- …I regularly did homework or performed other course-related services.
- …I made two or more versions of my homework before I finally handed it in.

- …I learnt something that changed my understanding of a particular issue.
- …I independently developed a model / concept / instrument / programme via the application of subject-specific methods
- …I tried to engage in another perspective to understand an issue or a concept better.
- …I asked questions during discussions or contributed in another way.
- …I went to the lecture without having read the required texts or made the requested exercises.
- …I searched independently for further literature.
- …I explained the course material to one or several other students.
- …I asked another student to help me to understand the course materials.
- …I got prepared for the exam by working on or discussing the material of the course together with other students.
- …I did a presentation.

Taking into account also the valuable comments from the free text fields, these constructs provide very valuable information about the activities of both the teaching staff and the students. This can be used for intense reflection upon the teaching staff´s and students´ activities and, hence, opens the space for further continuing improvement concerning teaching and learning processes.

4.   FIRST PRELIMINARY FINDINGS

4.1.   First Results

During the winter term 2013/2014, we evaluated four innovative TLPs within the scope of our pilot study, namely "Foundations of Electrical Engineering", "Finite Element Method", "Construction Informatics" and "Selected Chapters of Aircraft Construction"; the number of returned questionnaires varied between 4 and 169.

However, what could have possibly been guessed – only by looking at the number of the generated returns – is that all of our TLPs differ significantly in the number of participating students, the study phase (bachelor or master) and the nature of the respective courses.

When we thought about the design of the questionnaire, we supposed that the innovative TLPs will set themselves apart from other lectures in a positive way. This consideration is depicted in the question: "How do you assess the quality of your learning process in this course compared to learning in other courses?" Students were asked to answer this question by using a five-level bipolar Likert-scale with the answering options "better" (1) or "worse" (5).

The results reveal that the learning process is perceived to be better in three of the TLPs, whereas it is perceived to be worse in one of the TLPs. The most favourable value of the arithmetic mean was reached in the course with the smallest number of participants; however, this represents also the smallest sample and cannot be seen as representative. The least favourable value was reached in a medium-sized class with approx. 50 participants and can be explained by the fact that the respective chair was trying a new concept for the first time which did not run as smoothly as expected and will sure improve in the future.

As the last questionnaires could just recently be processed, data analysis and interpretation are still in progress and a more comprehensive overview of our first findings can be part of our presentation in Birmingham in September 2014.

4.2   Limitations

These and many more considerations need to be taken into account when analysing and interpreting the data. Not only do we have very diverse TLPs, but also different quality of the data and therefore also heterogeneous results. Furthermore, it would have been desirable to evaluate the TLPs with the same questionnaire before and after the didactical (re-)conception of the courses. However, this had not been possible as we needed to adapt the questionnaire to engage in a competence- and activity-based perspective.

4.3   Prospects

After the execution of our pilot study in 4 TLPs during the winter term 2013/2014, our next steps include the evaluation of the remaining 5 TLPs as well as a critical review of the questionnaire after completion. All results will be discussed with the involved chair heads and the responsible research and teaching assistants to leverage this feedback as a trigger for constant improvement.

5 CONCLUSION

One of our main goals was to develop and test a valuable questionnaire to evaluate student activities in lectures. Ideally, we manage to collect the data of two to three diverse cohorts which enable us to compare the results and keep records of the – hopefully positive – development of the innovative TLPs in our project-line *tu wimi* *plus*. Thus, this first attempt can also be considered as an inspiration for full evaluation in the next project period. However, to make evaluation a success, the process needs to foster constant reflection upon and communication about the results and to support continuous improvements and conjoint development. Therefore, all people involved – project management, coordination, teaching staff and students – need to be heard to achieve the best possible outcome in terms of teaching and learning.

From the perspective of scientific continuing education the results of the newly designed questionnaire lead to more far reaching questions such as what new aspects can we learn to qualify professors and research and teaching assistants didactically to deliver innovative lectures? One possible answer might be to offer special training for change agents in activating and motivating teaching and learning methods. These thoughts lead us to the innovative TLPs of the project-line *tu wimi* *plus* where this intention has already become reality. Finally, the preliminary evaluation results give us hints how to foster students´ activities in and between lectures and provide further valuable insights what we can learn that supports us throughout the residual term of *tu wimi* *plus*.

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