

# Features of innovative lectures that distinguish them from traditional lectures and their evaluation by attending students

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*To support students at the often-times difficult transition from high school to university mathematics, some universities in Germany have introduced innovative lectures. The WiGeMath project evaluated to what extent these measures fulfill their self-set goals. During the evaluations, specific questionnaire items and lecture observations were applied to investigate which characteristics made these lectures different from traditional ones and in how far students valued these features in achieving the courses' learning objectives. The results show that students in the redesigned lectures value guidance and clarification rather than abstractions and that redesigned lectures include more social interactions and student engagement than traditional lectures.*

*Keywords: Mathematics Education, Novel approaches to teaching, Observation, Secondary-Tertiary Transition, Higher Education*

## Background and aim of the paper

Many students face difficulties at the transition from high school to university mathematics (Gueudet, 2008). Some universities give support by establishing redesigned lectures, by which we mean lectures that are usually held during the first semester and, unlike traditional lectures, do not focus on university mathematics content. They may, for instance, rather help students who have already failed certain tests to revise the necessary foundations for their further studies or they focus on study techniques like problem solving. Good experiences with lectures or courses that do not focus on the presentation of new theory have been documented in the UK with focus on problem-based learning of analysis (Alcock & Simpson, 2002) or problem solving activities (Tall & Yusof, 1998). Meanwhile, traditional lectures are still both widespread and criticized for neither promoting students' active learning nor exploiting their potential in drawing students into higher mathematical thinking (Pritchard, 2015). Promoting innovative support is the goal of the WiGeMath project (german for Effects and success conditions of mathematics learning support in the introductory study phase), which is a joint research project of the Universities of Hannover and Paderborn (Colberg et al., 2016). It evaluates diverse support measures including redesigned lectures. First, the project developed a taxonomy that serves to categorize features and goals of support measures (Liebendörfer et al., 2017; Kuklinski et al., 2018). This taxonomy was then used to lead guided interviews with the lecturers about the courses' goals. Previous research showed that redesigned lectures were successful in meeting at least some of their goals (Kuklinski et al., 2018). Students' mathematical self-concept and self-efficacy did not decline significantly in these lectures unlike in traditional lectures (Rach & Heinze, 2017), and toolbox beliefs decreased. Our research questions are (1) which course features named by lecturers did students find helpful in reaching learning goals and (2) which observable characteristics distinguish these courses from traditional ones.

## Method

With regard to research question (1), we will first report on a questionnaire survey and then, for research question (2), on lecture observations. After we had interviewed the lecturers about their concepts of the redesigned lectures, covering their envisioned teaching strategies, the learning goals they wanted students to achieve and which activities they hoped the students would engage in to reach the goals, we developed questionnaires that aimed at evaluating if attending students felt the lecturers succeeded in meeting their own goals. We applied a special concept for lecture course evaluations called the Bielefelder Lernzielorientierte Evaluation (BiLOE, Frank & Kaduk, 2017) which serves to investigate to what extent students feel they have reached certain learning objectives, which activities they found helpful in achieving those they feel confident they achieved and what reasons they see for not reaching the others. The items looked as displayed in Figure 1.

Question: To what extent have you achieved the following learning objectives?				
	Achieved entirely	Rather achieved	Rather not achieved	Not achieved at all
I can handle various strategies for problem solving.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Question: To what extent did you find the following activities helpful in achieving the learning objectives? → Please fill this out only for those learning objectives that you achieved entirely or rather achieved.									
	I did not do this.	Learning objective 1: I can handle various strategies for problem solving.				Learning objective 2: ...			
		Very helpful	Rather helpful	Less helpful	Not helpful at all	Very helpful	Rather helpful	Less helpful	Not helpful at all
I worked on problems of various types in the lecture.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
...	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

**Figure 1: Example items of the BiLOE**

This questionnaire was given to the students towards the end of the term. The students were asked only to fill out the part of the helpful activities for those goals they felt they had reached or rather reached. An overview of our samples is given in table 1.

Cohort	Engineering students		Pre-service teachers			
Location	Kassel	Stuttgart	Kassel	Oldenburg	Paderborn	Würzburg
<i>n</i> (f/m)	13 (0/13)	55 (11/44)	12 (6/6)	102 (54/48)	45 (18/27)	41 (20/21)
Method	Paper-pencil		Online	Paper-pencil		

**Table 1: Overview of the sample size (*n*) and the numbers of female (*f*) and male (*m*) participants**

Moreover, we conducted lecture observations. We used the WiGeMath taxonomy to develop a guideline to observe the redesigned lectures and created an observation sheet where the observer has to mark different categories as they apply during five-minute-sections that we split the whole session into. The observation sheets for the non-participating observation contained a series of tables like in figure 2. As to the categories of jargon of mathematics and memorizing, these were coded if the lecturer explained the use of a mathematical formula/ character or named a character like  $\in$  or if he asked students to learn a definition, proof scheme or calculation rule by heart, respectively.

		<u>Jargon of mathematics</u>	<u>Memorizing</u>	<u>Media</u>	<u>Form of interactions</u>	<u>Problem solving/ task solving</u>
<u>Time:</u> 0.00 Min.- 5.00 Min.	<u>Themes:</u>	<input type="checkbox"/> Explanation:	<input type="checkbox"/> Definition:	<input type="checkbox"/> Board <input type="checkbox"/> OHP <input type="checkbox"/> Power-point	<input type="checkbox"/> Lecturer presenting, facing the board <input type="checkbox"/> Lecturer presenting, facing the students	<input type="checkbox"/> Students look for an answer <input type="checkbox"/> Lecturer helps during the solving process → kind of help:
<u>Explicit reference to school</u>		<input type="checkbox"/> Translation:	<input type="checkbox"/> Proof scheme:	<input type="checkbox"/> PC-Simulation <input type="checkbox"/> Work-sheet <input type="checkbox"/> Calculator <input type="checkbox"/> Tablet-PC	<input type="checkbox"/> Lecturer asks questions <input type="checkbox"/> Students answer <input type="checkbox"/> Student asks, lecturer responds <input type="checkbox"/> Student asks, student responds <input type="checkbox"/> Discussion <input type="checkbox"/> Individual work <input type="checkbox"/> Partner work <input type="checkbox"/> Group work	<input type="checkbox"/> Students present their results <input type="checkbox"/> Lecturer presents the solution <input type="checkbox"/> Wrong approaches to the solution are discussed
<u>Explicit reference to profession</u>			<input type="checkbox"/> Calculation rule:			
<u>Explicit reference to university</u>						

**Figure 2: Extract from the observation sheet**

For each of the evaluated lecture courses, we employed two student assistants to observe the lecture course at three times during the semester, once in November, once in December and once in January (the semester lasts from October to January). The observers studied mathematics but were not regularly taking part in the lecture courses observed. They had been given the observation sheet and a manual including examples and they had been trained using a short video episode of a lecture to make sure they had understood the categories and their handling in the way we had intended them. The students were advised not to communicate so we would get independent results from them which led to a few disagreements in their codings but their overall assessments matched. To have a reference point as to the deviation that the evaluated lecture courses showed from traditional lecture courses, we also had two students evaluate a traditional linear algebra section and a traditional analysis section for first semester students.

## Results

We will first look at the results of the BiLOE and then analyze the lecture observations. For the BiLOE, the lecturers named some activities that they expected students to engage in, which did not seem to deviate from traditional lectures. These included attending the lecture sessions, working on homework alone or in groups or revising the lecture notes.

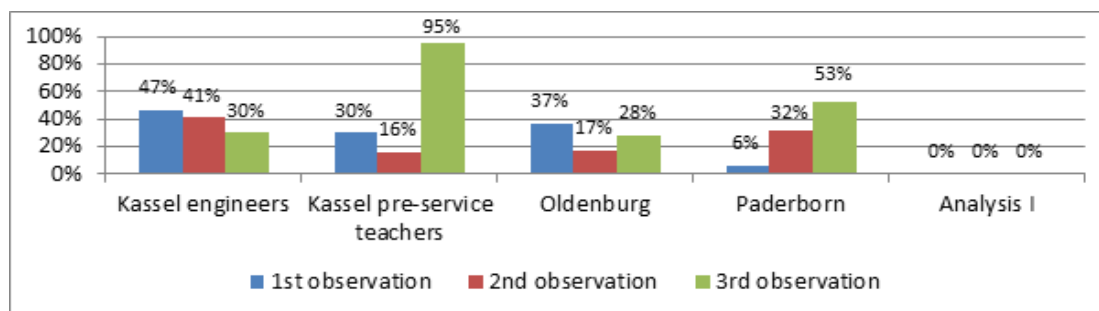
Yet, there were other activities that seemed to be of a more innovative and supportive kind. These activities very much appealed to the students as can be seen from the percentage of students that found them to be rather helpful or very helpful in achieving the lectures' learning objectives. Although the lecturers were free to name any activities they wanted without having been given categories or guidelines, the activities they named could be grouped into five different classes, namely reflection, testing oneself in a safe place, work with examples, work with prototypes and social interactions, see table 2.

With regard to research question (1), the categories of reflection and work with prototypes seemed to be the most helpful ones in the eyes of the students as more than 60% (for some of the activities a lot more than that) found them rather helpful or very helpful for all given learning objectives. All categories seem to reflect a learning atmosphere that is closer to school life than to university life. The categories of reflection, work with examples and work with prototypes all suggest that students hope for guidance and clarification rather than abstractions. Moreover, they do not like the feeling that they have to prove themselves, they rather want to work without pressure or in cooperation with others.

<b>Reflection</b>	Paying deeper attention to common mistakes	76% - 92%
	Reflecting on every step while solving problems	67% - 83%
	After solving a problem, reflecting which solution techniques were used	74% - 90%
	Reflecting the preconditions and the steps in every proof of the lecture	75% - 85%
	Looking for common patterns in proofs	67% - 96%
<b>Testing oneself in a safe place</b>	Writing mathematical texts myself	42% - 59%
	Doing smaller proofs myself	77% - 100%
	Working on difficult problems in an easier form at first	68% - 80%
<b>Work with examples</b>	Revising the examples from the lecture	40% - 77%
	Having the lecturer demonstrate how to prove	82% - 92%
	Having the lecturer explain different proof methods in detail	63% - 86%
<b>Work with prototypes</b>	Getting to know problems with many different facets	78% - 85%
	Working with very appealing proofs	60% - 100%
<b>Social interactions</b>	Asking the lecturer for help when I got stuck	59% - 79%
	Asking the lecturer for feedback even where my solutions were correct	54% - 72%
	Working on content together with others	40% - 88%

**Table 2: Activity categories and percentages of students who found the activity rather helpful or very helpful for all given learning objectives**

With question (2) in mind, we will now focus on the observation results. Although the predominant media used was limited to the blackboard almost exclusively, just as in traditional mathematics lectures, we found some interesting deviations in the social interactions that took place as well as in the way that students were engaged in problem and task solving processes. In all lectures, we observed various instances where the lecturer asked questions and students answered, indicating that interactions took place regularly. Besides, students also asked questions repeatedly. This suggests that the learning atmosphere in the lectures made students comfortable to openly express their comprehension difficulties. Yet, we did not encounter instances where a student asked a question and another then answered. In consequence, discussions did not take place and neither did typical teaching conversations. Although we observed a few phases of single, partner or group work, these stayed an exception which also indicates that the lecture atmosphere stayed distinct from a typical school classroom. Rather, the format of a lecture remained central and the two forms of interaction that were predominant in all courses were the lecturer talk facing the blackboard and the lecturer talk facing the students. But the fact that other forms of interactions did occur is enough to make the lectures distinct from traditional ones. In fact, phases where the students were actively engaged in problem or task solving processes did not occur in the traditional lectures we observed (Analysis I in Figure 3). In contrast, such phases were observed in all redesigned lectures and there was even one observation where students were active to this effect in 95% of the time (cf. Figure 3).



**Figure 3: Engagement of students in problem solving in some of the lectures**

As students rated the category of testing themselves in a safe place as helpful in the BiLOE, it seems like they profited from these periods of student task solving.

## Discussion

### Methodological discussion

To examine the features of redesigned lecture courses and in how far students find them helpful, we decided to make use of an established evaluation instrument called the BiLOE and to hire students who observed lecture sessions focusing on certain categories based on the WiGeMath taxonomy which we provided them with. To be precise, in applying the BiLOE we used an established evaluation method that we connected to the WiGeMath taxonomy and we developed an observation instrument that is easy to use with small training effort of the observers. Moreover, we did not rely on single observations but employed two raters.

The results of the BiLOE must be interpreted as personal estimates only. Though the students indicated how helpful they found the given activities to be in achieving the learning goals, we cannot say whether they actually did achieve these goals. Other indicators like exam results or homework assignments would have had to be examined to make a qualified statement in this respect. It would also be possible to use a pre- and post-test design to measure the students' understanding of the content. Moreover, the results we got from the BiLOE may be biased as we only surveyed those students that attended the lectures. Had we questioned all registered students of the course, results might have been different.

Concerning the observations, the two student observers did not always agree in their codings. However, we could not calculate inter-rater reliabilities due to unmatched timings by the observers. We recommend parallel timing for both observers in future research and maybe a more elaborate training. Yet, our results show that the use of simple methods can reveal important lecture features.

### Discussion of the results

The data show that successful, innovative lectures may benefit from the five elements of reflection, testing oneself in a safe place, work with examples, work with prototypes and social interactions. It is possible to implement such elements in traditional settings and students value these elements.

According to Slomson (2010) the format of lectures remains the dominant way of teaching for university mathematics students at the beginning of their studies and he claims that they have hardly changed for 40 years. Our results show, that changes are possible. They contradict the text of Wood

et al. (2007) referring to Gibbs et al. (1992) who claim that university lectures are more or less uninterrupted monologues by lecturers where student activity was limited to listening and note-taking. The innovative approach of the projects in WiGeMath is visible as in the traditional lectures we only encountered lecturer talk and no problem solving by the students during the lecture. In fact, Slomson (2010) gives four characteristics of lectures and one of them is that there is scarce interaction between the lecturer and his audience and the focus of the lecturer lies in transmitting a set amount of material. Moreover, Wainwright et al. (2004) also observed traditional mathematics lectures and did not encounter any instances where students collaborated or interacted with other students or the lecturer. Yet, students do seem to be interested in being more engaged during lectures just as we found in our research. In fact, Willcoxson (1998) found that students value teacher-student and student-student interactions in the lectures they attend and as Cavanagh (2011) makes clear lectures that engages students in more than just note-taking have positive effects in students' approaches to learning and their long-term understanding.

That students found social interactions and the work with examples helpful in achieving the learning goals goes hand in hand with the findings by Slomson (2010) that students prefer lectures with exactly these features and by Anthony (2000) that students believe that availability of support helps to lead to students' academic success. Moreover, Wood et al. (2007) explain the lasting percentage of students attending lectures where they could easily access the material online by the importance that these students must place on human contact in their university learning experience.

In another study that evaluated the success of so-called lectorials which blend traditional lecturing with more engaging activities where students learn cooperatively also found that most of the students valued these activities as they helped them in deeper understanding the content and in staying interested (Cavanagh, 2011).

While students in our surveys found the work with prototypes and examples helpful in achieving the learning goals, Anthony (2010) found that students did not allocate an important role to the practice with examples for achieving academic success. Yet, Anthony (2010) refers to the self-directed study of examples rather than the work with examples during lecture time. Conversely, Cavanagh (2011) found that students valued an abundance of examples in the lectorials he surveyed as they increased motivation and interest in the tasks.

An important question is, however, what caveats lecturers see in these innovative formats. A major concern might be the pressure they feel to cover all the contents (Johnson, Ellis, and Rasmussen, 2016). We should then discuss extending the time given for such lectures as well as the sustainability of students' learning.

### **Implications for research, policy and teaching**

Our results indicate that lecturers should consider restructuring their lectures so that students feel more secure to engage with the contents as well as with the lecturer and other students. Where possible, an abundance in examples might help students in understanding and then feeling more confident in the lecture content. So even though the traditional format of the lecture cannot be said to be useless in transmitting mathematical knowledge, our results indicate that students value social interactions and more lively formats which make the content illustrative by means of examples.

The lecture courses we evaluated differ from traditional lecture courses in more respects than the ones we focused on in this paper. In the categorization of the WiGeMath taxonomy, their focus on revisions of content and on study techniques or mathematical working techniques rather than on mathematical content would be differences in the individual and system-related goals of the measures. Yet, the measures also show specificities in their frame conditions and their characteristics. For example, the measures for engineering students in Kassel and Stuttgart are set out with small groups where the students work in an atmosphere that resembles school lessons. The lecture courses in Kassel and Oldenburg, where we focused on the pre-service teachers, indeed address this group predominantly rather than traditional lecture courses which mathematics majors and pre-service teachers attend together. The lecture course in Paderborn uses two tests in the course of the semester to prepare the students for the final exam and the structure of university mathematics exams in general whereas the lecture course in Würzburg does not include any examination at all. In this text, we looked at some further aspects of the lecture courses' learning culture and didactical features but to evaluate in how far students find these other features helpful in their learning process might be an endeavor worth undertaking in the future.

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